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Profit-enhancing know-how disclosure: A strategic view

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Profit-enhancing know-how disclosure: A strategic view*

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Abstract

In general, the disclosure of know-how and technological knowledge could harm the disclosing firm. Firms, however, often share their know-how freely and yet enhance their profits. We provide a theoretical framework and a new insight into know-how disclosure. We consider a multiproduct oligopolistic market in which an incumbent firm that can disclose its cost-reducing know-how and several new entrants exist. Each firm supplies products in two separate markets. The incumbent firm has already allocated its production resources to one market (market A) and discloses its know-how concerning production in market A. We show that the disclosure of know-how for cost reduction can enhance the profit of the incumbent (the disclosing) firm. Using the disclosed know-how, the entrants can produce for a low cost in market A and allocate their production resources to the other market. As a result, competition in market A is less severe than that in the case in which the incumbent does not disclose its know-how. We also provide several extensions of the basic scenario.

JEL classification codes: L13, M21, D21

Key words: know-how, disclosure, resource allocation, multiproduct firms

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1 Introduction

1.1 Motivation and related papers

Basically, disclosure of know-how and technological knowledge is beneficial from the viewpoint of social welfare. Such behavior, however, could rebound on the disclosing firm. To encourage the disclosure of know-how or knowledge related to production efficiency improvement, the governments of many countries ensure exclusive rights of innovators through patent laws, and innovators can license their know-how or technological knowledge to firms and institutes. In the literature of know-how disclosure, therefore, the following two topics are discussed with great interest: (1) how to licence (see Kamien and Tauman (1984, 1986), Katz and Shapiro (1985, 1986), and Muto (1993), among others) and (2) how to protect innovators (see Gilbert and Shapiro (1990), Klemperer (1990), Denicolò and Franzoni (2004) and other special issues of the *RAND Journal of Economics* (see Saloner (1990)) as well as Scotchmer (2004)).

On the other hand, some researchers point out that innovating firms often do not sell or license their innovation but instead freely reveal the details of their innovation to rival firms. For instance, von Hippel (1988) points out that rival firms in the steel mini-mill industry routinely exchanged technical information, and he proposes a theory of know-how sharing based on the idea that it reduces costs (see also von Hippel and Schrader (1996)).[1]

In the literature of economics, some researchers discuss the profitability of freely revealing knowledge related to production technologies (e.g. cost-reducing higher skills). We now concentrate on three papers that treat revelations of technical information to all the players in the market. This type of revelation is also discussed in our paper and is the main concern of this study.

In his examination of the history of technical advances in England's Cleveland district during the nineteenth century, Allen (1983, pp.18–20) provides three situations in which the revelation of technical information might be profitable. One of them is as follows. If the production process involves a natural resource that commands a rent, and if the invention lowers the firms' processing costs of only that portion of the resource with certain characteristics, then the owners of those firms

[1] Eaton and Eswaran (2001) construct a model based on the idea of von Hippel (1988).

might benefit from releasing technical information.[2]

In the R&D literature, De Fraja (1993) considers an R&D tournament in which two firms invest until an innovation occurs.[3] In his model, when the payoff of the loser is close to that of the winner, the firms disclose their knowledge concerning R&D investments because disclosure shortens the expected duration of the R&D competition and reduces investment costs.

Free revelation of knowledge and know-how is observed in the information technology industry.[4] As pointed out by Mustonen (2005), some firms create competition by supporting open-source communities, in which programs are substituted for another firm's programs. Based on the idea of Lerner and Tirole (2002), Mustonen (2005) develops an analytical model in which a copyright firm and a copyleft (open-source) community compete in a program market and shows that the copyright firm makes its program compatible with that of the copyleft community and supports the copyleft community if the network effect of the program is weak.

In this paper, we provide a theoretical framework to show a new insight into know-how disclosure related to production technologies. An incumbent firm that can disclose its cost-reducing know-how and several new entrants exist. If the incumbent firm discloses its know-how, all entrants learn it, and their production costs decrease. Under some conditions, through the disclosure, the incumbent firm can achieve a higher profit.

We now explain the basic setting of our model. We consider a multiproduct oligopolistic market. An incumbent firm that can disclose its cost-reducing know-how and several new entrants exist. Each firm supplies its products in two separate markets, A and B. Each multiproduct firm has to allocate its production resource for the markets. If a firm allocates its resource for market A, it can produce a lower marginal cost in market A, but it has to incur a higher marginal cost in market B.[5] The

[2] The remaining situations are as follows. (1) If the world is characterized by competition among firms in different regions with different relative factor prices, each region can lower its costs and raise resource rents relative to other regions by practicing collective invention and broadcasting technical information. (2) Output and profits would be greater if the existing regime of trade secrets were replaced by a new regime of free information exchange. Based on one of the possibilities listed by Allen (1983), Cowan and Jonard (2003) developed a formal model that accounts for the dynamics of knowledge and collective invention and demonstrated that a communication network structure has a strong influence on system performance.

[3] In the context of an R&D race, Bar (2006) considers the strategic publishing of research findings.

[4] See Kende (1998), Raymond (1999), and Lerner and Tirole (2002)

[5] This setting is somewhat similar to the spatial discrimination model, in which firms choose their locations. For

incumbent firm has already allocated its resources to market A and discloses its know-how concerning production in market A. From such disclosure, the entrants can economize on their production in market A. In our paper, we assume that the disclosed know-how is more effective for an entrant that allocates its resources to market B (called type B) than for one that allocates its resources to market A (called type A). In the literature on R&D, as the efficiency of a product improves, the marginal effect of cost-reducing activities decreases. We now apply these steps to our settings. In market A, type A is more efficient than type B. Therefore, the benefit from know-how disclosure for type A is smaller than for type B.[6]

Such resource allocations are commonly observed in many industries. For instance, if in the automobile industry, the "market" is represented by car size, resource allocation by a firm may indicate that the firm produces small cars efficiently and large cars inefficiently. In the consumer electronics industry, possible interpretations of the "market" include televisions, refrigerators, and electronic ovens, and a resource allocation by a firm could be interpreted as its ability to produce televisions efficiently while being unable to produce electronic ovens efficiently.

From the model, we show that the disclosure of know-how for the purpose of cost reduction can enhance the profit of the incumbent (disclosing) firm. That is, it is possible that revealing technical information could be profitable. We now show the intuition behind this result. First, suppose that the incumbent does not disclose its know-how. In this case, some entrants allocate their resources to market A, while others allocate theirs to market B. The number of firms that allocate their resources to market A is nearly equal to that of firms that allocate to market B. Now, suppose that the incumbent discloses its know-how. Using the disclosed know-how, each entrant can produce its product at a low marginal cost in market A. Allocating their resources to market A is ineffective for the entrants. Know-how disclosure induces some entrants to change the allocation patterns of their resources, which mitigates the competition in market A because the number of tough competitors in market A (firms allocating their resources to market A) decreases because of know-how disclosure.

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discussions of the spatial discrimination model, see Hamilton, Thisse, and Weskamp (1989), Anderson and Neven (1991), Pal (1998), and Matsushima (2001), among others.

[6] To clarify the analysis, we assume that the benefit of know-how disclosure for type A is sufficiently small. In the latter part of the introduction, we provide the intuition behind the result based on this assumption.

The decrease in the number of competitors is beneficial for the incumbent firm. Of course, know-how disclosure reduces the production costs of entrants in market A who allocate their resources to market B. This is harmful for the incumbent firm. These are trade-offs. In our model, if the incumbent firm sets the degree of know-how disclosure appropriately, the former positive effect dominates the latter negative one. Therefore, revealing technical information may be profitable.

In the model, know-how disclosure can harm entrants who allocate resources to market B. As mentioned earlier, know-how disclosure reduces production costs of entrants into market A who allocate their resources to market B, which is beneficial for them. On the other hand, know-how disclosure induces some entrants to change the allocation patterns of their resources. It enhances the competition in market B because the number of tough competitors in market B (firms allocating their resources to market B) increases because of know-how disclosure. These are trade-offs. In this sense, the profits of the entrants who allocate their resources to market B are seen as the flip side of the profit of the incumbent. The result implies that the incumbent firm may disclose its know-how in its industry as a payoff-enhancing entry deterrent.

Signaling and disclosure elements have been analyzed by economics researchers.[7] Some of these discuss knowledge disclosure to all market participants, which is also discussed in our paper.

Bhattacharya and Ritter (1983) discuss a situation in which an asymmetrically informed agent is motivated to communicate a privately known attribute. To raise external financing in the capital market, the informed agent has to disclose technological information of direct usefulness to competitors. The firm, therefore, faces a trade-off between reducing the value of its informational advantage and raising finance on better terms that reflect its innovation prospects. The main concern in their paper is knowledge disclosure as a credible persuasive device, and this mechanism is quite different from that in our paper.

Anton and Yao (2004) discuss how much of an innovation should be disclosed and how much should be kept secret.[8] An innovating firm has private information about an invention that enables firms

[7] See for instance, Okuno-Fujiwara, Postlewaite, and Suzumura (1990) and Anton and Yao (1994).

[8] Anton and Yao (2003) also consider the strategic transmission of enabling information. There is potential value to an innovator firm in signaling a strong capability via a disclosure that transfers technical knowledge to a competitor. They show a positive relation between the degree of knowledge transfer and the efficiency of the innovator.

to reduce their marginal costs. The innovating firm decides whether to protect via patent and how much of the invention to disclose. They show that in a large innovation range, the innovator eschews a patent and partially discloses its knowledge.

The paper proceeds as follows. The next subsection provides a quantitative example of our basic model. Section 2 discusses the case of a Japanese supermarket chain. Section 3 outlines the basic model. Section 4 presents results, and Section 5 extends the basic model. Finally, Section 6 offers some concluding remarks. The proofs of the paper are presented in the supplementary material on the author's web site (http://norick.sakura.ne.jp/research/jems.pdf).

1.2 Quantitative example

We now provide a quantitative example to clarify the mechanism of our main results.

There are four multiproduct firms. Firm 0 is the incumbent firm, and firms 1, 2, and 3 are entrants. Each firm supplies its products in two separated markets, A and B. Market i is for product i ($i = A, B$). Let p_i denote the price of the production in market i ($i = A, B$), and let q_i denote its quantity. The demand functions in markets A and B for the products are represented by $q_A = 1 - p_A$ and $q_B = 1 - p_B$, respectively. In each market, the firms compete in quantity.

Each multiproduct firm supplies its products to the markets. Each has to locate in one of the markets. Each firm can produce its product without costs in the market in which it locates, while it has to incur a constant marginal cost t to produce its product in the other market. To ensure positive quantities supplied by each firm, we assume that $t < 1/4$. We can interpret "market" as varieties of goods, and the point of a firm's location as the firm's most efficient sector.

Firm 0 has already located at A, that is, it has already allocated its resources to product A. The other firms decide where to locate. Before they choose their locations, firm 0 decides whether to disclose its know-how concerning product A. If it discloses its know-how, a firm locating at B can produce product A with a constant marginal cost $\tau(< t)$ (τ is a positive constant). That is, know-how disclosure by firm 0 reduces the marginal costs of the rivals. The disclosure helps entrants making units of product A. By controlling the amount of information concerning the product that it efficiently produces, firm 0 is able to control the level of τ.

The game runs as follows. In the first stage, firm 0 decides whether to disclose its know-how concerning product A. If it decides to disclose, it sets the level of τ. In the second stage, given the decision of firm 0, firms 1, 2, and 3 decide where to locate. In the third stage, given the locations of the firms, each firm decides on the quantities to supply to the markets.

Before we discuss the main concern, we show the result of n-firm quantity (Cournot) competition. Let c_i $(i = 1, \ldots, n)$ be the constant marginal cost of firm i. When the (inverse) demand function is $p = 1 - Q$ (p: price; Q: the aggregate industry output), the profit of firm i (π_i) is:

$$\pi_i = \frac{(1 + \sum_{j=1}^{n} c_j - (n+1)c_i)^2}{(n+1)^2}.$$

We consider two cases: (i) firm 0 does not disclose its know-how, and (ii) firm 0 discloses its know-how. We now discuss the locations of firms.

