Manufacturing & Service Operations Management

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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MANUFACTURING & SERVICE OPERATIONS MANAGEMENT
Vol. 17, No. 4, Fall 2015, pp. 470–479
ISSN 1523-4614 (print) | ISSN 1526-5498 (online)

http://dx.doi.org/10.1287/msom.2015.0533

Joint Selling of Complementary Components Under Brand and Retail Competition

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Suppliers of complementary goods often package their items together when selling to downstream retailers. One motivation behind this behavior is to reduce double marginalization through coordinated pricing so that system efficiency is improved and individual members can also benefit. The objective of this paper is to understand how competition in supply chains would impact such joint selling partnerships among complementary suppliers. We first model competition at the supply level, which is generated from the existence of multiple partially substitutable brands (or suppliers) for a particular component. We then extend the analysis to a model that also involves retail competition caused by decentralization among retailers who assemble suppliers' components into final products and sell to customers. The analysis of a model with two complementary components, one of which has multiple brands, indicates that the supply-level competition discourages joint selling of complementary goods. That is, when competing brands become more alike (or substitutable), complementary suppliers act more independently in pricing and selling their items. However, retail competition leads to an opposite effect: Competition among retailers would actually encourage complementary suppliers to package their goods together and act jointly.

Keywords: joint selling; complementary components; brand competition; retail competition
History: Received: April 16, 2013; accepted: February 19, 2015. Published online in *Articles in Advance* May 13, 2015.

1. Introduction

Products sold in the end-customer market are often assembled from complementary components. In many cases, these components are perfectly complementary in the sense that customers can generate a positive utility only if they are consumed together. For example, in the high-technology industries, hardware and software need to be combined into an integrated system to deliver positive value to end users. These components could be manufactured by different independent suppliers, and it seems natural that the suppliers may bundle their goods together and sell them as packages to downstream players. In the process, suppliers may cooperatively set prices for these packages and subsequently share the joint profit. An example of such coordinated behavior among complementary suppliers/manufacturers is the DVD Forum (or Consortium), which is an international organization consisting of hardware, software, media, and content companies that develop and use DVD formats. When the DVD content and players were first introduced into the market, the joint selling behavior was observed between the DVD content providers (in the film industry) and the DVD player producers (in the consumer electronics industry). They aimed to set a competitive price for the combination of these two components and promote the sales of the new technology (see, e.g., Varian 2001).

In the case with two complementary components each having a monopoly supplier, it has been established by Cournot (1929) that joint selling of the two complementary components results in a lower selling price and a higher demand level because of elimination of horizontal double marginalization. Consequently, it leads to a higher total profit for both component suppliers, which provides players an incentive to price and sell jointly. In practice, it is common to observe multiple competing brands for some of the components. The introduction of the brand competition, however, may change the dynamics of suppliers' coordinating behaviors. This is because a supplier may generate sales through multiple substitutable final products that contain its component. A joint selling alliance may increase sales of a supplier's component involved in the alliance, but it may hurt its demand through other final products because of competition. Hence, the existence of brand competition may complicate complementary players' incentives for alliances. In addition to brand competition, another type of competition that can arise in a system with multiple final products is caused by decentralized retailers; that is, whether these products are sold by a single retailer or by multiple retailers. In this paper we also examine the effect of competition among retailers on upstream suppliers' incentives for coalition formation.

To understand how brand and retail competition affects alliance formation, we adopt a stylized model with only two complementary components, a and b. We start with a base model assuming a monopolist supplier for component a and n partially differentiated brands for component b each provided by an independent supplier (i.e., a 1-*by*-n setup). Suppliers sell their goods to downstream retailers, who then assemble and subsequently sell them to end customers. A final product is a combination of the two complementary components. Hence, contingent on the brand name of component b to be used, there are n substitutable final products in the market. In the wholesaling process, complementary suppliers are free to package their items together and form selling coalitions. In the retailing process, two systems are studied—one with a single retailer selling all n final products and the other with a dedicated retailer for each final product. Analysis of the base model aims to address the following two main research questions:

(1) How would competition among multiple brands of a component, i.e., brand competition, affect complementary suppliers' incentives for coalition formation?

(2) In the presence of brand competition, how would decentralization among retailers, i.e., retail competition, change such incentives?

Our analysis shows that stronger competition among final products (or less differentiated brands) lowers complementary suppliers' incentives of joint selling of their components. That is, brand competition *discourages* coalition formation. However, we observe an opposite effect of retail competition on suppliers' incentives for alliances: retail competition *encourages* coalition formation. It is more likely for complementary suppliers to bundle their items if retailers are more decentralized.

2. Literature Review

Joint selling of complementary components has been studied recently in operations management; see, e.g., Granot and Yin (2008), Nagarajan and Bassok (2008), Nagarajan and Sošić (2009), and Yin (2010). However, these papers assume a monopolist supplier for each of these complementary components, which leads to a unique final product. We introduce multiple differentiated final products to understand the effect of brand competition on upstream suppliers' joint selling incentives.

