DISCUSSION PAPER SERIES

Discussion paper No. 166

The optimal choice of internal decision-making structures in a network industry

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September 2017

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Abstract

Focusing on the role of compatibility between products, we consider the choice of internal decision-making structures—i.e., centralization and decentralization—and its effect on welfare in a network industry where there are horizontally differentiated products associated with network externalities. We demonstrate that if the degree of a network externality is sufficiently large, it is socially optimal to choose decentralization. Furthermore, in the case of consumer *ex post* expectations, it is optimal for the firm's owners to choose centralization. However, it is socially preferable given a particular condition.

Keywords: internal decision-making; centralization; decentralization; network externality; compatibility; multiproduct monopoly

JEL Classifications: D43, D62, L14, L15, L41

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1. Introduction

In general, the choice of managerial decision-making structures in corporate organizations is a very important issue not only for owners (holding companies) but also for researchers in economics as well as in business and management. As described in Dargaud and Jacques (2015, p. 155), an optimal organizational design depends on a number of factors. For example, Maskin et al. (2000) model an organization as a hierarchy of managers. Harris and Raviv (2002) explain organization structures, based on the coordination of interactions among activities. Baye et al. (1996), Tan and Yuan (2003), and Creane and Davidson (2004) consider organizational structures from the point of view of strategic behavior; e.g., divisionalization, franchising, and divestiture incentives.

We follow Dargaud and Jacques (2015) who analyze the centralized organization (i.e., unitary form) and the decentralized organization (i.e., multidivisional form) to develop a theory of the centralization of firms engaged in multimarket collusive agreements. Similarly, Rasch and Wambach (2009) use centralized/decentralized structure to consider how the choice of internal decision-making rules affects the sustainability of collusive behavior.

In this paper, we consider the choice of internal decision-making structures and its effect on welfare in a network industry, focusing on the role of compatibility between products. That is, we show that the optimal choice depends on the properties of network products and the timing of consumer expectations about network size.

We often observe network externalities and compatibilities (interconnectivities) in network industries. These include not only telecommunications, internet businesses, application software and hardware, banking and credit card systems, and others associated with the progress of information and communication technologies but also airlines, railways, electric power, and so on.[1]

Recently, we have also seen that a holding company resulting from merger and acquisitions (M&A), with multi-divisional local unit firms that provide the products and service, arises in network industries.[2] In this case, our research question is how the holding company formed by M&A decides to delegate decision-making to the local firms. The question in the context of our model is how the holding company chooses its internal decision-making structures; i.e., centralization or decentralization. We demonstrate the conditions under which a profit maximizing holding company chooses either centralization or decentralization. Furthermore, we also examine the impact of the choice on social welfare. This is related to antitrust and competition policies.

In the following section, we set up the model and examine the noncooperative Cournot duopoly case as a benchmark. In Section 3, we consider the optimal choice of internal decision-making structures and then examine its effect on welfare, particularly on consumer surplus. Furthermore, in Section 4, changing the assumption regarding consumer expectation about network size, we similarly investigate the choice of internal decision-making structures and its effect on welfare. In the last section, we present our conclusions and remaining problems.

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[1] Grajek (2010) empirically analyzes network externalities in the mobile phone industry.

[2] Gandal (2002) discusses merger policy in a network industry.

2. The Model

2.1. Demand for horizontally differentiated products with network externality

We consider a network industry where there are two horizontally differentiated products associated with network externalities. Applying the frameworks of Economides (1996) and Häckner (2000), we assume the following inverse demand function of product *i*:

$$p_i = A - q_i - \gamma q_j + N(S_i^e), \tag{1}$$

where A is the intrinsic market size of product *i*, q_i is the output of product *i*, and $\gamma \in (0,1)$ represents the level of product substitutability. Furthermore, $N(S_i^e)$ is the network externality function, where S_i^e represents the expected network size of product *i*. We assume a linear network externality function, $N(S_i^e) = nS_i^e$, where $n \in [0,1)$ represents the level of network externality. We also assume that the expected network size of product *i* is given by:

$$S_i^e \equiv q_i^e + \phi_k q_j^e, \quad k = N, M, \tag{2}$$

where $\phi_k \in [0,1]$, $k = N, M$, denotes the level of product *i*'s compatibility (interoperability and interconnectivity) with the other product *j* in the cases of noncooperative Cournot competition as a benchmark (*N*) and a multiproduct monopoly case (*M*) formed by the centralized decision-making.