When firm 0 does not disclose its know-how, the following location pattern is a unique equilibrium outcome: 2 firms (including firm 0) locate at A, and two firms locate at B. Under the location pattern, each firm's profit is:

$$\pi_A = \pi_B = \frac{(1+2t)^2}{25} + \frac{(1+2t-5t)^2}{25} = \frac{2 - 2t + 13t^2}{25}. \quad (1)$$

When firm 0 discloses its know-how and sets the value of τ at $\tau = t - t^2$, the following location pattern is the unique equilibrium outcome: firm 0 locates at A, and the other three firms locate at B. Under this location pattern, each firm's profit is:

$$\begin{aligned} \pi_A^d &= \frac{(1+3(t-t^2))^2}{25} + \frac{(1+t-5t)^2}{25} = \frac{2 - 2t + 19t^2 - 18t^3 + 9t^4}{25}, \\ \pi_B^d &= \frac{(1+3(t-t^2)-5(t-t^2))^2}{25} + \frac{(1+t)^2}{25} = \frac{2 - 2t + 9t^2 - 8t^3 + 4t^4}{25}. \end{aligned} \quad (2)$$

The discussion turns now to the difference in firm 0's profit when it discloses its know-how and when it does not. From (1) and (2), the difference is as follows:

$$\pi_A^d - \pi_A = \frac{3t^2(2 - 6t + 3t^2)}{25} > 0, \quad (t < 1/4).$$

That is, the disclosure of its know-how is beneficial for firm 0. A lower value of $\tau(< t)$ induces a change in the location of one entrant firm. In our model, the cost-reducing know-how has an effect on the specialization strategies (location strategies) of entrant firms. Through know-how disclosure, locating at B is more profitable for entrant firms, so the number of firms in market A is smaller than in market B. The competition condition in market A becomes less competitive. Note that if the number of firms in the markets is fewer than four, know-how disclosure does not function because such a locational distortion does not matter.

2 The case of a Japanese supermarket chain

2.1 Background

In general, a firm would never disclose its know-how. However, there are firms that act in a manner that differs from this common practice. For example, it is known that Kansai Supermarket (hereinafter referred to as KSP), a regional supermarket chain in Japan, actively disclosed its own know-how to potential rivals between 1970 and 1985, which was a growth period for the supermarket industry in Japan.

KSP, a regional chain, was established in 1959. As the "Kansai" in its name indicates, KSP is a retailer with stores only in the Kansai region, which includes Osaka and Hyogo. In March 2004, the firm had gross sales of approximately 102 billion yen, from a total of 51 stores.

It has been widely acknowledged by the industry and academic societies that KSP was a pioneer in Japan in the establishment of the supermarket business (Ishihara (1998)). Until KSP began to innovate, it was believed that the job of controlling the freshness of such perishable foods as vegetables and fish could only be performed by specialized craftsmen. In the 1970s, KSP analyzed the tacit knowledge possessed by craftsmen, broke down that knowledge, standardized it and put it into a manual. As a result, it became possible for KSP to realize a sales space in which even part-time workers, for low labor costs, could maintain freshness at the same level as that achieved by craftsmen. It has been recognized in the industry that these activities by KSP were revolutionary, evidenced by the fact that 91 articles about the activities of KSP appeared in the same monthly trade journal *Hanbai Kakushin*, which means Revolution in Retailing in Japanese, between 1971 and 1984.

2.2 Know-how disclosure

The period from 1970 to 1985, when KSP was actively innovative, was the time that the supermarket industry was established in Japan and was also a period of growth for the industry. Figure 1 shows the fluctuations in the number of stores and gross sales amounts from 1975 to 1985 for Maruetsu and Life (both major supermarket chains), Okuwa (which operates on about the same scale as KSP) and KSP.

[Insert Figure 1 about here.]

The gross sales per store are the only data available by which to compare the business results for the stores at the time—and in comparing these data, we find from Figure 2 that KSP's business results surpassed those of other firms.

[Insert Figure 2 about here.]

What we wish to draw attention to here is the fact that KSP, a supermarket chain that had developed cutting-edge know-how, actively disclosed this to other firms in the same industry, including its rivals. Rather than limiting itself to disclosing know-how through the above-mentioned magazine articles, the firm actively disclosed it through the activities of a business exchange group. It has been reported that a maximum of 77 supermarket firms participated in this group to absorb the know-how of KSP (Mizuno (2005)).

This case example is very interesting for a number of reasons. First is the fact that the know-how that KSP disclosed was at the cutting edge of the industry at the time. Second is the timing by which KSP disclosed its know-how as it was developed. Third is the fact that among the firms to whom KSP disclosed its know-how were rival supermarkets who had stores in the same geographical area. The final reason is the fact that those firms spared no effort to obtain the know-how in question. Innovation-related information such as know-how is sometimes difficult to transfer (von Hippel (1994) and Ogawa (1998)). Thus, KSP not only allowed those firms to observe its stores and lent them manuals but also sometimes even dispatched its own employees to instruct employees of the other firms and brought employees from the other firms into its own stores for a number of years in order to transmit know-how to them.

It would be difficult to understand the above-mentioned actions of KSP from the viewpoint that know-how that is unique to one's own firm should be protected. However, that is only if one assumes that the firm in question is a single-product firm that only handles one product. The moment one assumes that the firm in question handles two or more products, it becomes possible for that firm to create a favorable situation for itself by disclosing its know-how to its rivals.

The KSP case presented here is not categorized into patterns concerning positive effects of know-how disclosure (see Section 1.1). In the case of KSP, there are no reciprocities of know-how among firms, KSP has no input sectors or upstream firms, and there is no production complementarity or network externality among KSP and other retailers. From the discussion above, we cannot say that there are no effects of cost saving or signaling. This matter is discussed in Section 6.

2.3 Further observations

As mentioned above, the following is clarified by the analysis in this paper. That is, assuming that a firm handles more than one product, it may be possible for that firm to create a competitive advantage for itself by disclosing know-how to its rivals. If a firm discloses to a rival know-how regarding a certain product, it means that the rival to whom the disclosure is made will be in possession of know-how about the product in question—and it will therefore think it reasonable to allocate management resources to another product. As a result, the firm to whom the disclosure has been made will no longer sink management resources into the same product field as the firm that has disclosed know-how, enabling the discloser to maintain its competitive advantage.

The analysis findings given above have also been observed in the case example of KSP, discussed above. It has been reported that some of the rival firms to whom know-how about the management of perishable foods was disclosed by KSP took action to differentiate themselves by selecting goods, including deluxe imported goods and prepared food, among others (Ogawa, August 1, 2005; interviews with the President of KSP).

3 The model

There are n multiproduct firms. Firm 0 is the incumbent firm, and firms 1, 2, ..., $n-1$ are entrants. Each firm supplies its products in two separate markets, A and B. Market i is for product i ($i = A, B$). Let p_i denote the price of the production in market i ($i = A, B$), and let q_i denote its quantity. The demand functions in markets A and B for the products are represented by $q_A = 1-p_A$ and $q_B = 1-p_B$, respectively. In each market, the firms compete in quantity.

Each multiproduct firm supplies its products to the markets. Each of them has to locate in one of the markets. The incumbent can produce its product without costs in the market in which it locates, while it has to incur a constant marginal cost $c+t$ to produce its product in the other market. Each entrant incurs a constant marginal cost c in the market in which it locates, while it has to incur a constant marginal cost $c+t$ to produce its product in the other market. That is, the incumbent firm is more efficient than the entrants in the market in which it locates. As discussed in the former section, KSP is a pioneering firm in its most advantageous market and has considerable know-how about production. The assumption is congruent with the facts.

We can interpret "market" as varieties of goods and the point of a firm's location as the firm's most efficient sector.[9] For example, in the automobile industry, "space" represents car size, and a firm's location indicates that the firm produces small cars efficiently but large cars inefficiently. In the consumer electronics industry, possible interpretations of "space" include televisions, refrigerators, and electric ovens, and a firm's location could be interpreted as its ability to produce televisions efficiently and its inability to produce electronic ovens efficiently.[10]

Firm 0 has already located at A, that is, it has already allocated its resources to product A. The other firms decide where to locate. Before choosing their locations, firm 0 decides whether to disclose its know-how concerning product A. If it does, a firm locating at B can produce product A with a constant marginal cost $c+\tau$ ($\tau \in [0,t]$). That is, know-how disclosure by firm 0 reduces the marginal

[9] In a spatial price discrimination model, Matsushima and Matsumura (2003) use the interpretation. We can also interpret the marginal cost t as a transport cost to supply the market in which it does not locate.

[10] This interpretation is similar to those of Eaton and Schmitt (1994) and Norman and Thisse (1999). To explain flexible manufacturing systems (FMS), they use spatial price discrimination models.

costs of the rivals. The disclosure helps entrants making units of product A.

[Insert Table 1 here.]

The range of τ indicates the ability of the incumbent firm to make the entrants locating in market B more competitive. As discussed in von Hippel (1994) and Ogawa (1998), innovation-related information such as know-how is sometimes difficult to transfer. Because of this difficulty, we assume that the value of τ cannot be negative.[11]

We have assumed that the effect of knowledge disclosure is asymmetric. The disclosed know-how is effective only for the entrants locating in market B. In other words, nonspecialists in product A can use the disclosed know-how, but specialists cannot use it. We now discuss examples related to our assumption of cost-reducing know-how disclosure. We believe these examples to be somewhat similar to our model setting.

We now consider a lecture on an intermediate microeconomic analysis (information found, for instance, in an intermediate microeconomics textbook). The lecture is not useful for economists, who already understand the topic, but it is useful for noneconomists. Therefore, this lecture is redundant and ineffective for economists, and any improvement in their productivity is negligible. However, it would provide additional knowledge and be effective for noneconomists, and improvements in their productivity would be significant. In our model, firms locating at A correspond to the economists mentioned above, and firms locating at B correspond to the noneconomists. The know-how disclosure by the incumbent firm corresponds to the lecture on intermediate microeconomic analysis. If a disclosure of knowledge is similar in character to the lecture, our setting is plausible.[12]

We now provide another example.[13] Consider the competition between Microsoft and Apple in the operating system (OS) market. First, suppose that an upgrade of the Macintosh operating system

[11] We admit that we assume disclosure to market A to be zero. We mention the justification for this assumption later. If we assume that the marginal cost of the entrant firms locating in market A decreases by the disclosure, the analysis becomes more complicated.

[12] Of course, we can make a counterexample of knowledge transfer. Consider a seminar on advanced research in mathematical economics. The seminar is *not* useful for *noneconomists* but is useful for economists. The seminar may inspire them to undertake new research papers. The noneconomists, however, can neither understand the seminar nor take away any ideas. This type of knowledge transfer is unsuitable for our model.

[13] This example is mentioned in Shaffer and Zettelmeyer (2002).

occurs and the new user interface is even easier to use than previously. The improvement in the customer interface is related to the concerns of Apple's *core* consumers. Second, suppose that changes in Apple's networking support now enable Macs to be better integrated into PC networks. The compatibility with prevailing PC standards is for the sake of consumers who care relatively more about compatibility and who are thus more likely to prefer Windows (Apple's *noncore* consumers). The latter type of quality improvement is related to the cost reduction (know-how disclosure) in our model. The noncore consumers are somewhat similar to the firms locating in market B (firms not specializing in the disclosed technology).

We now discuss the relation between the activity by KSP and the effect of the know-how disclosure. KSP disclosed know-how in several ways. The first was interviews published in trade journals (introduction in journals) and the second was presentation through lectures. Know-how made available through journals and lectures was often information relating to visual items such as product line-up and store layout. While the know-how disseminated via these two methods contributed to the increase of productivity throughout the entire supermarket industry, such know-how was common knowledge for firms dealing mainly in fresh food[14]. This example is similar to the first one mentioned above.

The game runs as follows. In the first stage, firm 0 decides whether to disclose its know-how concerning product A. If it decides to disclose, it sets the level of τ ($\tau \in [0, t]$). In the second stage, given the decision of firm 0, n firms decide where to locate. In the third stage, given the locations of the firms, each firm decides on the quantities to supply to the markets.

[14] KSP also transferred know-how by accepting employees for OJT. In this case, firms that sent employees were able to absorb hidden know-how of KSP, invisible property that cannot be obtained through store visits. Such know-how contributed to competitive advantage in the fresh food sections of firms having absorbed the know-how. A large number of firms that sent employees to obtain such know-how were newcomers from outside the industry. In contrast, many firms that had already had know-how concerning food sales were satisfied with know-how acquired through trade journals and lectures and did not send their employees for OJT. Such firms came to allocate resources with a focus on delicatessen and processed food operations rather than fresh food (the relationship between the efficiency and allocation of resources will be discussed briefly in Section 5.3). Moreover, firms acquiring know-how through all three of these methods (mainly newly entered firms) had come to deal with the same selection of goods as KSP. For manufacturers, this meant that supermarkets that had acquired know-how from KSP would purchase the same products that they were supplying to KSP. KSP was, therefore, able to use this leverage to negotiate the price of products with manufactures and succeeded in procuring products at lower prices. This result is consistent with the assumption of the model (See Mizuno and Ogawa, 2004).

4 Result

We now show the main results of the paper. Before we discuss our main concern, we show the result of n-firm quantity (Cournot) competition.[15] Let c_i ($i = 1, \dots, n$) be the constant marginal cost of firm i. When the (inverse) demand function is $p = 1 - Q$ (p: price; Q: the aggregate industry output), the profit of firm i (π_i), Q, and consumer surplus (CS) are:

$$\pi_i = \frac{(1 + \sum_{j=1}^{n} c_j - (n+1)c_i)^2}{(n+1)^2}, \; Q = \frac{n - \sum_{j=1}^{n} c_j}{n+1}, \; CS = \frac{(n - \sum_{j=1}^{n} c_j)^2}{2(n+1)^2}. \tag{3}$$

In the following two subsections, we consider two cases: (1) firm 0 does not disclose its know-how, and (2) firm 0 discloses its know-how. We now discuss the locations of firms.