A number of papers in the economics and operations literature examine systems with two complementary components, each having two competing brands, which leads to maximum four different final products. Economides and Salop (1992) consider such a setting under various structures that describe which components are sold in packages and which are sold individually. However, they focus on system performance for each exogenously given structure and do not evaluate individual suppliers' preferences. We endogenously formulate suppliers' decisions on whether or not to package their goods and derive equilibrium structures. In a more recent paper, Cai et al. (2012) study individual players' incentives in a similar model setting. However, their main research question is to understand the impact of a revenue sharing contract on whether or not suppliers should sell either one brand exclusively or both brands of their complementary parties. Different from our paper, they assume players being self-profit maximizers and do not consider joint pricing.

Our model setting can also be considered as a simple assembly system with only two complementary components. There is an extensive literature on assembly systems studying various issues in operations. Some papers focus on inventory policies for centralized assembly systems; see, e.g., Song and Zipkin (2003) for a comprehensive review of this research direction. Others consider decentralized assembly systems with a single final product, and their interest is on pricing, capacity decisions, contracting issues, and the structure of the assembly lines, etc.; see, e.g., Tomlin (2003), Wang and Gerchak (2003), Gerchak and Wang (2004), Bernstein and DeCroix (2004, 2006), Netessine and Zhang (2005), Wang (2006), Hsu et al. (2006), and Fang et al. (2008). Note that in both centralized and decentralized assembly systems discussed above, there is a single final product available in the market. Bernstein et al. (2007) consider a model with two competing final products assembled from three different components, one of which is common and the other two are product specific. With suppliers being independent, they focus on the suppliers' capacity decisions, the assembler's wholesale pricing decision, and the issue of whether the common component should be provided by two dedicated suppliers. See Bernstein et al. (2007) and the references therein for a review of component commonalities in assembly systems. In this literature, however, suppliers of complementary components do not consider joint selling. We incorporate product competition into a simple assembly system and look into complementary suppliers' coordinating behaviors.

We assume in this paper that competing brands of any component are partially differentiated. If brands are perfectly substitutable, our model can be considered as a special case of the model studied in Jiang and Wang (2010) with two complementary components needed for the final product. In their paper, since competing items are identical, these items engage in pure price competition, and the one with the lowest price will survive and obtain all demand. Hence, one and only one final product captures the whole market, and it is irrelevant to consider different degrees of brand competition. In terms of alliances, there are papers in operations analyzing the possibility of joint selling among competing players; see, e.g., Granot and Sošić (2005), Jin and Wu (2006), and Nagarajan and Sošić (2007). However, in this paper joint selling is only among complementary players.

Finally, another related area of study is on mergers and acquisitions in industry organization or strategic alliances between firms. In this paper, the joint selling opportunities evaluated by complementary manufacturers are more of an operational consideration and may involve only one or a few product lines among their full product or service spectrum. Firms retain their independent business identities. Our motivation is to understand how upstream and downstream parties interact with each other, cooperatively and competitively, to supply and sell their products to the end customers through a decentralized supply chain.

3. Model Framework

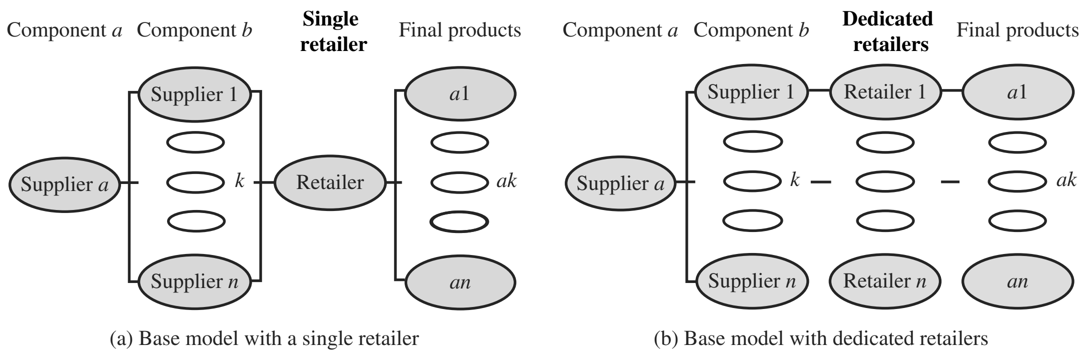
We start with a base model that has two types of complementary components, a and b, where component a has a monopolist supplier, namely supplier a, and component b has n competing brands, each provided by a dedicated supplier, namely supplier k, where $k \in \{1, 2, \ldots, n\}$ and $n \geq 2$. We assume that the competing brands of component b are partially substitutable to each other. For simplicity, in the base model, we also assume that suppliers of component b are symmetric in terms of their demands and cost structures. This model framework will be referred to as a *1-by-n model* in the sequel. The case with both components having competing brands will be discussed in the online appendix (available as supplemental material at http://dx.doi.org/10.1287/msom.2015.0533). We assume that all customers need to consume both components a and b to generate a positive utility, which implies that there is no additional stand-alone demand for individual components.