Considering the concept of a fulfilled expectation, we assume that consumers develop expectations for network sizes before the firms make their output decisions.[3] Thus, when deciding the output level, the expected network sizes are given for the

[3] See Katz and Shapiro (1985) and Economides (1996).

firms.

Furthermore, we assume that production costs are zero, because we observe low and even negligible running costs and marginal production costs in internet businesses. We also assume that there are no costs of decentralization; e.g., various costs incurred in changing product lines and resource reallocation.

2.2. Benchmark: Noncooperative Cournot duopoly

As a benchmark, we consider that two firms noncooperatively compete on quantities, *à la* Cournot, in the market. Based on equation (1), the profit function of firm *i* is given by:

$$\pi_i = \left\{A - q_i - \gamma q_j + N(S_i^e)\right\}q_i. \tag{3}$$

The first-order condition (FOC) of profit-maximization is:

$$\frac{\partial \pi_i}{\partial q_i} = p_i - q_i = A - 2q_i - \gamma q_j + N(S_i^e) = 0. \tag{4}$$

At the point of a fulfilled expectation—i.e., when $q_i^e = q_i$ and $q_j^e = q_j$—in view of equations (2) and (4), we obtain the following:

$$A - (2-n)q_i - (\gamma - n\phi_N)q_j = 0. \tag{5}$$

Assuming a symmetric equilibrium—i.e., $q_i = q_j = q_N$ —we derive the following fulfilled expectation Cournot equilibrium (*N*):

$$q_N = \frac{A}{2 - n + (\gamma - n\phi_N)}, \tag{6}$$

where $n\phi_N$ is the level of network compatibility in the case of noncooperative Cournot competition. Because this holds that $p_N = q_N$, based on equation (4), the profit in the case of noncooperative Cournot competition is expressed as $\pi_N = (q_N)^2$.

3. Internal Decision-Making Structures and Welfare

To consider the optimal choice of internal decision-making structures—i.e., either centralized or decentralized—we assume that there is a holding company (owners and stockholders) that owns two local unit firms, which respectively provide horizontally differentiated products with network compatibilities. We use a two-stage game. That is, in the first stage, the holding company decides whether or not to delegate the quantity-setting decision to its local unit firms. In the second stage, in the case of nondelegation, the centralized firm (i.e., the multiproduct firm) decides the output levels of the two products; in the case of delegation—i.e., decentralization—two local unit firms noncooperatively decide the output level. We derive a subgame perfect Nash equilibrium by backward induction.

3.1. The centralized decision-making structure: A multiproduct monopoly

The holding company centralizes quantity-setting. This implies that the holding company itself determines the output level of the two products. Thus, we can say that the holding company is a multiproduct monopoly.

The multiproduct monopoly that provides products *i* and *j* (hereafter, the monopoly) determines the output level to maximize the following total profits:

$$\Pi_M = \pi_i + \pi_j$$
$$= \{A - q_i - \gamma q_j + N(S_i^e)\}q_i + \{A - q_j - \gamma q_i + N(S_j^e)\}q_j. \tag{7}$$

The FOC is given by:

$$\frac{\partial \Pi_M}{\partial q_i} = p_i - q_i - \gamma q_j = A - 2q_i - 2\gamma q_j + N(S_i^e) = 0. \tag{8}$$

At the point of a fulfilled expectation—i.e., when $q_i^e = q_i$ and $q_j^e = q_j$—in view of equations (2) and (8), we obtain the following:

$$A - (2 - n)q_i - (2\gamma - n\phi_M)q_j = 0. \tag{9}$$

Assuming a symmetric equilibrium—i.e., $q_i = q_j = q_M$ —we derive the following fulfilled expectation equilibrium (*M*):

$$q_M = \frac{A}{2 - n + (2\gamma - n\phi_M)}, \tag{10}$$

where $n\phi_M$ is the level of network compatibility in the case of the monopoly.