4.1 Nondisclosure of know-how

Suppose that the incumbent and k entrant firms locate at A, and $n - (k+1)$ firms locate at B ($k = 0, 1, \dots, n-1$). The profit of the incumbent firm (denoted as $\pi_I(k,t)$), the profit of the entrant firm locating at A (denoted as $\pi_A(k,t)$), and the profit of the firm locating at B (denoted as $\pi_B(k,t)$) are:

$$\begin{aligned}
\pi_I(k,t) &= \frac{(1 + (n-1)c + ((k+1) \times 0 + (n-k-1)t) - (n+1) \times 0)^2}{(n+1)^2} \\
&\quad + \frac{(1 + nc + ((k+1)t + (n-k-1) \times 0) - (n+1)(c+t))^2}{(n+1)^2} \\
&= \frac{(1 + (n-1)c + (n-k-1)t)^2}{(n+1)^2} + \frac{(1 - c - (n-k)t)^2}{(n+1)^2},
\end{aligned} \tag{4}$$

$$\begin{aligned}
\pi_A(k,t) &= \frac{(1 + (n-1)c + ((k+1) \times 0 + (n-k-1)t) - (n+1)c)^2}{(n+1)^2} \\
&\quad + \frac{(1 + nc + ((k+1)t + (n-k-1) \times 0) - (n+1)(c+t))^2}{(n+1)^2} \\
&= \frac{(1 - 2c + (n-k-1)t)^2}{(n+1)^2} + \frac{(1 - c - (n-k)t)^2}{(n+1)^2},
\end{aligned} \tag{5}$$

$$\begin{aligned}
\pi_B(k,t) &= \frac{(1 + (n-1)c + ((k+1) \times 0 + (n-k-1)t) - (n+1)(c+t))^2}{(n+1)^2} \\
&\quad + \frac{(1 + nc + ((k+1)t + (n-k-1) \times 0) - (n+1)c)^2}{(n+1)^2} \\
&= \frac{(1 - 2c - (k+2)t)^2}{(n+1)^2} + \frac{(1 - c + (k+1)t)^2}{(n+1)^2}.
\end{aligned} \tag{6}$$

[15] The method for deriving the result is discussed in Shy (1995, pp.126–127).

If $\pi_A(k,t) \geq \pi_B(k-1,t)$, the firms locating at A have no incentive to move to B. If $\pi_B(k,t) \geq \pi_A(k+1,t)$, the firms locating at B have no incentive to move to A. Therefore, if the inequalities hold, the location pattern in which k entrants locate at A is an equilibrium outcome. From the inequalities, we have the condition:

$$R - 1 \leq k \leq R, \quad \textit{where} \quad R \equiv \frac{n-1}{2} - \frac{c}{2t}.$$

The value of k depends on whether n is odd or even. We derive the following condition (note that, when R is an integer, there exist two integers that satisfy the inequalities. In this case, we assume that $k = R - 1$).

Lemma 1 *If the following condition mentioned in (7) holds, the following location pattern is a unique equilibrium outcome: the incumbent and k entrant firms locate at A, and $n-k-1$ firms locate at B.*

$$k = \begin{cases} \frac{n}{2} - h & \textit{if } c \in [(2h-3)t, (2h-1)t) \textit{ and } n \textit{ is even } (h = 2, 3, \ldots), \\ & \textit{if } c \in (0, t) \textit{ and } n \textit{ is even } (h = 1), \\ \frac{n-1}{2} - h & \textit{if } c \in [2(h-1)t, 2ht) \textit{ and } n \textit{ is odd, } (h = 2, 3, \ldots), \\ & \textit{if } c \in (0, 2t) \textit{ and } n \textit{ is odd } (h = 1). \end{cases} \tag{7}$$

The location pattern is quite natural. As the number of firms in a location (market) increases, the intensity of competition in that market is enhanced. The intensity of competition in the other market diminishes. The numbers of firms in each market are balanced. However, if the cost advantage of the incumbent firm, which is reflected by the value of c, becomes significant, several entrants avoid market A because the incumbent is the tough competitor. The number of firms locating in market B is larger than that in market A.

From (3), consumer surplus (denote as CS_n) is:

$$CS_n(k,t) = \frac{(n - ((n-1)c + (n-k-1)t))^2}{2(n+1)^2} + \frac{(n - (nc + (k+1)t))^2}{2(n+1)^2}. \tag{8}$$

From (4), (5), (6), and (8), social welfare (denote as SW_n) is:

$$\begin{aligned} SW_n(k,t) &= CS_n(k,t) + \pi_I(k,t) + k\pi_A(k,t) + (n-k-1)\pi_B(k,t) \\ &= \frac{2n(n+2) - 2(n+2)(2n-1)c + (4n^2+4n-5)c^2}{2(n+1)^2} \end{aligned} \tag{9}$$

$$- \frac{[2n(n+2) - 2(3n^2 - (2k-3)n - 3(k+1))c]t}{2(n+1)^2}$$
$$+ \frac{[(4k+5)n^2 - 2(2k^2+k-2)n - 6(k+1)^2]t^2}{2(n+1)^2}.$$

4.2 Disclosure of know-how

Suppose that the incumbent and k entrant firms locate at A, and $n-(k+1)$ firms locate at B ($k = 0, 1, \ldots, n-1$). The profit of the incumbent firm (denoted as $\pi_I(k,\tau)$), the profit of the entrant firm locating in A (denoted as $\pi_A(k,\tau)$), and the profit of the firm locating in B (denoted as $\pi_B(k,\tau)$) are:

$$\pi_I(k,\tau) = \frac{(1+(n-1)c+(n-k-1)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k)t)^2}{(n+1)^2}, \tag{10}$$
$$\pi_A(k,\tau) = \frac{(1-2c+(n-k-1)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k)t)^2}{(n+1)^2}, \tag{11}$$
$$\pi_B(k,\tau) = \frac{(1-2c-(k+2)\tau)^2}{(n+1)^2} + \frac{(1-c+(k+1)t)^2}{(n+1)^2}. \tag{12}$$

Suppose that k entrants (k is denoted in (7)) locate in market A before the know-how is disclosed. We now show the condition that the disclosure of know-how induces one of the k entrants to locate in market B.

If $\pi_A(k-1,\tau) > \pi_B(k-2,\tau)$, the firms locating in A have no incentive to move to B. If $\pi_B(k-1,\tau) > \pi_A(k,\tau)$, the firms locating in B have no incentive to move to A. Therefore, if τ is in the following range, the location pattern in which $k-1$ entrants locate at A is an equilibrium outcome. We have the following lemma.

Lemma 2 *Suppose that k entrants (k is denoted in (7)) locate in market A before the know-how is* *disclosed. If τ is in the following range, $k-1$ entrants locate in A:*

$$\tau \in \begin{cases} \left(\dfrac{-(1-2c)+\sqrt{(1-2c)^2+4h((1-c)t-(h+1)t^2)}}{2h}, \right. \\ \qquad \left. \dfrac{-(1-2c)+\sqrt{(1-2c)^2+4(h-1)((1-c)t-ht^2)}}{2(h-1)} \right] \\ \qquad\qquad \text{if } c \in ((2h-3)t,(2h-1)t] \text{ and } n \text{ is even} \\ \left(\dfrac{-(1-2c)+\sqrt{(1-2c)^2+4((1-c)t-2t^2)}}{2}, \dfrac{t(1-c-t)}{1-2c} \right] \\ \qquad\qquad \text{if } c \in (0,t) \text{ and } n \text{ is even and } h=1 \\ \left(\dfrac{-(1-2c)+\sqrt{(1-2c)^2+2(2(h+1)-1)(1-c)t-(4(h+1)^2-1)t^2}}{2(h+1)-1}, \right. \\ \qquad \left. \dfrac{-(1-2c)+\sqrt{(1-2c)^2+2(2h-1)(1-c)t-(4h^2-1)t^2}}{2h-1} \right] \\ \qquad\qquad \text{if } c \in (2(h-1)t, 2ht], \text{ and } n \text{ is odd.} \end{cases} \tag{13}$$

where:

$$k = \begin{cases} \dfrac{n}{2}-h & \text{if } c \in [(2h-3)t,(2h-1)t) \text{ and } n \text{ is even } (h=2,3,\ldots), \\ & \text{if } c \in (0,t) \text{ and } n \text{ is even } (h=1), \\ \dfrac{n-1}{2}-h & \text{if } c \in [2(h-1)t, 2ht) \text{ and } n \text{ is odd}, \ (h=2,3,\ldots), \\ & \text{if } c \in (0,2t) \text{ and } n \text{ is odd } (h=1). \end{cases}$$

On the range described in (13), the highest value of τ is the most profitable for the incumbent firm. Therefore, the incumbent firm sets the value of τ as follows:

$$\tau_e = \begin{cases} \dfrac{-(1-2c)+\sqrt{(1-2c)^2+4(h-1)((1-c)t-ht^2)}}{2(h-1)} \\ \qquad \text{if } c \in ((2h-3)t,(2h-1)t] \text{ and } n \text{ is even} \\ \dfrac{t(1-c-t)}{1-2c} \\ \qquad \text{if } c \in (0,t) \text{ and } n \text{ is even and } h=1 \end{cases} \tag{14}$$

$$\tau_o = \frac{-(1-2c)+\sqrt{(1-2c)^2+2(2h-1)(1-c)t-(4h^2-1)t^2}}{2h-1} \tag{15}$$

$$\text{if } c \in (2(h-1)t, 2ht], \text{ and } n \text{ is odd.}$$

In this case, the profits of the firms are (τ is in (14) or (15)):

$$\pi_I(k-1,\tau) = \frac{(1+(n-1)c+(n-k)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k+1)t)^2}{(n+1)^2}, \tag{16}$$

$$\pi_A(k-1,\tau) = \frac{(1-2c+(n-k)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k+1)t)^2}{(n+1)^2}, \tag{17}$$

$$\pi_B(k-1,\tau) = \frac{(1-2c-(k+1)\tau)^2}{(n+1)^2} + \frac{(1-c+kt)^2}{(n+1)^2}. \tag{18}$$

As shown in Table 1, locating in B is cost advantageous for firms. Firms locating in B are able to supply products to market A at a low marginal cost (τ), which is smaller than t, but firms locating in A have to incur the higher marginal cost t to supply their products to market B. As the value of τ decreases, the cost advantage is more significant. Given a location pattern in which k entrant firms locate in market A, as the value of τ decreases, to obtain the cost advantage, one of the firms that would locate in A moves from A to B. Therefore, under the level of τ in (14) or (15), a firm changes its location from A to B.

From (3), consumer surplus (denoted as $CS(k-1,\tau)$) is (τ is in (14) or (15)):

$$CS(k-1,\tau) = \frac{(n-((n-1)c+(n-k)\tau))^2}{2(n+1)^2} + \frac{(n-(nc+kt))^2}{2(n+1)^2}. \tag{19}$$

From (16), (17), (18), and (19), social welfare (denoted as $SW(k-1,\tau)$) is (τ is in (14) or (15)):

$$\begin{aligned} SW(k-1,\tau) &= CS(k-1,\tau) + \pi_I(k-1,\tau) + (k-1)\pi_A(k-1,\tau) + (n-k)\pi_B(k-1,\tau) \qquad (20) \\ &= \frac{n(n+2)-(n-1)(2(n+2)-(3n+5)c)c}{2(n+1)^2} \\ &\quad - \frac{(n-k)(2(n+2-(3n+5)c)-((2k+1)n+3k+2)\tau)\tau}{2(n+1)^2} \\ &\quad + \frac{n(n+2)(1-c)^2 - 2k(n+2)(1-c)t + k(2n^2-2(k-2)n-(3k-2))t^2}{2(n+1)^2}. \end{aligned}$$

4.3 The incumbent firm

The discussion turns now to the difference in firm 0's profit when it discloses its know-how and when it does not. From (4) and (16), we can derive the difference. Before we discuss the profitability of know-how disclosure, we define two symbols that represent the difference in firm 0's profit when it discloses its know-how and when it does not. J_o (*resp.* J_e) is the difference when n is odd (*resp.* even).

$$\begin{aligned} J_o(t,h) &\equiv \pi_I\left(\frac{n-1}{2}-(h+1),\tau_o\right) - \pi_I\left(\frac{n-1}{2}-h,t\right), \\ J_e(t,h) &\equiv \pi_I\left(\frac{n}{2}-(h+1),\tau_e\right) - \pi_I\left(\frac{n}{2}-h,t\right). \end{aligned}$$

If this is positive, that is, $J_o(t,h) > 0$ (or $J_e(t,h) > 0$), the disclosure of its know-how is beneficial for firm 0. We have the following propositions. Propositions 1 and 2 (*resp.* 3 and 4) are related to the case in which n is odd (*resp.* even).