In selling to downstream retailers (or assemblers), supplier a and suppliers of component b can determine whether or not to form coalitions to jointly sell their goods. In this paper we allow coalitions to be formed only between *complementary* component suppliers, i.e., between supplier a and a supplier of component b. In other words, a single alliance does not involve multiple competing suppliers of component b. First, allowing coalitions to be formed only among complementary (but not competing) suppliers is to avoid potential anti-trust problems associated with price-setting cartels by competing firms (see, e.g., Nagarajan and Sošić 2007). Second, joint selling of complements is a prevalent feature in practice, examples including textbooks bundled with relevant software and cellular phones packaged with wireless services, etc. This topic has been extensively studied by researchers in economics (see, e.g., Kobayashi 2005, Bhargava 2013). Because of price coordination, joint selling of products may be considered potentially anticompetitive, especially when products are competitive or not naturally related. However, it is often complicated to evaluate potential harm and benefits of such an alliance to determine whether it violates anti-trust laws (Kobayashi 2005). In fact, different perspectives or decisions may be taken by different authorities; see a case discussed in Nalebuff (2008). Given its prevalence in practice, we consider joint selling of complements, which seems less likely to be legally controversial, relative to joint selling of noncomplementary products. Our goal is to understand complementary suppliers' incentives for such coordinating behaviors in the presence of brand and retail competition.

Following some existing studies on coalition formation (see, e.g., a survey paper by Nagarajan and Sošić 2008), we assume that the cost structure of the players and the demand functions are common knowledge to all the participants of the game. Without loss of generality, we assume that a unit of final product needs a unit of component a and a unit of component b. Because of n different brands of component b, items provided by the $n+1$ suppliers are assembled into n partially substitutable final products by retailers. To model the effect of retail competition, we consider decentralization in retailing. Figure 1 describes the two extreme cases: one with a single retailer selling all n final products and the other with n retailers each selling one final product. In each framework, channel members play a three-stage game. Following Figure 1, the sequence of events is described as follows. For convenience, the key notation used in the sequel is summarized in Table A.1 in the online appendix.

- *Stage* 1—*Alliance Formation Stage*. Our model starts with supplier a and suppliers of component b deciding whether or not to jointly sell their components to downstream retailer(s). The outcome of this stage is that supplier a has formed alliances with m suppliers of component b, where $m \in \{0, 1, \ldots, n\}$, and

Figure 1 **Base Model Framework**



component a and the remaining $n-m$ brands of component b, if any, will be sold independently (or separately) to retailer(s). We refer to this outcome as a coalition structure with m alliances (or coalitions) in the sequel. In an extreme structure with $m=0$, all suppliers will act independently. This structure is named as the independent structure or the no-alliance structure. In another extreme structure with $m=n$, supplier a forms alliances with all the n suppliers of component b. This structure is named the full alliance or the grand coalition.

To determine whether a coalition structure would emerge in equilibrium and become a stable outcome, we need to specify the stability concept that suppliers will follow in this stage. Throughout the paper, we will adopt the pairwise stability concept from network formation games since complementary suppliers' decisions on joint selling can be considered as a network formation problem. Pairwise stability is based on the notion of Nash equilibrium by considering single link deviations only and was first used by Jackson and Wolinsky (1996). It requires that no individual suppliers can benefit by terminating a coalition unilaterally or no two complementary suppliers can benefit by creating a new alliance between themselves. This stability concept is often interpreted as a necessary condition for network equilibrium and proves very useful in many applications such as social relationships, partnerships, and coauthorships (see, e.g., Jackson 2005, Ilkilic 2010). Pairwise stability has also been used in studying coalition formation games in operations management (see, e.g., Granot and Yin 2008, Nagarajan and Sošić 2008, Yin 2010, Fang and Cho 2014).