Using equation (8), because the monopoly price is expressed as $p_M = (1+\gamma)q_M$, the profit of a unit firm is given by $\pi_M = (1+\gamma)(q_M)^2$. Thus, the total profits are expressed as: $\Pi_M = 2\pi_M = 2(1+\gamma)(q_M)^2$.

Taking equations (6) and (10), we obtain the following relationship:

$$q_M > (<) q_N \Leftrightarrow n(\phi_M - \phi_N) > (<) \gamma, \tag{11}$$

where $n(\phi_M - \phi_N)$ implies the net level of network compatibilities. If the net level is nonpositive, as is well known, the output level in the case of the monopoly is always smaller than that in the case of noncooperative Cournot competition. However, if the net level is larger than the level of product substitutability—i.e., $n(\phi_M - \phi_N) > \gamma$ —the output level in the case of the monopoly is larger than that in the case of noncooperative Cournot competition. This implies that the monopoly increases consumer surplus compared with the case of noncooperative Cournot competition.

It is necessary to maintain the condition—i.e., $n(\phi_M - \phi_N) > \gamma$—that there is a stronger network externality—i.e., $n > \gamma$—and that the level of compatibility in the case of the monopoly is larger than that in the case of noncooperative Cournot competition; i.e., $\phi_M > \phi_N$.

Next, with respect to the profit per a unit firm, we derive the following relationship:

$$\pi_M > (<) \pi_N \Leftrightarrow \sqrt{1+\gamma}(q_M) > (<) q_N$$

$$\Leftrightarrow \left(\sqrt{1+\gamma} - 1\right)\{2 - n + (\gamma - n\phi_N)\} + n(\phi_M - \phi_N) - \gamma > (<) 0.$$

Thus, if $n(\phi_M - \phi_N) > \gamma$, then it holds that $\pi_M > \pi_N$. In this case, consumer surplus increases compared with the case of noncooperative Cournot competition. This result implies that the monopoly is more socially preferable to noncooperative Cournot competition.

The above relationship can be also expressed as:

$$\pi_M > (<) \pi_N \Leftrightarrow \Gamma(\gamma) + \left[(1+\phi_M) - \sqrt{1+\gamma}(1+\phi_N)\right] n > (<) 0, \qquad (12)$$

where $\Gamma(\gamma) \equiv \left[\sqrt{1+\gamma}(2+\gamma) - 2(1+\gamma)\right] > 0$ and $1 > n > \gamma > 0$. Even with $n(\phi_M - \phi_N) < \gamma$, based on equation (12), if $\dfrac{1+\phi_M}{1+\phi_N} \geq \sqrt{1+\gamma}$, then it holds that $\pi_M > \pi_N$. Furthermore, if $\dfrac{1+\phi_M}{1+\phi_N} < \sqrt{1+\gamma}$, equation (12) can be rewritten as:

$$\pi_M > (<) \pi_N \Leftrightarrow \mathrm{N}(\gamma, \phi_M, \phi_N) > (<) n, \qquad (13)$$

where $\mathrm{N}(\gamma, \phi_M, \phi_N) \equiv \dfrac{\Gamma(\gamma)}{\sqrt{1+\gamma}(1+\phi_N)-(1+\phi_M)} > 0$. Thus, if $\mathrm{N}(\gamma, \phi_M, \phi_N) > n$, it holds that $\pi_M > \pi_N$.

3.2. Decentralized decision-making structure

The holding company decides to delegate the quantity decision-making power to its local unit firms (*D*). Thus, two independent firms provide products *i* and *j* for each other, given that the level of compatibility between the products is the same as that in the monopoly; i.e., $\phi_D = \phi_M$.