Proposition 1 *Suppose that $c < 2t$ ($h = 1$) and that n is odd and larger than or equal to 5. There exists $\bar{t}$ such that $J_o(t,1) = 0$. For any $t \in (c/2, \bar{t})$, the disclosure increases the profit of the incumbent firm.*

Proposition 2 *Suppose that $2t \leq c < 4t$ ($h = 2$) and that n is odd and larger than or equal to 7. If n and c satisfy $J(c/2, 2) > 0$, for any $t \in (c/4, c/2]$, the disclosure increases the profit of the incumbent firm, otherwise there exists $\bar{t}'$ such that $J_o(t,2) = 0$, and for any $t \in (c/4, \bar{t}')$, the disclosure increases the profit of the incumbent firm.*

Proposition 3 *Suppose that $c \in (0,t)$ and that n is even and larger than or equal to 4. The disclosure increases the profit of the incumbent firm.*

Proposition 4 *Suppose that $c \in (t, 3t)$ and that n is even and larger than or equal to 6. If $J_e(c,2) > 0$, for any $t \in [c/3, c)$, the disclosure increases the profit of the incumbent firm. Otherwise, there exists $\bar{t}''$ such that $J_e(t,2) = 0$, and for any $t \in (c/3, \bar{t}'')$, the disclosure increases the profit of the incumbent firm.*

As the value of τ decreases, the cost advantage of firms locating in B is enhanced. In other words, the disadvantage of the firm disclosing its know-how is enhanced by the decrease in the level of τ. Based on this property, some may believe that such know-how disclosure is obviously harmful for the disclosing firm. In our model, however, another view has been provided.

This view is that know-how disclosure induces some firms to change their plans for location ("specialized" products). As mentioned in Lemma 2, these firms change their specialized product from product A to product B. The change mitigates the competition in market A and is beneficial for the firm disclosing its know-how. This view is not discussed in the literature of know-how disclosure, thus constituting a new insight into the issue.

As in Propositions 1, 2, and 4, if c is large, know-how disclosure that reduces the costs of its rivals is effective for the incumbent firm. In other words, when the incumbent firm has a cost advantage, such know-how disclosure tends to be beneficial. We provide two examples, in which $c = 1/100$ and $c = 1/20$.

[Insert Figure 3 here.]

We now discuss the case in which h is larger than two. After tedious calculus, we find that, given the value of c and n, as the value of h increases, the condition that the disclosure enhances profit of the incumbent firm tends to hold (see the supplementary material). Note that h is related to the value of t. As the value of h increases, the value of t decreases. That is, as the value of t becomes smaller, the condition tends to hold.

[Insert Figures 4a and 4b here.]

We now show the mechanism by which the disclosure is profitable when c is large. The know-how disclosure has the following effects: (1) an improvement in efficiency of firms locating in market B, (2) a decrease in the number of firms in market A. The first effect is negative and the second is positive for the incumbent firm. The significance of those effects depends on the values of t, c, and n.

Before we explain the relation between the two effects and the values of t, c, and n, we consider an $n + 1$ firms Cournot oligopoly with cost asymmetries. We now suppose that the marginal cost of the incumbent firm is zero, those of $n - k$ entrant firms locating at A are c, and those of k entrant firms locating at B are $c + t$. We can easily find that the profit of the incumbent firm is $\pi_G \equiv (1 + nc + kt)^2/(n + 2)^2$. By disclosure, k and t change to $k + 1$ and $\tau(t, c)$, where τ is a function of t and c (see equations (14) and (15)). We can explain those changes as follows:

$$\Delta\pi_G = \frac{((k+1)\tau(t,c) - kt))(2 + 2nc + kt + (k+1)\tau(t,c))}{(n+2)^2} > 0.$$

Using $\Delta\pi_G$, we evaluate the effects of the increments in t, c, and n.

We first show that, given that the value of t is not small in the range in which k entrant firms locate in market B, as the value of t increases, the positive effect of know-how disclosure diminishes. Note that this logic holds true if the increment in t does not change the initial location pattern (see the discussion in Section 4.1). When we differentiate $\Delta\pi_G$ with respect to t, there are two effects related to the increment in t:

$$\frac{\partial \Delta\pi_G}{\partial t} = -\frac{2k(1+nc+kt)}{(n+2)^2} + \frac{2(k+1)(1+nc+(k+1)\tau(t,c))}{(n+2)^2}\frac{\partial \tau(t,c)}{\partial t}.$$

The first term is the effect of the increment in t itself. The second term is the effect of the increment in τ caused by the increment in t.

We now mention the intuition behind the result that the first term is negative. When t is small, entrant firms locating in market B have already been tough competitors in market A. Although the competitiveness of these entrant firms is improved by the disclosure, the magnitude of the improvement is not very significant. When t is large, entrant firms locating in market B have not yet been competitors in market A. Following the disclosure, however, those entrant firms can easily access market A. That is, by the disclosure, these entrant firms emerge as competitors in market A. The "entries" have significant impact.[16]

The second term reflects the fact that the level of τ increases in the value of t. This is a positive effect on the value of $\Delta\pi_G$ because a higher value of τ keeps the market A less competitive. We now show the relation between τ and t. Differentiating τ in (14) or (15) with respect to t twice, we find that τ is a concave function in t. That is, as the value of t increases, the positive effect on the value of $\Delta\pi_G$ is less effective.

Those two terms present a trade-off. When t is small (*resp.* large), the latter positive (*resp.* the former negative) effect dominates. That is, $\Delta\pi_G$ is concave with respect to t. In this setting, we can show that when t is sufficiently small, $\Delta\pi_G$ is not small, but when t is large enough, $\Delta\pi_G$ is small (the proofs of the propositions related to the incumbent firm's profit are closely related to the explanation). Therefore, when t is large enough, the disclosure is not so effective.

Secondly, we show that as the value of c increases, the positive effect of the know-how disclosure is enhanced. Note that the logic holds true if the increment in c does not change the initial location

[16] Using a simple Cournot duopoly with asymmetric costs and a linear demand ($p = 1 - Q$), we can also explain the mechanism. We now suppose that the marginal cost of the efficient (inefficient) firm is zero (t). The profit of the efficient firm is $(1+t)^2/9$. Differentiating it with respect to t, we have $2(1+t)/9$. That is, the higher the value of t, the more significant the marginal effect of the increment (also the decrement) in t. This is similar to the discussion in the main text.

pattern. When we differentiate $\Delta\pi_G$ with respect to c, there are two effects related to the increment in c:

$$\frac{\partial \Delta\pi_G}{\partial c} = \frac{2n((k+1)\tau(t,c) - kt))c}{(n+2)^2} + \frac{2(k+1)(1+nc+(k+1)\tau(t,c))}{(n+2)^2}\frac{\partial \tau(t,c)}{\partial c} > 0.$$

Differentiating τ in (14) or (15) with respect to c, we find that τ is increasing in c. Considering these two effects, we find that $\Delta\pi_G$ is increasing with respect to c. The higher the efficiency of the incumbent firm, (the larger the value of c), the more effective the per-unit price change, because the quantity supplied by the firm is larger when efficiency is greater (c is larger). By the disclosure, the incumbent firm reduces the number of firms in market A, and then the price in the market increases. Therefore, the positive effect of the disclosure becomes significant as the value of c increases.

Finally, we shall discuss the effect of the increment in n. The increment in n affects both the negative and the positive effects mentioned above: the efficiency improvement of firms locating in market B, and the decrease in the number of firms at market A. The effect of the increment in n depends on how those two effects change. In this case, the former negative effect dominates the latter one. Differentiating $\Delta\pi_G$ with respect to n, we can easily show this property. As the value of n increases, the former negative effect of the decreases in the value of τ becomes significant because the number of firms who benefit from the efficiency improvement from the disclosure increases. On the other hand, as the value of n increases, the latter positive effect diminishes because the elimination of one firm is not effective when the number of firms is large.

4.4 Entrants

In this subsection, we consider the effect of know-how disclosure on the profits of entrant firms. As mentioned in Section 4.2, know-how disclosure enhances the efficiencies of the rival firms. At first glance, it would be expected to increase the profits of the rivals locating in market B. In the model, however, the converse holds.

In both the nondisclosure and the disclosure cases, the firms locating in the same market earn the same profit levels (see the discussion in Sections 4.1 and 4.2, and the equations in (5), (6), (11), and (12)).

Entrants locating in A We first calculate the change in the profits of entrants that locate in market A. Using $\pi_A(k,t)$ in (5) and $\pi_A(k-1,\tau)$ in (11), we calculate the difference between the profit in which the incumbent firm discloses its know-how and that in which it does not. After some calculus, we have the following proposition.

Proposition 5 *Suppose that $c \in (0, 2t)$. There exists $\tilde{t}$ such that $J_o^A(t,1)=0$. For any $t \in (c/2, \tilde{t})$, the disclosure increases the profit of the incumbent firm.*

Proposition 6 *Suppose that $c \in (2t, 4t)$. There exists $\tilde{t}'$ such that $J_o^A(t,2)=0$. For any $t \in (c/4, \tilde{t}')$, the disclosure increases the profit of the incumbent firm.*

$$J_o^A(t,h) \equiv \pi_A\left(\frac{n-1}{2}-(h+1),\tau_o\right)-\pi_A\left(\frac{n-1}{2}-h,t\right).$$

Proposition 7 *Suppose that $c \in (0,t)$ and that n is even. The disclosure increases the profits of the entrant firms locating in A.*

Proposition 8 *Suppose that $c \in (t, 3t)$ and that n is even. There exists $\tilde{t}''$ such that $J_e^A(t,2)=0$. For any $t \in (c/3, \tilde{t}'')$, the disclosure increases the profit of the incumbent firm.*

$$J_e^A(t,h) \equiv \pi_A\left(\frac{n}{2}-(h+1),\tau_e\right)-\pi_A\left(\frac{n}{2}-h,t\right).$$

As in the case of the incumbent firm, because of the disclosure, the profits of entrant firms locating at A can increase.

We briefly discuss the case in which h is larger than two. We find that, given the value of c and n, even though the value of h increases, the condition that the disclosure enhances the profits of the entrant firms does not hold (see the supplementary material). This is quite different from the case of the incumbent firm. The difference stems from the difference between their marginal costs. The marginal cost of the incumbent firm is zero in market A, but that of the entrant firms is c. As mentioned in the former subsection, the cost advantage enhances the profitability of the know-how disclosure. The entrant firms locating in market A, however, do not have such an advantage. This is the reason for the difference between the incumbent firm and the entrant firms.

Entrants locating at B We now calculate the change in the profits of entrants that locate in market B. Using $\pi_B(k,t)$ in (6) and $\pi_B(k-1,\tau)$ in (12), we calculate the difference between the profit in which the incumbent firm discloses its know-how and that in which it does not. We have the following proposition.

Proposition 9 *Suppose that $c \in (2(h-1)t, 2ht)$ and n is odd. The disclosure decreases the profits of entrant firms locating in market B.*

Proposition 10 *Suppose that $c \in [(2h-3)t, (2h-1)t)$ (when $h=1$, $c \in (0,t)$) and n is even. The disclosure decreases the profits of entrant firms locating in market B.*

Because of the disclosure, a firm that would otherwise locate in A moves to B. This enhances the competition in market B. If the level of τ were small enough, the transport cost reduction (positive) effect of the disclosure would dominate the negative effect of competition. In this case, however, the disclosing firm sets the level of τ (see (14) or (15)) at an intermediate level. Therefore, the enhanced competition harms the entrant firms locating in market B. In this sense, the profits of the entrants that allocate their resources to market B can be seen as the flip side of the profit of the incumbent. The result implies that the incumbent firm may disclose its know-how in its industry as a payoff-enhancing entry deterrent.

4.5 Welfare

In this subsection, because of its mathematical complexity, we only consider the cases in which $h=1$, that is, (i) n is odd and $c<2t$, and (ii) n is even and $c<t$.

From (8), (9), (19), and (20), we can calculate the difference between $CS(k-1,\tau)$ and $CS(k,t)$, and that between $SW(k-1,\tau)$ and $SW(k,t)$. We calculate two cases in which $c=1/100$ and $c=1/20$. The consumer surplus when know-how is disclosed is larger than that when it is not. On the other hand, social welfare when the know-how is disclosed is larger than that when it is not if t is not large.

[Insert Figure 5 here.]

We now show the mechanism by which consumer surplus is increased by the disclosure. Suppose that a fixed amount of the product exists in the markets. Equal allocation of the product to markets A

and B is the worst way from the perspective of consumer surplus because consumer surplus is convex with respect to the quantity supplied. An asymmetric allocation of the product occurs because of the relocation induced by the disclosure. This asymmetric allocation increases consumer surplus.

We now show the mechanism by which social surplus is decreased by the disclosure when t is large. From the viewpoint of social welfare, know-how disclosure has two effects. One is an efficiency-enhancing effect, and the other is a location-distorting effect. The former is positive, and the latter is negative. The positive effect is enhanced by the decreases in the level of τ because the efficiency of firms locating in B improves. The negative effect stems from reduced competitiveness, which is induced by the asymmetric location pattern, in market A. As the level of t increases, the competition in A is weakened because the entrants locating in B become less aggressive than those in A.