- *Stage* 2—*Wholesale Pricing Stage*. Suppose that supplier a has formed joint selling coalitions with m suppliers of component b, i.e., there are m packages of complementary components, and the rest are sold individually to the retailer, where $m \in \{0, 1, \ldots, n\}$. Because of symmetry of suppliers of component b in the base model, without loss of generality we assume that the first m suppliers of component b are in alliance with supplier a. Throughout the paper we will use index "i" to denote suppliers of component b in alliance with supplier a, and index "j" to denote suppliers of component b independent of supplier a. For packaged components a and i, where $i \in \{1, \ldots, m\}$, we assume that their suppliers will jointly determine a wholesale price w_{ai} for the whole package to maximize the total profit generated from selling this package to the retailer (i.e., the coalitional profit). This assumption is appropriate, since such a wholesale price decision involves both participating suppliers' performance. For components a and j sold individually, where $j \in \{m+1, \ldots, n\}$, we assume that suppliers a and j will choose their own individual wholesale prices w_a and w_j, respectively. For price w_j, we assume that it is determined to maximize supplier j's profit. For the individual wholesale price of component a, w_a (where $w_a \leq \min(w_{a1}, \ldots, w_{am})$), we assume that it is determined to maximize supplier a's total profit generated from individual selling of this component to the retailer that will be assembled in all final products aj, where $j \in \{m+1, \ldots, n\}$.
- *Stage* 3—*Retail Pricing Stage*. For simplicity, we assume that suppliers are willing to offer their items to retailers (either as packages or individual components) and retailers assemble them into n different final products and sell to end customers. For a given coalition structure with m alliances and wholesale prices offered by suppliers $\{w_{a1}, \ldots, w_{am}, w_a, w_{m+1}, \ldots, w_n\}$, retailer(s) determines retail prices for the n final products, $\vec{p} \equiv \{p_{a1}, p_{a2}, \ldots, p_{an}\}$. The resulting demand function for a final product ak, where $k \in \{1, \ldots, n\}$, can be characterized by function q_{ak}, which depends on $\vec{p}$ and the competition intensity (or substitutability) among these products. For simplicity, we use a single parameter, θ, to capture the competition intensity from individual competitors. In the framework with a single retailer, these retail prices maximize the total profit of the monopolist retailer, $\Pi_R = \Sigma_{k=1}^{n}(p_{ak} - w_{ak} - c_R)q_{ak}(\vec{p})$, where $w_{ak} = w_a + w_k$ for $k \in \{m+1, \ldots, n\}$ and c_R is the retailer's assembly cost. In the framework with n

dedicated retailers, all the retailers set their individual retail prices simultaneously to maximize their own profits, $\Pi_R^k = (p_{ak} - w_{ak} - c_R^k)q_{ak}(\vec{p})$, where $k \in \{1, \ldots, n\}$ and c_R^k is an individual retailer k's assembly cost.

Given the demand functions, decisions, and model parameters, we can express the suppliers' profit functions under a given structure with m coalitions as follows: For components sold in packages, the total coalitional profit function of the whole package is $\Pi_{ai} = \Pi_{ai}^a + \Pi_{ai}^i = (w_{ai} - c_a - c_i)q_{ai}(\vec{p})$, for $i \in \{1, \ldots, m\}$, where c_a and c_i are suppliers a and i's individual production costs, and Π_{ai}^a and Π_{ai}^i are the proportion of the coalitional profit allocated to the two coordinating suppliers under a predetermined allocation rule. For components sold individually, supplier j's profit function is $\Pi_j = (w_j - c_j)q_{aj}(\vec{p})$, for $j \in \{m+1, \ldots, n\}$; supplier a's profit function is $\Pi_a = \Sigma_{j=m+1}^n (w_a - c_a)q_{aj}$. Hence, supplier a's total profit function can be written as $\Pi_a^T = \Sigma_{i=1}^m \Pi_{ai}^a + \Pi_a$.

4. Model Analysis

In this section we first provide some sufficient stability conditions for a coalition structure to be pairwise stable and understand how brand competition may affect alliance formation. We then present two special cases to understand these conditions and their intuitions.

For a given coalition structure with m alliances, let us assume that the equilibrium profits for the $n+1$ suppliers and retailer(s) can be uniquely characterized by using backward induction and assuming a rule to allocate the coalitional profit. Denote by $\Pi_a^T(m)$, $\Pi_i(m)$ and $\Pi_j(m)$ the equilibrium profits for suppliers a, i and j, respectively, where $i \in \{1, \ldots, m\}$ and $j \in \{m+1, \ldots, n\}$. For $m \geq 1$, if an alliance is terminated between suppliers a and i, we denote by $\Pi_a^T(m-1)$ and $\Pi_i'(m-1)$ their corresponding equilibrium profits in the new structure with $m-1$ alliances. Similarly, for $m \leq n-1$, if a new alliance is formed between suppliers a and j, we denote by $\Pi_a^T(m+1)$ and $\Pi_j'(m+1)$ their corresponding equilibrium profits in the new structure with $m+1$ alliances.

Proposition 1 (Stability Conditions for a Coalition Structure). *In the* 1-*by*-n *model, a coalition structure with* m *alliances is stable if the following conditions are jointly satisfied*:

(1) *For any* $i \in \{1, \ldots, m\}$, *we have* $\Pi_i(m) \geq \Pi_i'(m-1)$ *when* $\Pi_a^T(m) \geq \Pi_a^T(m-1)$; *and for any* $j \in \{m+1, \ldots, n\}$, *we have* $\Pi_j(m) \leq \Pi_j'(m+1)$ *when* $\Pi_a^T(m) \leq \Pi_a^T(m+1)$.

(2) $\Pi_a^T(m) \geq \max\{\Pi_a^T([m-1]^+), \ \Pi_a^T(n - [n-(m+1)]^+)\}$.