Because each firm noncooperatively decides the output level, based on the case of noncooperative Cournot competition in Section 2.2, we derive the following equilibrium output level:

$$q_D = \frac{A}{2-n+(\gamma - n\phi_M)}. \tag{14}$$

In this case, the total profits are given by $\Pi_D = 2\pi_D = 2(q_D)^2$.

Based on equations (6) and (14), comparing the output level and profit per a unit firm, we obtain the following relationships:

$$q_D > (<) q_N \Leftrightarrow \phi_M > (<) \phi_N, \tag{15}$$

$$\pi_D > (<) \pi_N \Leftrightarrow q_D > (<) q_N \Leftrightarrow \phi_M > (<) \phi_N. \tag{16}$$

Given the noncooperative output decisions in both cases, the output levels and profits depend on the levels of compatibility.

3.3. The optimal decision–making structure and welfare

We examine which internal decision-making structure (i.e., centralized or decentralized) the holding company decides on in the first stage. Because the total profits in these cases are $\Pi_M = 2\pi_M = 2(1+\gamma)(q_M)^2$ and $\Pi_D = 2\pi_D = 2(q_D)^2$, we derive the following relationship:

$$\Pi_D > (<)\Pi_M \Leftrightarrow n > (<)M(\gamma, \phi_M), \tag{17}$$

where $M(\gamma, \phi_M) \equiv \frac{\Gamma(\gamma)}{\left(\sqrt{1+\gamma}-1\right)(1+\phi_M)} > 0$.[4]

In view of equation (17), if the degree of a network externality—i.e., n—is larger than $M(\gamma, \phi_M)$, with the same degree of product substitutability and compatibility as in the case of the monopoly, then it is optimal for the holding company to choose decentralization of quantity decision-making. Otherwise, the holding company chooses centralization of quantity decision-making, so that a multiproduct monopoly provides the two products.

We examine whether the decision by the holding company is socially preferable in terms of consumer and thus total surplus. Taking equation (1), consumer surplus is given by $CS_k \equiv (1+\gamma)(q_k)^2$, where $k = N, M, D$.

In view of equations (10) and (14), the following holds:

$$q_D > q_M. \tag{18}$$

This is because, given the same level of compatibility in both cases, the noncooperative output level under delegation is always larger than the monopoly output level.[5] Thus, it holds that $CS_D > CS_M$.

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[4] It holds that $\mathrm{N}(\gamma, \phi_M, \phi_N) > (<)M(\gamma, \phi_M) \Leftrightarrow \phi_M > (<)\phi_N$.

[5] The FOC is expressed as: $\left.\frac{\partial \Pi_M}{\partial q_i}\right|_{\frac{\partial \pi_i}{\partial q_i}=0} = \frac{\partial p_j}{\partial q_i} q_j = -\gamma q_j < 0$. In this case, because the relationship between the products is substitutionary, we have equation (18).

Therefore, we have the following result.

Proposition 1

If the degree of a network externality is sufficiently large—i.e., $n > M(\gamma, \phi_M)$*—then a decentralized decision-making structure is optimal for the holding company. Furthermore, decentralization is socially preferable because not only consumer surplus but also total profits increase.*

Conversely, if the degree of a network externality is small—i.e., $n < M(\gamma, \phi_M)$ —the holding company chooses the centralized decision-making structure. In this case, an implicit collusion—i.e., a multiproduct monopoly—arises. This case is not preferable for consumers, because consumer surplus decreases. For example, from the viewpoint of antitrust authorities and competition policy, if centralization is evaluated on consumer surplus, the antitrust authorities may not allow the decision of the holding company.

Furthermore, if the level of compatibility between the products in the case of the monopoly, which is the same as that of a unit firm under decentralization, is larger than that in the case of noncooperative Cournot competition—i.e., $\phi_M > \phi_N$ —it holds that $CS_D > CS_N$ and $\Pi_D > \Pi_N$. That is, consumer surplus and total profits under decentralization are larger than in the case of noncooperative Cournot competition.