5 Extension

In this section, we extend the basic model.

5.1 Interdependent demand

In this subsection, we consider a case in which the products in markets A and B are interdependent. To consider this case, we set the inverse demand functions in the markets as follows:

$$p_A = 1 - Q_A - \gamma Q_B, \quad p_B = 1 - Q_B - \gamma Q_A,$$

where Q_i $(i = A, B)$ is the total quantity supplied by the firms in market i $(i = A, B)$, and γ is the degree of product differentiation between the products. In the basic setting, we have assumed that $\gamma = 0$, that is, the products are independent.

We now suppose that there exist an incumbent firm and four entrant firms, that is, 5 firms exist. In this case, the incumbent firm and one entrant firm locate in market A, and the rest of the entrant firms are located in market B.

Before the incumbent firm discloses its know-how, one entrant firm locates in A and three entrant firms locate in B. We can easily show that the location pattern appears as an equilibrium outcome if $c < 2t$.

We now suppose that the entrant firm locating in A moves to market B because of the disclosure. We now show the condition that the entrant firm locating in market A under the nondisclosure case moves to market B following the disclosure. The condition is:

$$\tau_\gamma \equiv J_\gamma - (1 - 2c - (1 - c - 2t)\gamma),$$
$$\text{where } J_\gamma \equiv \sqrt{(1 - 2c - (1 - c - 2t)\gamma)^2 + t(2 - 2c - 3t - 2(1 - 2c)\gamma)}.$$

We now consider the relation between the degree of product differentiation and the profitability of know-how disclosure. Differentiating τ_γ with respect to γ, we have:

$$\frac{\partial \tau_\gamma}{\partial \gamma} = \frac{(1 - c - 2t)J_\gamma - \{(1 - 2c)(1 - c - t) - (1 - c - 2t)^2\gamma\}}{J_\gamma}.$$

After some calculus, we find that this is negative. As the degree of differentiation decreases, the incumbent firm sets the level of τ lower. Someone might consider that the disclosure of know-how tends to be less profitable. This is in fact true.

To show the relation between the degree of differentiation and the profitability of know-how disclosure, we consider two cases: $c = 1/200$ and $c = 1/50$. The relation is shown in Figures 6 and 7. From the figures, we find that the profitable area becomes large as the value of c increases and that the profitable range shrinks as the value of γ increases.

[Insert Figures 6 and 7 here.]

We now show the intuition behind the result. As the value of γ increases, the competition in market B has a greater effect on the competition in market A because the degree of product differentiation between the products is weaker. The converse also holds, that is, the competition in market A has a greater effect on the competition in market B. A lower value of τ is not so effective for firms locating in market B because the increment in the quantities supplied in market A decreases the price in market B. Therefore, to induce an entrant firm that would locate in market A to locate in market B, the incumbent firm sets the value of τ at a lower level. This is not beneficial for the incumbent.

5.2 Licensing

We allow the incumbent firm to determine the number of firms that acquire its technological know-how. We suppose that $c = 0$ and the number of firms, n, is even. The incumbent firm charges several firms a linear fee for its know-how. If a firm has the know-how, it can produce a product for market A at the marginal cost $c = 0$, even though it locates in market B. The informed firm has to pay the linear fee fq_i to the incumbent firm, where q is the quantity supplied by the informed firm.

We now suppose that because of the licensing issue, $n/2-m$ firms locate in market A, and $n/2+m$ firms locate in market B ($m \in \{1, 2, \dots, n/2-1\}$). The firms locating in B have the disclosed know-how. The profit functions of the firms locating at A (B) are:

$$\begin{aligned}
\pi_I &= \left(1 - \sum_{i=1}^{n} q_{iA}\right) q_{iA} + \left(1 - \sum_{i=1}^{n} q_{iB} - t\right) q_{iB} + f \sum_{i=n/2+m+1}^{n} q_{iA}, \\
\pi_A &= \left(1 - \sum_{i=1}^{n} q_{iA}\right) q_{iA} + \left(1 - \sum_{i=1}^{n} q_{iB} - t\right) q_{iB}, \\
\pi_B &= \left(1 - \sum_{i=1}^{n} q_{iA} - f\right) q_{iA} + \left(1 - \sum_{i=1}^{n} q_{iB}\right) q_{iB}.
\end{aligned}$$

The quantities supplied by firms are:

$$\begin{aligned}
q_{aA} &= \frac{2+(n+2m)f}{2(n+1)}, \; q_{bA} = \frac{2-(n-2m+2)f}{2(n+1)}, \\
q_{aB} &= \frac{2-(n+2m+2)t}{2(n+1)}, \; q_{bB} = \frac{2+(n-2m)t}{2(n+1)}.
\end{aligned}$$

The profits of the firms are:

$$\begin{aligned}
\pi_I(n/2+m) &= \frac{(2+(n+2m)f)^2}{4(n+1)^2} + \frac{(2-(n+2m+2)t)^2}{4(n+1)^2} \\
&\quad + \frac{(n/2+m)(2-(n-2m+2)f)}{2(n+1)}, \\
\pi_A(n/2+m) &= \frac{(2+(n+2m)f)^2}{4(n+1)^2} + \frac{(2-(n+2m+2)t)^2}{4(n+1)^2}, \\
\pi_B(n/2+m) &= \frac{(2-(n-2m+2)f)^2}{4(n+1)^2} + \frac{(2+(n-2m)t)^2}{4(n+1)^2}.
\end{aligned}$$

To keep the firms locating in market B from relocating, the following inequality must hold (note that, if a firm that has a right to the know-how rejects the offer, it locates in market A):

$$\pi_B(n/2+m) \geq \pi_A(n/2+m-1) \quad \Leftrightarrow \quad \frac{2n(t-f)-(m-1)f^2-mt^2}{(n+1)^2} \geq 0.$$

Considering the constraint, the incumbent sets f to maximize its profit $\pi_I(n/2+m)$. The constraint is binding and the optimal level of f is:

$$f = \begin{cases} \dfrac{1+4(m-1)t(1-mt) - \sqrt{1+4(m-1)t(1-mt)}}{2(m-1)\sqrt{1+4(m-1)t(1-mt)}} & \text{if } m \neq 1, \\ t - t^2 & \text{if } m = 1. \end{cases}$$

Note that, when $m = 1$, the per unit gain of the license is $t - (t - t^2) = t^2$. This is the same as the value of τ discussed in the previous section. Although calculating the optimal number of m is not easy, we can show a numerical example. When $n = 20$, the optimal number of m is $9(= n/2 - 1)$ if and only if $t \leq 0.0442$, otherwise ($t \in (0.0442, 1/20]$) it is 8 (note that, the inequality $t < 1/n$ is the sufficient condition that the quantities supplied by the firms in each market are positive).

5.3 Asymmetric marginal costs

Thus far in the discussion, the marginal costs of entrant firms have had the same value. We now introduce a cost asymmetry among the firms. The marginal cost of firm i is c_i. $l_i = 0$ (*resp.* $l_i = 1$) represents the situation that firm i locates in market A (*resp.* market B). The transport cost per unit from A and B is t, and that from B to A is τ. Before the disclosure of know-how, $t = \tau$. After the disclosure, τ becomes smaller than t.

Given the locations of the firms, $l_1, l_2, \ldots, l_n$, the profit function of firm i is:

$$\begin{aligned} \pi_i &= \frac{(1 + \sum_{j=1}^{n} c_j - (n+1)c_i - (n+1)\tau l_i + \tau \sum_{j=1}^{n} l_j)^2}{(n+1)^2} \\ &\quad + \frac{(1 + \sum_{j=1}^{c} c_j - (n+1)c_i - (n+1)t(1-l_i) + t \sum_{j=1}^{n}(1-l_j))^2}{(n+1)^2}. \end{aligned}$$

Because the profit function of firm i is convex with respect to l_i, the profit is maximized at $l_i = 0$ or $l_i = 1$. We now denote the profit when firm i locates at $l_i = 0$ (*resp.* $l_i = 1$) as π_i^0 (*resp.* π_i^1). The difference $\pi_i^0 - \pi_i^1$ is:

$$\pi_i^0 - \pi_i^1 = \frac{n\left[-2\left(1 + \displaystyle\sum_{j=1}^{n} c_j - (n+1)c_i\right)(t-\tau) - n(nt^2 + (n-2)\tau^2) + 2(t^2+\tau^2)\displaystyle\sum_{j\neq i} l_j\right]}{(n+1)^2}.$$

If this is positive, firm i locates at $l_i = 0$, otherwise, it does so at $l_i = 1$.

Suppose that all firms choose the same location $l_i = 0$ or $l_i = 1$ ($i = 1, 2, \ldots, n$). When $\tau = t$ (that is, the know-how is not disclosed), the difference $\pi_i^0 - \pi_i^1$ does not depend on the marginal costs of the firms. Therefore, efficiency does not affect the location choices of the firms. When $\tau < t$ (that is, the know-how is disclosed), the difference depends on the coefficient of $(t-\tau)$, that is, $-2(1+\sum_{j=1}^{n} c_j - (n+1)c_i)$. As the value of c_i (the last term in the coefficient of $(\tau - t)$) decreases, the coefficient decreases, and then $\pi_i^0 - \pi_i^1$ decreases. Therefore, relatively efficient firms tend to locate in $l_i = 1$, and the converse holds. By the disclosure, inefficient entrant firms tend to locate in market A where the incumbent has already located. From the perspective of the incumbent firm, knowledge disclosure is beneficial.

As mentioned in footnote 14 in Section 3, firms entering the business from outside the industry had sent employees to KSP in order to acquire know-how regarding the essential elements of competitive advantage of KSP and utilize it for their own competitive advantage (as was mentioned before, it is somehow difficult to actually distribute the information due to information stickiness: see von Hippel (1994)). Meanwhile, many firms with some degree of food sales know-how acquired KSP's know-how through journals and lecture presentations only and came to devote management resources to product areas other than fresh food. We think that the fact has some consistency with the result.

5.4 Multiple incumbent firms

We now briefly discuss the case in which there is more than one incumbent firm. In this case, if the following conditions hold, the results presented here would be preserved: (1) the disclosing firm has a cost advantage, (2) the location pattern before entrant firms appear is optimal. Given these two conditions, if entrant firms appear in the industry, the disclosure of know-how distorts the locations of the entrant firms and is beneficial for the incumbent firm. As discussed above, the incumbent firm benefits from only one firm's location change. Therefore, we believe that our results above could be applicable for broader situations because those two conditions are not very restrictive.

6 Concluding remarks

We have examined the positive effects of a firm disclosing its know-how to rival firms. In general, firms do not disclose know-how to rival firms when it would give them a competitive advantage. This is because once a firm has disclosed its know-how, the rival firm will probably use that information to diminish the competitive advantage of the discloser. As a result, the firm that has disclosed the information might lose its competitive advantage. This is why it is generally assumed that a firm should never disclose its know-how.

However, a regional retail-chain has acted in a manner contrary to this common belief. KSP was an innovator in supermarket operations and actively disclosed its own know-how to existing and potential rivals between 1970 and 1985, which was a growth period for the supermarket industry in Japan.

On the basis of this observation, we provided a theoretical framework to explain such know-how disclosure to rivals. We showed that a firm could create a competitive advantage for itself by disclosing its know-how if we assume that a firm handles more than one product and the disclosing firm has a cost advantage. If a firm discloses its know-how regarding a certain product to a rival, the rival thus, it would be reasonable for the rival to allocate management resources to another product. As a result, the rival will no longer allocate management resources to the same product field as the discloser, and the discloser will be able to maintain its competitive advantage.

The case of KSP provides a good example. Some of the rival firms to whom know-how on the management of perishable foods was disclosed by KSP took action to differentiate themselves from KSP by selecting goods, including deluxe imported goods and prepared food, among other products. As a consequence, KSP maintained its competitive advantage.

An implication of this study is that a multiproduct firm could gain a competitive advantage from know-how disclosure when the product markets of the firm are growing. This strategy could be particularly attractive to mass merchandisers such as Wal-Mart because such retailers generally handle two or more product categories and always search for promising new product categories. For example, in the growing Electric Commerce market, Amazon.com might be able to maintain its competitive advantage if it discloses its know-how in book inventory management to rival firms.

We believe that our model could be applicable not only to retailing but also to multiproduct manufacturers. For instance, in the digital home appliance market, such as that for DVDs or cameras, it might be a good strategy for Panasonic to disclose its know-how in DVD production to Samsung and Haier Electronics Group to maintain its global market leadership. In this respect, the applicability and generalizability of our model will need to be explored.