Proposition 1 indicates that, if supplier a's preferences play a dominant role in shaping the stability conditions for a structure with m coalitions, then we only need to ensure that supplier a does not have an incentive to deviate from the status quo with m coalitions to a structure with either $m-1$ or $m+1$ coalitions. Let us assume that, for any given n and θ, there exists a unique integer value of m, say, m^*, that satisfies the two stability conditions specified in Proposition 1. To understand how the level of brand competition affects coalition formation, we need to examine how m^* changes with θ. This question will be addressed subsequently.

In §§4.1 and 4.2, we will consider two special cases—one with a single retailer and the other with n dedicated retailers assuming the following linear deterministic demand functions for the final products and zero costs for production and assembly. That is,

$$q_{ak} = A - (1+\alpha)p_{ak} + \frac{\alpha}{n}\sum_{t=1}^{n}(p_{at}), \tag{1}$$

where $k \in \{1, 2, \ldots, n\}$, $A(>0)$ is the demand intercept and $\alpha \in [0, \infty)$ measures the degree of substitution among final products. This demand function can be derived from a maximization problem of a representative customer with a quadratic utility function (see Singh and Vives 1984, Ingene and Parry 2007). It has been used in economics, marketing, and operations (see, e.g., McGuire and Staelin 1983; Roller and Tombak 1990, 1993; Nagarajan and Sošić 2007).

First, for a given final product, $1+\alpha-\alpha/n$ measures its "self-price elasticity," and α/n stands for its "cross-price elasticity," which measures the competition (or substitutability) from a single competitor. Note that the self-price elasticity is always greater than the total cross-price elasticity from all competitors, since $1+\alpha-\alpha/n > \alpha(n-1)/n$ because of $n \geq 2$. Moreover, based on the self- and cross-price elasticity, we can quantify the relative degree of substitution from a single competitor as $\theta \equiv \alpha/(n+\alpha(n-1))$ (which is defined by the ratio of the cross-price elasticity from a single competitor to self-price elasticity and measures *individual competition intensity*) and the relative degree of substitution from all competitors as $(n-1)\theta = \alpha(n-1)/(n+\alpha(n-1))$ (which measures *aggregate competition intensity*), where θ strictly increases in α. It is clear that the higher the value of θ (or α) is, the stronger competition among final products. For $\alpha = 0$, we have $\theta = 0$, which indicates that final products are completely independent from each other in their demands and there is no competition. For $\alpha \to \infty$, we have individual competition intensity $\theta \to 1/(n-1)$ and aggregate competition intensity $(n-1)\theta \to 1$, which means that for any given final product, the combination of all its competitors becomes a perfect substitute to this final product economically.

Second, the aggregate demand for all final products, $nA - \sum_{t=1}^n (p_{at})$, is downward-sloping in the total retail price, and it also implies that the competition intensity among final products (i.e., the value of α or θ) does not affect the price elasticity in the aggregate level, which is a reasonable feature, since, in the aggregate market level, how strongly final products compete with each other should not impact the slope of the total demand curve. However, this does not imply that competition intensity should not have an impact on the total market potential nA. Indeed, A can decrease in θ to echo the benefits of product differentiation (see Cai et al. 2012).

Also, in the next two subsections, we will assume that suppliers in alliance agree to share the collective gains based on the proportional allocation rule. Under proportional allocation, members of a coalition share the joint (or coalitional) profit proportionally to their corresponding profits obtained when selling their goods individually, keeping all other components' selling format as is. The proportional allocation rule has been adopted by practitioners for revenue or cost allocation among coordinating players because of its simplicity. For example, it has long been used in airline alliances, where total revenue from a connecting itinerary is often divided proportionally to local fares (see, e.g., Netessine and Shumsky 2005, Wright et al. 2010, Hu et al. 2013). In group purchasing games, coordinating buyers may also split the total purchasing cost proportionally to their individual order quantities (see, e.g., Chen and Yin 2010, Chen et al. 2010, Nagarajan et al. 2010). In our model, suppliers set wholesale prices, and the components are complementary. Hence, the profit is allocated proportionally to their wholesale prices.

4.1. The 1-by-n Model with a Single Retailer

Given the linear demand function previously discussed, the three-stage 1-by-n base model presented in Figure 1(a) with a monopolist retailer can be analyzed by using backward induction. In a structure with m coalitions, the equilibrium decisions and profits are derived and summarized in Table A.2 in the online appendix. Some observations can be made by examining the equilibrium expressions in this table. First, supplier a's individual wholesale price w_a^* is always strictly less than w_{ai}^*, which prevents the retailer from using packages to replace demand for individual component a. Second, the retailer will set retail prices such that all final products have positive sales. Third, the market potential parameter A acts simply as a scale factor in individual channel members' equilibrium profits. It implies that this parameter will not affect the stable coalition structures, as long as all the final products have an equal market potential. However, if products have asymmetric market potentials, stable outcomes could be sensitive to market potential parameters (see a discussion in the online appendix).