4. The Case of Consumer *Ex Post* Expectations

So far, we have assumed that the expected network size is given for the centralized monopoly and decentralized local firms because consumers form their expectations about network size before the output decision. We call this the case of consumer *ex ante* expectations. In this section, we consider the case where consumers form their expectations for network size after the output decision—i.e., *ex post* expectations—and thus the firms can affect the network size.[6] In this case, $q_i^e = q_i$ and $q_j^e = q_j$, because consumers believe the firms' output levels in forming their expectations of network size. Thus, equation (2) is revised as follows: $S_i^e = S_i = q_i + \phi_k q_j$, $k = N, M$. Accordingly, in the case of consumers' *ex post* expectations, the inverse demand function is given by:

$$\hat{p}_i = A - (1-n)\hat{q}_i - (\gamma - n\phi_k)\hat{q}_j. \tag{19}$$

Hereafter, by following the same procedure as in the previous sections, we derive the equilibrium outputs and profits in the cases of noncooperative Cournot competition, a multiproduct monopoly by centralization (hereafter, monopoly), and decentralization. See Table 1.

Insert Table 1

With respect to the outputs, we obtain the following relationships:

$$\hat{q}_M > (<)\hat{q}_N \Leftrightarrow n(2\phi_M - \phi_N) > (<)\gamma, \tag{20}$$

$$\hat{q}_D > (<)\hat{q}_N \Leftrightarrow \phi_M > (<)\phi_N, \tag{21}$$

6 In other words, we examine a subgame perfect Nash equilibrium in which consumers observe output levels before making actual consumption decisions. Because consumers have to make their choice given the choices of all other consumers in the Nash equilibrium, each consumer's beliefs about the behavior of other consumers are confirmed.

$$\hat{q}_D > (<)\hat{q}_M \Leftrightarrow \gamma > (<) n\phi_M. \tag{22}$$

Thus, if it holds that $n(\phi_M - \phi_N) > \gamma \Leftrightarrow n\phi_M > \gamma + n\phi_N$, which is the condition in the case of consumer *ex ante* expectations, we derive the following relationship:

$$\hat{q}_M > \hat{q}_D > \hat{q}_N. \tag{23}$$

Equation (23) implies that consumer surplus in the case of the monopoly is larger than in the others.

In view of the profits as in Table 1, we can directly derive the following relationship: $\hat{\Pi}_M > \hat{\Pi}_D$. [7] Thus, the holding company chooses a centralized decision-making structure, so a centralized multiproduct monopoly arises in the case of consumers' *ex post* expectations.

Furthermore, as shown above, if $n\phi_M > \gamma + n\phi_N$, the centralized monopoly providing products with a sufficiently high level of network compatibility is preferable for consumers and the society. This result is different from that in the case of consumer *ex ante* expectations because in this case, the expected network size is exogenously given for output levels of both the centralized monopoly and the decentralized local firms. Thus, given the same level of network compatibility, as in equation (18), the equilibrium output level of the decentralized local firms is larger than that of the centralized monopoly. However, in the case of consumer *ex post* expectations, the expected network size is known for the centralized monopoly and the decentralized local firms, and they can decide their output levels according to the level of network

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[7] The profits in Table 1, we can derive the following relationships:
$$\hat{\Pi}_D > (<)\hat{\Pi}_M \Leftrightarrow \hat{\pi}_D > (<)\hat{\pi}_M \Leftrightarrow (1-n)(\hat{q}_D)^2 > (<)\{1-n+(\gamma - n\phi_M)\}(\hat{q}_M)^2$$
$$\Leftrightarrow (1-n)\left[\frac{1}{2(1-n)+(\gamma - n\phi_M)}\right]^2 > (<)\frac{1}{4\{1-n+(\gamma - n\phi_M)\}} \Leftrightarrow 0 > (<)(\gamma - n\phi_M)^2.$$

compatibilities. Thus, as in equation (22), the level of network compatibility under the centralized monopoly is larger with product substitutability, and the equilibrium output level of the centralized monopoly is larger than that of the decentralized local firms.[8] In addition, the prices of the centralized monopoly are higher than those of the decentralized local firms. As a result, the profits of the centralized monopoly are larger than those of the decentralized local firms.