As discussed by many researchers, know-how disclosure has several effects on the disclosing firms or persons. In this paper, we discussed the effect on the resource allocation strategies of firms. In the case of KSP, as discussed by Reymond (1999), signaling effects might be important. By disclosing its know-how, KSP might intend to appeal to upstream firms and rivals for the sake of its cost efficiency. First, we mentioned the effect of know-how disclosure on upstream firms. KSP buys many goods from upstream firms and sells the goods to consumers. As discussed in the literature on industrial organization, wholesale prices set by upstream firms decrease as the efficiency of the downstream firm is improved. Therefore, improving its efficiency by know-how disclosure would be effective for KSP. As reported by Mizuno and Ogawa (2004), know-how disclosure by KSP reduces wholesale prices. Providing a model to explain this effect is a consideration for future research. Second, we mentioned the effect of know-how disclosure on rivals. If rivals recognize KSP's cost efficiency in a particular product, they will tend to avoid allocating their resources to that particular product because they will realize that it is difficult to make a profit from it. The effect on the rivals will add weight to our main results.

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Location / Cost	MC at A	MC at B
Incumbent firm	0	$c+t$
Locating at A	c	$c+t$
Locating at B	$c+t$	c

(Nondisclosure)

Location / Cost	MC at A	MC at B
Incumbent firm	0	$c+t$
Locating at A	c	$c+t$
Locating at B	$c+\tau$	c

(Disclosure)

(MC: the constant marginal cost)

Table 1: The cost structures.

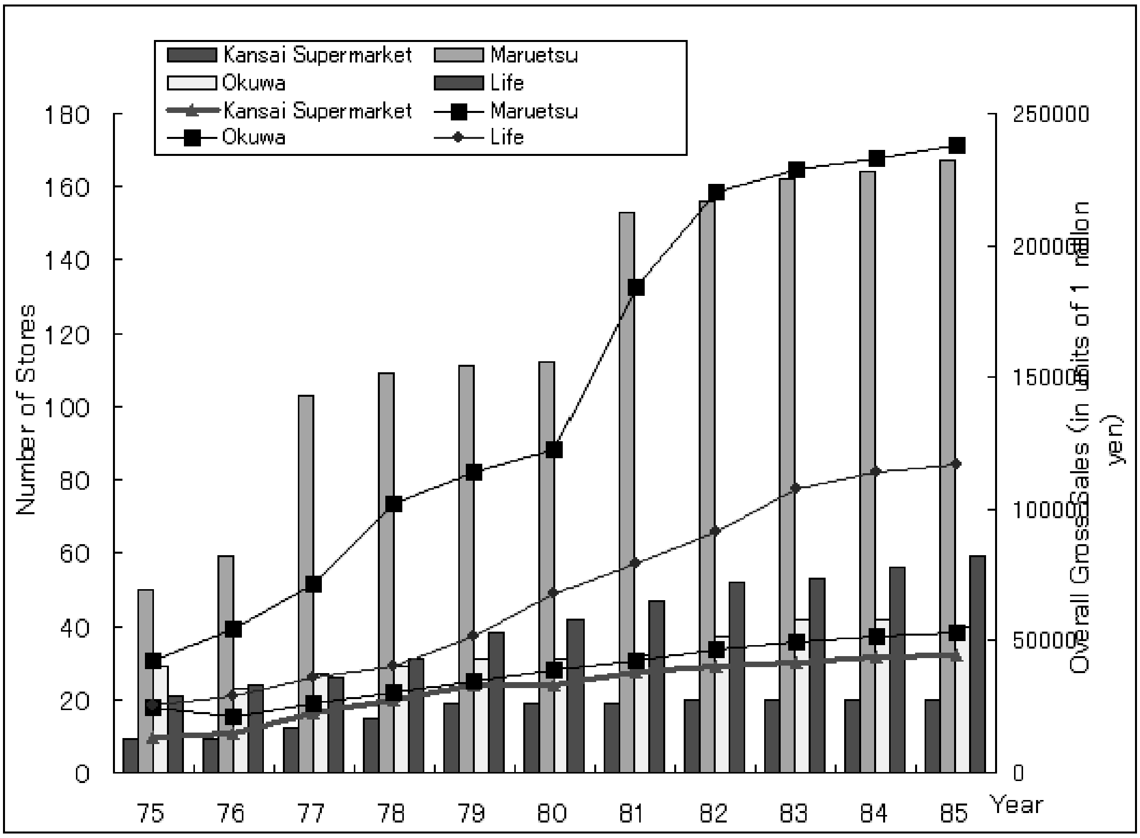

Figure 1: Number of Stores and Fluctuation in Overall Gross Sales between 1975 and 1985

Note 1: The authors referred to the Guide to Distribution Economics, 1975–1987 Issue (Nihon Keizai Shimbun, Inc.) in producing this graph.

Note 2: The bar graph shows the number of stores. The sequential line graph shows overall gross sales.

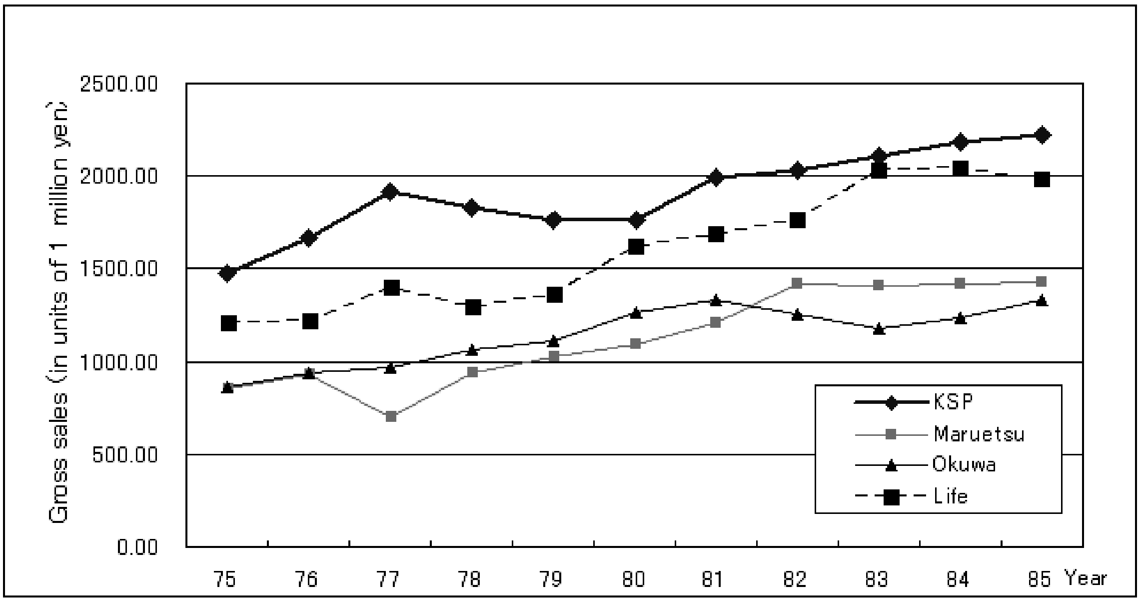

Figure 2: Fluctuation in Gross Sales per Store between 1975 and 1985

The authors referred to the Guide to Distribution Economics, 1975–1987 Issue (Nihon Keizai Shimbun, Inc.) in producing this graph.

Horizontal: year, Vertical: Gross sales per store (in units of 1 million yen)

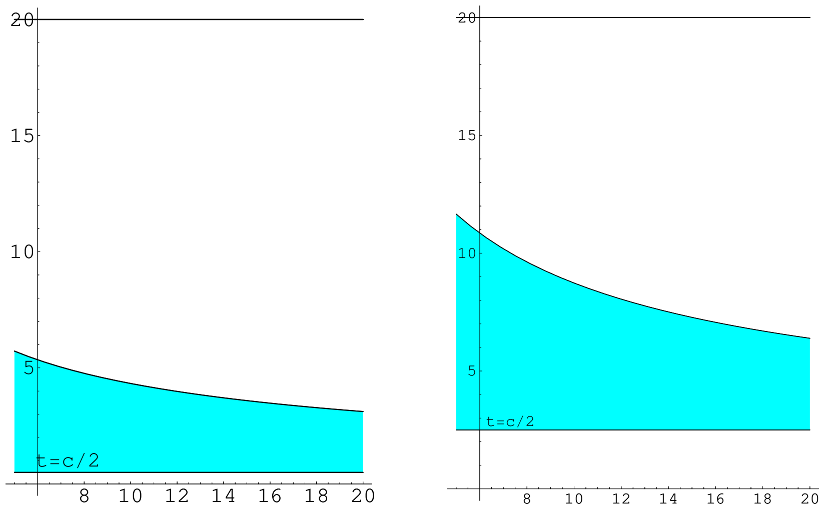

Figure 3: The effect of know-how disclosure on the incumbent firm ($c < 2t$)

(Horizontal: n, Vertical: $100t$, Left-hand: $c = 1/100$, Right-hand: $c = 1/20$)

The shaded area: The profit is increased by the disclosure.

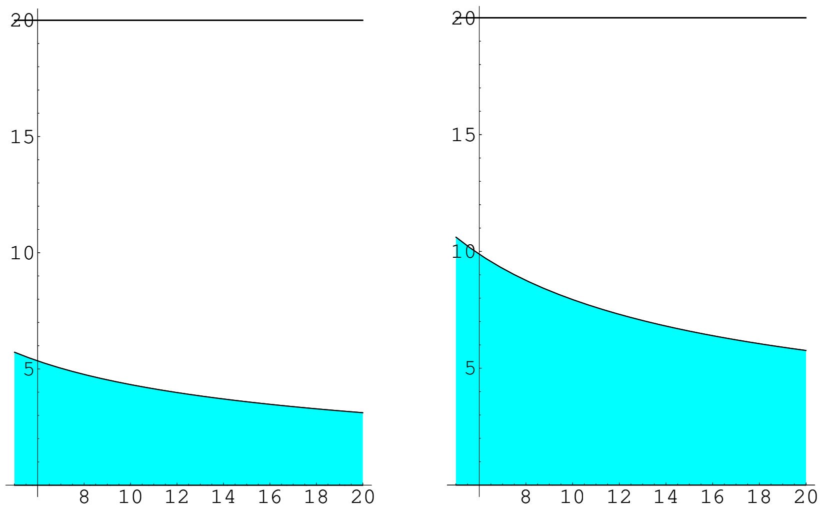

Figure 4a: The effect of know-how disclosure on the incumbent firm

(Horizontal: n, Vertical: $1000t$, Left-hand: $c = 1/100$, Right-hand: $c = 4/100$)

The shaded area: The profit is increased by the disclosure.

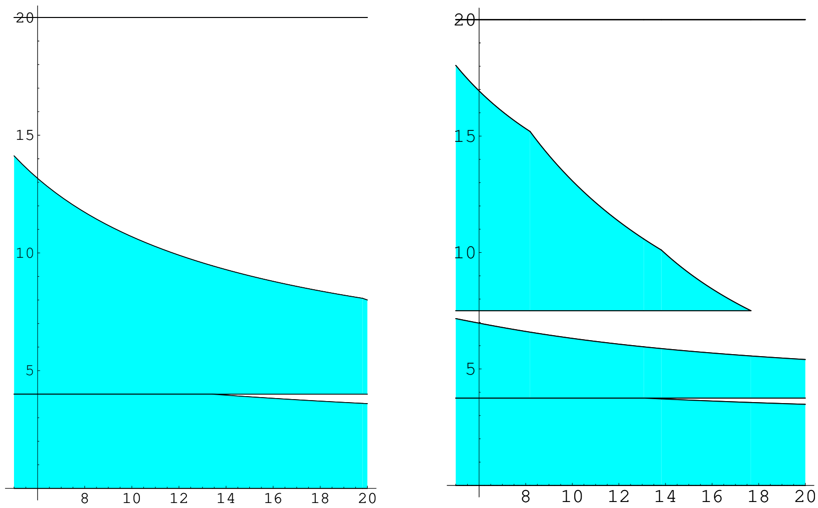

Figure 4b: The effect of know-how disclosure on the incumbent firm

(Horizontal: n, Vertical: $1000t$, Left-hand: $c = 8/100$, Right-hand: $c = 15/100$)

The shaded area: The profit is increased by the disclosure.