Finally, by examining the equilibrium decisions and profits given in Table A.2 in the online appendix, we observe that, in a given coalition structure, a final product whose components are sold in a package to the retailer has a lower total wholesale price, a lower retail price, higher demand, and a higher profit, relative to that whose components are sold individually to the retailer. This efficiency gain for the packaged components stems from the reduced double marginalization penalty, where only one margin (i.e., a joint wholesale price) is determined for the components of product ai whereas two margins are chosen in the case of product aj, one for each of its components. However, the above observation does not necessarily imply that complementary suppliers would always have an incentive to form alliances. Consider a simple 1-by-2 model where supplier a is in alliance with supplier 1 of component b and is independent of supplier 2 of component b. If suppliers a and 2 decide to establish a new alliance, this behavior may benefit sales of $a2$, but it may also hurt sales of product $a1$ because of brand competition between $a1$ and $a2$. Hence, it is not clear what would happen to supplier a's overall profit. On the other hand, if suppliers a and 1 decide to discontinue their alliance, this may hurt sales of product $a1$ but may also benefit sales of product $a2$. Again, the impact on supplier a's overall profit is unclear. These observations indicate some nontrivial trade-offs when complementary suppliers form or terminate alliances.

Given the equilibrium profits in Table A.2 in the online appendix and the proportional allocation rule to split the coalitional profit, we are now ready to characterize the stable coalition structures. Following Table A.2, in a coalition structure with m alliances, the total profit (or revenue because of zero production costs) of coalition ai (consisting of suppliers a and i) is as follows: $\Pi_{ai}(m) = A^2 n(\alpha(n-1)+n)(b_0+b_1 n + b_2 n^2)^2/2(d_0+d_1 n+d_2 n^2+d_3 n^3)^2$. To determine the proportions of this joint profit allocated to suppliers a and i, we first need to obtain their reservation profits. The reservation profits are defined by their individual profits if they decide to terminate the alliance and sell their components independently to the retailer, which can be obtained from Table A.2 for a structure with $m-1$ alliances:

$$\bar{\Pi}_{ai}^{a} = \frac{(\alpha(n-1)+n)^2}{2n(\alpha(m-1)+n)} w_j^2(m-1) \quad \text{and} \qquad \bar{\Pi}_{ai}^{i} = \frac{\alpha(n-1)+n}{2n} w_j^2(m-1), \tag{2}$$

respectively. Let us denote by β_m the proportion of coalitional profit Π_{ai} that goes to supplier a. Hence,

$1-\beta_m$ is the remainder that is allocated to supplier i. Immediately we have

$$\beta_m = \frac{\bar{\Pi}^a_{ai}}{\bar{\Pi}^a_{ai}+\bar{\Pi}^i_{ai}} = \frac{\alpha(n-1)+n}{2n+\alpha(n+m-2)} \quad \text{and}$$

$$1-\beta_m = \frac{\bar{\Pi}^i_{ai}}{\bar{\Pi}^a_{ai}+\bar{\Pi}^i_{ai}} = \frac{\alpha(m-1)+n}{2n+\alpha(n+m-2)}.$$

It is clear that supplier a's profit share is higher than that of its counterpart because of its monopoly position in supplying component a. Subsequently, we can calculate the profits of supplier a and suppliers of component b in a coalition structure with m alliances (where $0 \le m \le n$), which are presented in Equations (3)–(5), respectively:

$$\Pi^T_a(m) = A^2 n t_2 (n-\alpha+n\alpha)^2 \cdot (k_0+k_1 n+k_2 n^2+k_3 n^3+k_4 n^4+k_5 n^5), \quad (3)$$

$$\Pi_i(m) = A^2 n t_2 (n+(-1+m)\alpha)(n-\alpha+n\alpha) \cdot (b_1+b_2 n+b_3 n^2)^2, \quad (4)$$

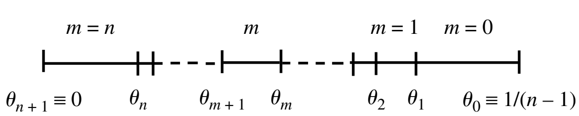
$$\Pi_j(m) = A^2 n t_1 (\alpha(n-1)+n)(\alpha m+n)^2 \cdot (-\alpha+2(1+\alpha)n)^2, \quad (5)$$

where $k_0 = 2m^2\alpha^4$; $k_1 = -m\alpha^3(-2+7m+2\alpha+6m\alpha)$; $k_2 = 2\alpha^2(-\alpha+m[-3+m(1+\alpha)(3+\alpha)+\alpha(3+5\alpha)])$; $k_3 = \alpha(4m^2\alpha(1+\alpha)^2+\alpha(10+9\alpha)-2m(1+\alpha)(-2+\alpha(9+7\alpha)))$; $k_4 = (1+\alpha)(-4\alpha(4+3\alpha)+m(1+\alpha)(1+\alpha(14+5\alpha)))$; $k_5 = 4(1+\alpha)^2(2+\alpha)$; $t_1 = 1/(2(d_0+d_1 n+d_2 n^2+d_3 n^3)^2)$; and $t_2 = t_1/((m-2)\alpha+n(2+\alpha))$, and b_1, b_2, b_3, d_1, d_2, and d_3 are given in Table A.2 in the online appendix.