We summarize the analysis discussed above as follows.

Proposition 2

If consumers form expectations about network size after the firms make their output decisions—i.e., ex post expectations—it is optimal for the holding company to choose the centralized decision–making structure (i.e., multiproduct monopoly). However, if $n\phi_M > \gamma + n\phi_N$, *the multiproduct monopoly is socially preferable because consumer surplus, total profits, and thus social surplus are larger than those in the cases of decentralization and noncooperative Cournot competition.*

Proposition 2 implies that collusive agreements and mergers—i.e. a multiproduct

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[8] The FOC of total profit maximization of the monopoly in the case of consumers' ex post expectations is given by: $\frac{\partial \hat{\Pi}_M}{\partial \hat{q}_i} = \hat{p}_i + \frac{\partial \hat{p}_i}{\partial \hat{q}_i}\hat{q}_i + \frac{\partial \hat{p}_j}{\partial \hat{q}_i}\hat{q}_j$. In this case, evaluating at the equilibrium of decentralization—i.e., $\frac{\partial \hat{\pi}_i}{\partial \hat{q}_i} = \hat{p}_i + \frac{\partial \hat{p}_i}{\partial \hat{q}_i}\hat{q}_i = 0$—the FOC is expressed as: $\left.\frac{\partial \hat{\Pi}_M}{\partial \hat{q}_i}\right|_{\frac{\partial \hat{\pi}_i}{\partial \hat{q}_i}=0} = \frac{\partial \hat{p}_j}{\partial \hat{q}_i}\hat{q}_j = -(\gamma - n\phi_M)\hat{q}_j$. If $\gamma > (<) n\phi_M$, the relationship of both products is substitutionary (complementary). The monopoly does not have (has) an incentive to provide more of the products. Thus, we have equation (22).

monopoly—are more efficient than noncooperative competition in terms of social welfare.

5. Concluding Remarks

We examined the optimal choice of internal decision-making structures and its welfare effect in a network industry. Focusing on the role of compatibility between products, we demonstrated that if the level of a network externality is sufficiently large, decentralization increases not only consumer surplus but also total profits compared with the cases of the centralized multiproduct monopoly and noncooperative Cournot competition. This result is socially preferable not only for consumers and antitrust authorities but also for the holding company (i.e., stockholders).

We should note that if consumers form their expectations of network size after a firm's output decision, the centralization of decision-making structure is optimal for the holding company. Thus, the centralized multiproduct monopoly provides horizontally differentiated products with network compatibilities. However, if the level of network compatibility under the multiproduct monopoly is sufficiently large, consumer surplus is larger than that in the cases of noncooperative Cournot competition and decentralization.

We appreciate that because the model is based on various specific assumptions, we should not directly apply the results to antitrust and competition policies. In future research, we intend to discuss more general cases, relaxing the limiting assumptions and extending the model to oligopolistic competition. In this paper, we have dealt with multiproduct monopoly case. However, in the case of oligopoly, we must consider the role of outside (multiproduct) firms when investigating the optimal choice of internal decision-making structures.

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Table 1: The case of consumers' *ex post* expectations

	Output	Profit and total profits
Noncooperative Cournot competition (Benchmark)	$\hat{q}_N = \dfrac{A}{2(1-n)+(\gamma - n\phi_N)}$	$\hat{\pi}_N = (1-n)(\hat{q}_N)^2$ $\hat{\Pi}_N = 2\hat{\pi}_N$
Centralization	$\hat{q}_M = \dfrac{A}{2\{1-n+(\gamma - n\phi_M)\}}$	$\hat{\pi}_M = \{1-n+(\gamma - n\phi_M)\}(\hat{q}_M)^2$ $\hat{\Pi}_M = 2\hat{\pi}_M$
Decentralization	$\hat{q}_D = \dfrac{A}{2(1-n)+(\gamma - n\phi_M)}$	$\hat{\pi}_D = (1-n)(\hat{q}_D)^2$ $\hat{\Pi}_D = 2\hat{\pi}_D$