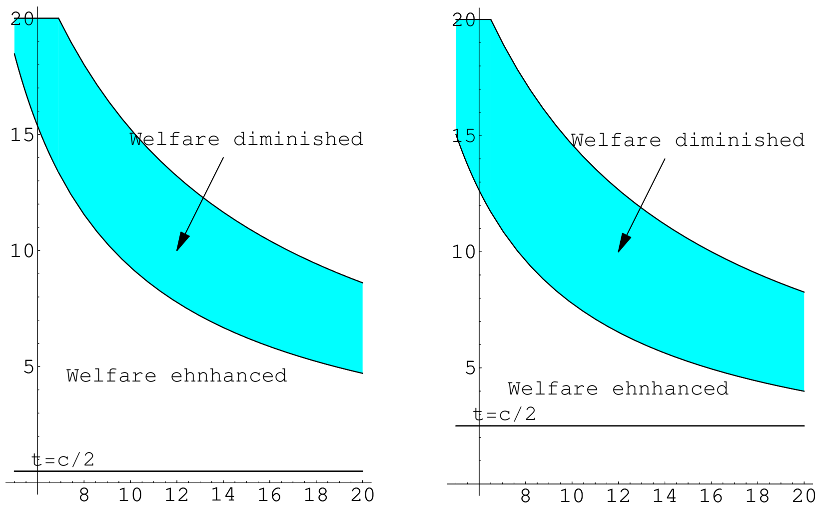

Figure 5: The effect of know-how disclosure on social welfare

(Horizontal: n, Vertical: $100t$, Left-hand: $c = 1/100$, Right-hand: $c = 1/20$)

The shaded area: welfare is diminished by the disclosure,
The nonshaded area below the shaded area: welfare is increased by the disclosure

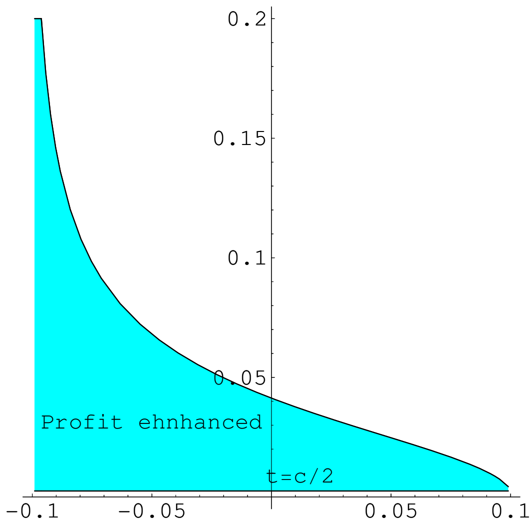

Figure 6: The profitability of know-how disclosure ($c = 1/200$)

(Horizontal: γ, Vertical: t, the shaded area: the profitable area for the incumbent)

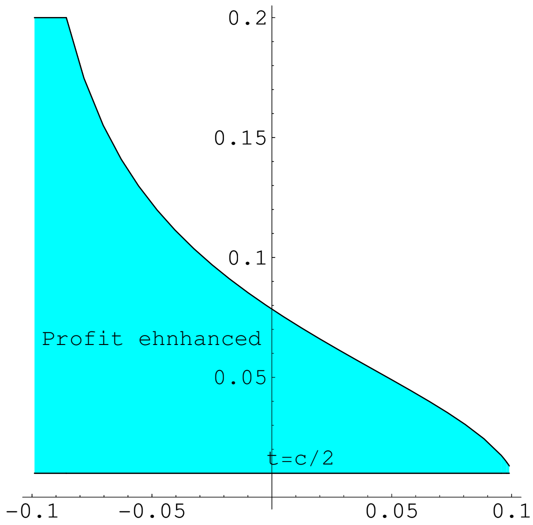

Figure 7: The profitability of know-how disclosure ($c = 1/50$)

(Horizontal: γ, Vertical: t, the shaded area: the profitable area for the incumbent)

Supplementary material

6.1 The incumbent firm

We now suppose that the incumbent firm is able to produce a unit of product A at no cost but has to incur the marginal cost $c+t$ to produce a unit of product B. The assumption is related to the cost advantage of the incumbent firm. Basically, each entrant has to incur the marginal cost c. Depending on its location choice, it has to incur an additional marginal cost in the opposite location, t or τ. Because of disclosure, the value of τ becomes smaller than t.

Suppose that k entrant firms locate at A and $n-(k+1)$ firms locate at B ($k=0,1,2,n-1$) (note that the incumbent has already located at A). The profit of the incumbent firm (denoted as $\pi_I(k,\tau)$), the profit of the entrant firm locating at A (denoted as $\pi_A(k,\tau)$), and the profit of the firm locating at B (denoted as $\pi_B(k,\tau)$) are:

$$\begin{aligned}
\pi_I(k,\tau) &= \frac{(1+(n-1)c+((k+1)\times 0+(n-k-1)\tau)-(n+1)\times 0)^2}{(n+1)^2} \\
&\quad + \frac{(1+nc+((k+1)t+(n-k-1)\times 0)-(n+1)(c+t))^2}{(n+1)^2} \\
&= \frac{(1+(n-1)c+(n-k-1)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k)t)^2}{(n+1)^2}, \qquad (21) \\
\pi_A(k,\tau) &= \frac{(1+(n-1)c+((k+1)\times 0+(n-k-1)\tau)-(n+1)c)^2}{(n+1)^2} \\
&\quad + \frac{(1+nc+((k+1)t+(n-k-1)\times 0)-(n+1)(c+t))^2}{(n+1)^2} \\
&= \frac{(1-2c+(n-k-1)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k)t)^2}{(n+1)^2}, \qquad (22) \\
\pi_B(k,\tau) &= \frac{(1+(n-1)c+((k+1)\times 0+(n-k-1)\tau)-(n+1)(c+\tau))^2}{(n+1)^2} \\
&\quad + \frac{(1+nc+((k+1)t+(n-k-1)\times 0)-(n+1)c)^2}{(n+1)^2} \\
&= \frac{(1-2c-(k+2)\tau)^2}{(n+1)^2} + \frac{(1-c+(k+1)t)^2}{(n+1)^2}. \qquad (23)
\end{aligned}$$

We have to distinguish two cases: n is odd; n is even. First, we consider the case in which n is odd, and then the case in which n is even.

n is odd When n is odd, in any case, the number of firms in each of the markets is different. Given that $k=(n-1)/2-h$ entrant firms locate in market A in the nondisclosure case ($c \in [2(h-1), 2ht)$,

($h = 1, 2, 3, \ldots$)), to induce an entrant firm that would locate in market A in the nondisclosure case to locate in market B, τ satisfies the following inequalities:

$$\pi_B\left(\frac{n-1}{2} - h - 1, \tau\right) - \pi_A\left(\frac{n-1}{2} - h, \tau\right) > 0$$
$$\pi_B\left(\frac{n-1}{2} - h - 2, \tau\right) - \pi_A\left(\frac{n-1}{2} - h - 1, \tau\right) < 0.$$

That is:

$$\begin{aligned}
& \pi_B\left(\frac{n-1}{2} - h - 1, \tau\right) - \pi_A\left(\frac{n-1}{2} - h, \tau\right) \\
= \; & \frac{(2-4c-(n-2h+1)\tau)^2}{4(n+1)^2} + \frac{(2-2c+(n-2h-1)t)^2}{4(n+1)^2} \\
& - \left(\frac{(2-4c+(n+2h-1)\tau)^2}{4(n+1)^2} + \frac{(2-2c-(n+2h+1)t)^2}{4(n+1)^2}\right) \\
= \; & -\frac{n((2h-1)\tau^2 + 2(1-2c)\tau - (2(1-c)-(2h+1)t)t)}{(n+1)^2} > 0. \\
& \pi_B\left(\frac{n-1}{2} - h - 2, \tau\right) - \pi_A\left(\frac{n-1}{2} - h - 1, \tau\right) \\
= \; & \frac{(2-4c-(n-2h-1)\tau)^2}{4(n+1)^2} + \frac{(2-2c+(n-2h-3)t)^2}{4(n+1)^2} \\
& - \left(\frac{(2-4c+(n+2h+1)\tau)^2}{4(n+1)^2} + \frac{(2-2c-(n+2h+3)t)^2}{4(n+1)^2}\right) \\
= \; & -\frac{n((2h+1)\tau^2 + 2(1-2c)\tau - (2(1-c)-(2h+3)t)t)}{(n+1)^2} < 0.
\end{aligned}$$

Solving the inequality, we have:

$$\begin{aligned}
& \frac{-(1-2c) + \sqrt{(1-2c)^2 + 2(2(h+1)-1)(1-c)t - (4(h+1)^2-1)t^2}}{2(h+1)-1} \\
& \quad < \tau < \frac{-(1-2c) + \sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2}}{2h-1}.
\end{aligned}$$

We now consider the case in which the incumbent firm sets the level of τ at the upper bound:[17]

$$\tau_o \equiv \frac{-(1-2c) + \sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2}}{2h-1}. \tag{24}$$

We can easily show that this is smaller than t if and only if $c < 2ht$ (note that we now consider the range of c, $[2(h-1)t, 2ht)$). The profit in which the incumbent discloses its knowledge and sets τ_o

[17] Under the range of τ, setting the following τ_o induces the highest profit of the incumbent firm. We can easily show that $\sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2}$ in (24) is positive if the quantities supplied by the firms are positive.

and that in which it does not are:

$$\begin{aligned}\pi_I\left(\frac{n-1}{2}-(h+1),\tau_o\right) &= \Big[(1+2h+n)\sqrt{(1-2c)^2+2(2h-1)(1-c)t-(4h^2-1)t^2} \qquad (25)\\ &\quad -(n-2h+3-4(1+hn)c)\Big]^2\big/ 4(n+1)^2(2h-1)^2\\ &\quad +\frac{(2-2c-(n+2h+3)t)^2}{4(n+1)^2},\\ \pi_I\left(\frac{n-1}{2}-h,t\right) &= \frac{(2+2(n-1)c+(n+2h-1)t)^2}{4(n+1)^2}+\frac{(2-2c-(n+2h+1)t)^2}{4(n+1)^2}. \qquad (26)\end{aligned}$$

If the difference between $\pi_I((n-1)/2-(h+1),\tau_o)$ in (25) and $\pi_I((n-1)/2-h,t)$ in (26) is positive, know-how disclosure enhances the profit of the incumbent firm. We now define $J_o(t,h)$ as follows:

$$J_o(t,h)\equiv\pi_I\left(\frac{n-1}{2}-(h+1),\tau_o\right)-\pi_I\left(\frac{n-1}{2}-h,t\right).$$

We now check the following three cases: (i) $h=1$ ($c\in(0,2t)$ or $t>c/2$), (ii) $h=2$ ($c\in[2t,4t)$ or $t\in(c/4,c/2]$), and (iii) h is larger than 2 ($c\in[2(h-1)t,2ht)$ or $t\in(c/(2h),c/(2(h-1))]$). First, we consider the case in which $h=1$ ($c\in(0,2t)$ or $t>c/2$). Differentiating $J_o(t,1)$ with respect to t twice, we have (note that c and t are smaller than 1/2 (a necessary condition that the quantities supplied by the firms are positive)):

$$\frac{\partial^2 J_o(t,1)}{\partial t^2}=-\frac{(n+3)[((1-2c)^2+2(1-c)t-3t^2)^{3/2}-(4-30c+69c^2-52c^3)]}{2(n+1)((1-2c)^2+2(1-c)t-3t^2)^{3/2}}<0.$$

Therefore, $J_o(t,1)$ is concave with respect to t. We now substitute $t=c/2$ (the lower bound of t) into $J_o(t,1)$, then we have:

$$J_o\left(\frac{c}{2},1\right) = \frac{3c^2}{2(n+1)}>0.$$

We find that there exists $\bar{t}$ such that $J_o(t,1)=0$ and that for any $t\in[c/2,\bar{t})$, disclosure increases the profit of the incumbent firm because $J_o(t,1)$ is concave. We can summarize this in the following proposition.

Proposition 1 *Suppose that $c\in(0,2t)$ and that n is odd and larger than or equal to 5. There exists $\bar{t}$ such that $J_o(t,1)=0$. For any $t\in(c/2,\bar{t})$, the disclosure increases the profit of the incumbent firm.*

Second, we consider the case in which $h = 2$ ($c \in [2t, 4t)$ or $c/4 < t \leq c/2$). In this case, n is larger than or equal to 7. Differentiating $J_o(t, 2)$ with respect to t three times, we have:

$$\frac{\partial^3 J_o(t,2)}{\partial t^3} = -\frac{3(n+5)(8-26c+23c^2)(n-1-4(2n+1)c)(1-c-5t)}{2(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{5/2}}.$$

The sign of $\frac{\partial^3 J_o(t,2)}{\partial t^3}$ does not depend on the value of t because $(1-c-5t)$ is always positive.[18] For any t, the sign of $\frac{\partial^3 J_o(t,2)}{\partial t^3}$ is always negative or always positive. Therefore, if $(\partial^2 J_o(t,2))/(\partial t^2)$ is negative when $t = c/4$ and $t = c/2$, the sign of $(\partial^2 J_o(t,2))/(\partial t^2)$ is negative for any t.

(1) $t = c/4$: Substituting $t = c/4$ into $(\partial^2 J_o(t,2))/(\partial t^2)$, we have:

$$\left.\frac{\partial^2 J_o(t,2)}{\partial t^2}\right|_{t=c/4} = -\frac{4(n+5)(2(32-72c-8c^2+81c^3)+c(160-516c+449c^2)n)}{(n+1)^2(4-5c)^3} < 0.$$

because the coefficient of n and the constant term is positive for any $c < 4/9$ (when $1-c-5t > 0$ and $t > c/4$, $c < 4/9$.).