These profit expressions above enable us to examine their deviation incentives under a given structure. Based on the pairwise stability concept, individual suppliers' profits in Equations (3)–(5), and Propositions 1 and 2, the necessary and sufficient conditions for a structure to be stable are characterized below.

Proposition 2 (Stable Coalition Structures). *In the base 1-by-n model with a single retailer, if coordinating suppliers follow the proportional allocation rule to share the coalitional profit, there exist n threshold values for θ, individual competition intensity, i.e., $\theta_1, \theta_2, \ldots, \theta_n$, where $\theta_{n+1} \equiv 0 < \theta_n \le \theta_{n-1} \le \cdots \le \theta_2 \le \theta_1 < 1/(n-1) \equiv \theta_0$, such that a structure with m coalitions (where $0 \le m \le n$) is stable if and only if $\theta_{m+1} \le \theta \le \theta_m$ (see also Figure 2).*

Figure 2 **Stable Coalition Structure**



First, note that the set containing pairwise stable coalition structures is never empty. Even if no alliances are formed in equilibrium, it implies that the no-alliance structure is an element of this set. Second, the extent to which complementary suppliers form alliances depends on competition intensity among final products (or brands of component b). Specifically, the stronger the competition, the less likely suppliers would form coalitions. In an extreme case when $\theta = 0$ (i.e., when final products are completely independent), supplier a would always form coalitions with all the suppliers of component b. Indeed, this setting can be considered as a model with only one final product assembled from two complementary components, each produced by a monopolist supplier. Hence, the result in this extreme case is consistent with the conclusions in, e.g., Cournot (1929).

The underlying rationale behind Proposition 2 can be explained as follows. Intuitively, an increase in brand competition for component b would reduce its suppliers' pricing power. This would also lower supplier a's pricing power if it is in alliance with these suppliers, which consequently reduces its profit gain and incentives in forming alliances with them.

Consider a coalition structure where suppliers a and n act independently. If they decide to deviate and form alliance an, this new alliance will affect both final product an and all the other $n-1$ final products, denoted by product set $\overline{an}$, on their wholesale and retail prices (namely, *the price effect*) and sales quantities (namely, *the demand effect*). For product an, the price effect is detrimental to suppliers a and n, since it leads to a decrease in wholesale and retail prices (because of lower horizontal double marginalization); however, the demand effect is beneficial because of an increase in the sales of product an (caused by price decrease). If final products are independent from each other (when $\theta = 0$), the new partnership an affects prices and sales of product an only. Clearly, the demand effect dominates the price effect, which provides an incentive for this alliance behavior (see, e.g., Cournot 1929). However, a positive competition intensity creates interactions (i.e., price and demand competition) among final products and complicates effects of alliance incentives.

Recall that the new alliance an may lead to a gain in the coalitional profit of selling package an. However, the wholesale prices and sales of the remaining $n-1$ products in set $\overline{an}$ will be reduced because of competition. Hence, supplier a's profit from sales of product set $\overline{an}$ is also reduced. When m is relatively small, component a is mainly sold independently, so supplier a's profit loss caused by alliance an dominates the potential profit gain and the net difference is even more when brand competition increases. As a result, supplier a has less incentive to form an alliance. When m is relatively large, most components are sold in packages, so the profit gain from alliance an to supplier n is marginal, and indeed the gain is dampened by stronger competition among final products. Hence, when final products compete more aggressively with each other, either supplier a or n's incentive for alliance formation will be reduced.

Finally, in terms of the effect of the number of competing brands, n, recall from the beginning of §4 that expression $(n-1)\theta$ measures the aggregate competition intensity for all competing products. This expression indicates that an increase in n (while keeping α fixed) should lead to a similar effect of an increase in α (while keeping n fixed). Hence, we may predict that an increase in n implies more competition among final products, and subsequently, alliances are less likely to be formed in equilibrium.

4.2. The 1-by-*n* Model with Dedicated Retailers

In this section we consider the model framework described in Figure 1(b) where there are n independent retailers. Without loss of generality, we assume that retailer k, $k \in \{1, 2, \ldots, n\}$, controls final product ak. For consistency and analysis simplicity, we assume that everything else remains the same as in the base model. Again, we use backward induction to solve for stable coalition structures in the three-stage game. The analysis process in determining retail and wholesale prices and then stability conditions is analog to that in the single-retailer case. Following this process, the stable coalition structures are presented in the proposition below.

Proposition 3 (Stable Coalition Structures Under Dedicated Retailers). *In the base* 1-*by*-n *model with dedicated retailers,*

(1) *there exist* n *threshold values for the relative individual competition intensity parameter* θ, *i.e.,* $\{\theta_1^{DR}, \theta_2^{DR}, \ldots, \theta_n^{DR}\}$, *where* $\theta_{n+1}^{DR} \equiv 0 < \theta_n^{DR} \le \theta_{n-1}^{DR} \le \cdots \le \theta_2^{DR} \le \theta_1^{DR} < 1/(n-1) \equiv \theta_0^{DR}$, *such that a structure with* m *coalitions* (*where* $0 \le m \le n$) *is stable if and only if* $\theta_{m+1}^{DR} \le \theta \le \theta_m^{DR}$;

(2) *moreover, we have* $\theta_k^{DR} \ge \theta_k$ *for any* $k \in \{1, 2, \ldots, n\}$.

Proposition 3(1) indicates that brand competition again discourages alliance formation. Proposition 3(2) implies that introduction of retail competition actually encourages alliance formation. The explanation is as follows. It is known that downstream competition among retailers leads to a demand increase for upstream suppliers but without losing too much in their profit margins. This results in an overall benefit for suppliers, which consequently enhances the potential profit gain via alliances. As stated in §4.1, a new partnership between independent suppliers a and n would hurt supplier a's profit collected from sales of products in set $\bar{an}$, and it may benefit suppliers a and n in terms of their profit obtained from sales of product an. Indeed, introduction of retail decentralization always dampens the detrimental effect (of alliance on products in set $\bar{an}$) and strengthens the beneficial effect (of alliance on product an). As a result, retail competition increases the overall profit gain via alliances and hence encourages suppliers to engage in coalitions.

Summarizing the analysis in §§4.1 and 4.2, we are ready to conclude that the degree of competition intensity among final products discourages alliance formation, whereas retail competition encourages it. In what follows, we provide a possible explanation for the opposite effect of the two sources of competition. Brand competition appears in the individual demand functions and could be considered as an exogenous factor to the supply chain structure, since it does not react to channel members' choices in the decision process. When the final products sold in the market become more substitutable, all of the supply chain members may get hurt. Indeed, one could verify in a 1-by-2 model that, in either the separate or joint selling case, the equilibrium sales volume decreases in the degree of brand competition. Hence, the suppliers' profit gain via alliances is reduced when brand competition increases. On the other hand, retailing is part of the supply chain structure. Both suppliers and retailers may react to the change in the level of retail decentralization. In a 1-by-2 model one could also verify that, in either the separate or joint selling scenario, the equilibrium sales volume increases in the number of retailers presented in the model. Hence, the upstream suppliers' performance via joint selling is amplified, which enhances their incentives to form alliances.

5. Managerial Insights and Concluding Remarks

Given the prevalence of selling coalitions formed among complementary suppliers in many industries, this paper has studied an analytical model to evaluate such incentives in the presence of brand and retail competition. As shown in our analysis, competition plays a significant role in determining whether or not complementary components should be sold in packages. For example, if a component has brands competing aggressively with one another, suppliers need to be more conservative in packaging their items together. However, retail competition shows favor for alliance formation. Building on our analysis and discussions both in the paper and in the online appendix, in Table 1 we summarize some conditions under which alliances are more likely to emerge in equilibrium.

Table 1 Conditions for More Alliances to Emerge in Equilibrium

- Lower brand competition, or more differentiated / less substitutable brands
- Smaller number of competing brands
- More decentralized retailing process
- Higher degree of cost asymmetry among competing suppliers when brand competition is moderate

Our study brings to light a number of managerial implications. First, a proper understanding of the type of the competition (i.e., either brand or retail competition) helps managers determine whether to form more or fewer alliances. Specifically, managers need to be cautious when forming coalitions with suppliers of a complementary component that has a highly competitive market. However, if the downstream retail system becomes more competitive or decentralized, then it makes more sense for complementary suppliers to form alliances. This suggests that suppliers need to be careful when selling packages of their goods to a large/powerful retailer who controls multiple competing final products. Second, when a supplier needs to choose a partner from multiple asymmetric complementary suppliers to form alliances with, the supplier needs to keep in mind the bargaining power of this partner, since they later need to negotiate on how to split the joint profit. Forming an alliance with a stronger partner may bring in more benefits in the aggregate level. However, the supplier who initially chooses a stronger supplier to form an alliance with may also be in disadvantage in sharing the collective gains because of the alliance, which leads to the initial supplier being worse off eventually.

Finally, note that we assume deterministic demand in all models considered. In practice, the product market may involve some demand uncertainty. To understand its effect, we conduct a preliminary study in a 1-by-2 model with one retailer. A random multiplier is added to the set of demand functions given in Equation (1). Our analysis of the no-alliance and the Full-alliance structures implies that full alliance is always preferred over no alliance if brand competition is relatively low. This observation again verifies that competition intensity discourages alliances. Our analysis also indicates that either forming alliances or an increase in brand competition would encourage the retailer to stock more inventories because of reduced wholesale and retail prices. In term of demand, we also assume that there is no separate demand stream for each individual component. It might be valuable to analyze a case that allows for additional demand for individual items and examine the effect of competition.

Supplemental Material

Supplemental material to this paper is available at http://dx.doi.org/10.1287/msom.2015.0533.

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