(2) $t = c/2$: Substituting $t = c/2$ into $(\partial^2 J_o(t,2))/(\partial t^2)$, we have:

$$\left.\frac{\partial^2 J_o(t,2)}{\partial t^2}\right|_{t=c/2} = -\frac{4(-H_a)(n+5)(8-26c+23c^2)}{3(n+1)^2(4-4c-11c^2)^{3/2}} - \frac{4(n+5)(n+2)}{3(n+1)^2} < 0.$$

because $(4-4c-11c^2)^{3/2}$ and $(8-26c+23c^2)$ are positive for any $c < 4/9$. Therefore, $J_o(t,2)$ is concave with respect to t. We now substitute $t = c/4$ (the lower bound of t) and $t = c/2$ (the upper bound of t) into $J_o(t,2)$, then we have:

$$\begin{aligned} J_o\left(\frac{c}{4}, 2\right) &= \frac{5c^2}{8(n+1)} > 0, \\ J_o\left(\frac{c}{2}, 2\right) &= \frac{(n+5)(2(n-1)-(7+17n)c)+(35+68n+5n^2)c^2}{36(n+1)^2} \\ &\quad - \frac{(n+5)(n-1-4(2n+1)c)\sqrt{4-4c-11c^2}}{36(n+1)^2}. \end{aligned}$$

If n and c are in the shaded area in Figure S1, $J_o(t,2)$ is positive for any $t \in [c/4, c/2)$, otherwise there exists $\bar{t}'$ such that $J_o(t,2) = 0$ and that for any $t \in [c/4, \bar{t}')$, disclosure increases the profit of the incumbent firm because $J_o(t,2)$ is concave. We can summarize this as follows:

Proposition 2 *Suppose that $c \in (2t, 4t)$ and that n is odd and larger than or equal to 7. If n and c satisfy $J_o(c/2, 2) > 0$, for any $t \in [c/4, c/2)$, the disclosure increases the profit of the incumbent firm,*

[18] In this case, the quantity supplied by the incumbent firm in market B is $(2-2c-(n+2h+3)t)/(2(n+1))$. If this is positive, $(1-c-5t)$ is also positive.

otherwise there exists $\bar{t}'$ such that $J_o(t,2)=0$, and for any $t \in (c/4, \bar{t}')$, the disclosure increases the profit of the incumbent firm.

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that given that $k=(n-1)/2-h$ entrant firms locate at A, $J_o(t,h)$ is minimized when $t=c/(2(h-1))$ or $t=c/(2h)$.[19] $J_o(c/(2h),h)=c^2(1+2h)/(2h^2(n+1))>0$. Therefore, if $J_o(c/(2(h-1)),h)$ is positive for any c, h, and n, in the given range of t ($[c/2h, c/(2(h-1))]$), disclosure enhances the profit of the incumbent firm. Note that h is related to the value of t. As the value of h increases, the value of t decreases.

We now show two examples of these values. From Figures S2 and S3, we find that as the value of h increases, the condition that the disclosure enhances the profit of the incumbent firm tends to hold. As mentioned earlier, as the value of h increases, the value of t decreases. That is, as the value of t becomes smaller, the condition tends to hold.

n is even Given that $k=n/2-h$ entrant firms locate in market A in the nondisclosure case ($c \in [(2h-3)t,(2h-1)t)$, ($h=1,2,3,\ldots$)), to induce an entrant firm that would locate in market A in the nondisclosure case to locate in market B, τ must satisfy the following inequalities:

$$\pi_B\left(\frac{n}{2}-h-1,\tau\right)-\pi_A\left(\frac{n}{2}-h,\tau\right)>0$$
$$\pi_B\left(\frac{n}{2}-h-2,\tau\right)-\pi_A\left(\frac{n}{2}-h-1,\tau\right)<0,$$

that is:

$$\begin{aligned}&\pi_B\left(\frac{n}{2}-h-1,\tau\right)-\pi_A\left(\frac{n}{2}-h,\tau\right)\\ =\;&\frac{(2-4c-(n-2h+2)\tau)^2}{4(n+1)^2}+\frac{(2-2c+(n-2h)t)^2}{4(n+1)^2}\end{aligned}$$

[19] We first differentiate $J_o(t,h)$ with respect to t three times. The sign of $(\partial^3 J_o(t,h))/(\partial t^3)$ does not depend on t but on the other parameters. This means that the sign $(\partial^3 J_o(t,h))/(\partial t^3)$ is always positive or always negative in the range of t, $[c/(2h), c/(2(h-1))]$. If the signs of $(\partial^2 J_o(t,h))/(\partial t^2)$ are negative at $t=c/(2h)$ and $t=c/(2(h-1))$, the sign of $(\partial^2 J_o(t,h))/(\partial t^2)$ is always negative for any $t\in[c/(2h),c/(2(h-1))]$. That is, $J_o(t,h)$ is concave with respect to t. Substituting $t=c/(2h)$ and $t=c/(2(h-1))$ into $(\partial^2 J_o(t,h))/(\partial t^2)$, we have the values of $(\partial^2 J_o(t,h))/(\partial t^2)$ at $t=c/(2h)$ and $t=c/(2(h-1))$. The numerators of the values are quadratic and concave functions with respect to n. Solving the quadratic equations $(\partial^2 J_o(t,h))/(\partial t^2)|_{t=c/(2h)}=0$ and $(\partial^2 J_o(t,h))/(\partial t^2)|_{t=c/(2(h-1))}=0$ with respect to n, we find that under both equations, the solutions are negative. Therefore, the values of $(\partial^2 J_o(t,h))/(\partial t^2)$ at $t=c/(2h)$ and $t=c/(2(h-1))$ are negative, that is, $J_o(t,h)$ is a concave function with respect to t.

$$
\begin{aligned}
& -\left(\frac{(2-4c+(n+2h-2)\tau)^2}{4(n+1)^2}+\frac{(2-2c-(n+2h)t)^2}{4(n+1)^2}\right) \\
= \;& -\frac{2n((h-1)\tau^2+(1-2c)\tau-(1-c-ht)t)}{(n+1)^2}>0. \\
& \pi_B\left(\frac{n}{2}-h-2,\tau\right)-\pi_A\left(\frac{n}{2}-h-1,\tau\right) \\
= \;& \frac{(2-4c-(n-2h)\tau)^2}{4(n+1)^2}+\frac{(2-2c+(n-2h-2)t)^2}{4(n+1)^2} \\
& -\left(\frac{(2-4c+(n+2h)\tau)^2}{4(n+1)^2}+\frac{(2-2c-(n+2h+2)t)^2}{4(n+1)^2}\right) \\
= \;& -\frac{2n(h\tau^2+(1-2c)\tau-(1-c+(h+1)t)t)}{(n+1)^2}<0.
\end{aligned}
$$

Solving the inequalities, we have:

$$
\frac{-(1-2c)+\sqrt{(1-2c)^2+4h(1-c-(h+1)t)t}}{2h}<\tau<W
$$

where

$$
W=\begin{cases}\dfrac{(1-c-t)t}{1-2c}, & \text{if } h=1,\\[2ex] \dfrac{-(1-2c)+\sqrt{(1-2c)^2+4(h-1)(1-c-ht)t}}{2(h-1)}, & \text{otherwise.}\end{cases}
$$

We now consider the case in which the incumbent sets the level of τ at the upper bound:

$$
\tau_e\equiv\begin{cases}\dfrac{(1-c-t)t}{1-2c}, & \text{if } h=1,\\[2ex] \dfrac{-(1-2c)+\sqrt{(1-2c)^2+4(h-1)(1-c-ht)t}}{2(h-1)}, & \text{otherwise.}\end{cases} \tag{27}
$$

We can easily show that τ_e is smaller than t if and only if $c<(2h-1)t$. The profit at which the incumbent discloses its knowledge and sets τ_e and that at which it does not are:

$$
\pi_I\left(\frac{n}{2}-(h+1),\tau_e\right)=\begin{cases}\Big[(n+2h)\sqrt{(1-2c)^2+4(h-1)((1-c)-ht)t} \\ \quad -(n-2h+4-2(2+(2h-1)n)c)\Big]^2\Big/16(h-1)^2(n+1)^2 \\ \quad +\dfrac{(2-2c-(n+2(h+1))t)^2}{4(n+1)^2}, \quad (h\neq 1), \\[2ex] \dfrac{(2(1-2c)(1+(n-1)c)+(n+2h)(1-c-t)t)^2}{4(1-2c)^2(n+1)^2}, \quad (h=1),\end{cases} \tag{28}
$$

$$
\pi_I\left(\frac{n}{2}-h,t\right)=\frac{(2+2(n-1)c+(n+2(h-1))t)^2}{4(n+1)^2}+\frac{(2-2c-(n+2h)t)^2}{4(n+1)^2}. \tag{29}
$$

If the difference between $\pi_I(n/2-(h+1),\tau_e)$ in (28) and $\pi_I(n/2-h,t)$ in (29) is positive, know-how disclosure enhances the profit of the incumbent firm. We now define $J_e(t,h)$ as follows:

$$
J_e(t,h)\equiv\pi_I\left(\frac{n}{2}-(h+1),\tau_e\right)-\pi_I\left(\frac{n}{2}-h,t\right).
$$

We now check the following cases: (i) $h = 1$ ($c \in (0, t)$ or $t > c$), (ii) $h = 2$ ($c \in [t, 3t)$ or $t \in (c/3, c]$), (iii) h is larger than 2.

First, we consider the case in which $h = 1$ ($c \in (0, t)$ or $t > c$). $J_e(t, 1)$ is:

$$J_e(t,1) = \frac{t\bar{J}}{4(1-2c)^2(n+1)^2},$$

where $\bar{J} \equiv 4c(1-2c)((1-c)(2+3n)+n^2c)+(n+2)(4-2(n+8)c+(5n+18)c^2)t^2-(2(1-c)-t)(n+2)^2t^2$. If $\bar{J}$ is positive, then $J_e(t, 1)$ is also positive. Differentiating $\bar{J}$ with respect to t twice, we have:[20]

$$\frac{\partial^2 \bar{J}}{\partial t^2} = -2(n+2)^2(2-2c-3t) < 0.$$

$\bar{J}$ is a concave function with respect to t. We now substitute $t = c$ (the lower bound of t) and $t = 2(1-c)/(n+6)$ (a necessary condition that the quantities supplied by the firms are positive) into $\bar{J}$, then we have:

$$\begin{aligned} \bar{J}_{t=c} &= 16c(1-2c)^2(n+1) > 0, \\ \bar{J}_{t=2(1-c)/(n+6)} &= \frac{8(n+2)(5n+26) - 4(n^4+19n^3+107n^2+168n-84)c}{(n+1)^3} \\ &\quad - \frac{2(-2n^5-25n^4+940n^2+2928n+384)c^2}{(n+1)^3} \\ &\quad - \frac{2(4n^5+65n^4+292n^3-60n^2-2112n-512)c^3}{(n+1)^3}. \end{aligned}$$

After some calculus, we can show that for any $c < 1/2$ (this is a necessary condition that the quantities supplied by the firms are positive) and n, $\bar{J}_{t=2(1-c)/(n+6)}$ is positive.[21]

Proposition 3 *Suppose that $c \in (0, t)$ and that n is even and larger than or equal to 4. The disclosure increases the profit of the incumbent firm.*

[20] In this case, the quantity supplied by the incumbent firm in market B is $(2-2c-(n+2h)t)/(2(n+1))$. If this is positive, $(2-2c-3t)$ is also positive.

[21] First, we differentiate $\bar{J}_{t=2(1-c)/(n+6)}$ with respect to c. This is a quadratic function with respect to c. Solving the quadratic equation $(\partial\bar{J}_{t=2(1-c)/(n+6)})/(\partial c) = 0$ with respect to c, we find that one solution (which we now denote as c_p) is positive and the other is negative. When $c = 0$, $(\partial\bar{J}_{t=2(1-c)/(n+6)})/(\partial c)$ is positive. Therefore, when $c \in [0, c_p]$, $\bar{J}_{t=2(1-c)/(n+6)}$ is increasing with respect to c, and when $c \in [c_p, 1/2]$, $\bar{J}_{t=2(1-c)/(n+6)}$ is decreasing with respect to c. If $\bar{J}_{t=2(1-c)/(n+6)}$ is positive when $c = 0$ and $c = 1/2$, then $\bar{J}_{t=2(1-c)/(n+6)}$ is positive for any $c < 1/2$. When $c = 0$, $\bar{J}_{t=2(1-c)/(n+6)}$ is $8(n+2)(5n+26)/(n+6)^3$. When $c = 1/2$, $\bar{J}_{t=2(1-c)/(n+6)}$ is $(n+2)^2(n+4)^2/4(n+6)^3$. Therefore, $\bar{J}_{t=2(1-c)/(n+6)}$ is positive.

Second, we consider the case in which $h = 2$ ($c \in [t, 3t)$ or $c/3 < t \leq c$). n is larger than or equal to 6. Differentiating $J_e(t, 2)$ with respect to t three times, we have:

$$\frac{\partial^3 J_e(t,2)}{\partial t^3} = -\frac{3(n+4)(8-10c+9c^2)(n-2(3n+2)c)(1-c-4t)}{(n+1)^2((1-2c)^2+4(1-c)t-8t^2)^{5/2}}.$$

The sign of $\frac{\partial^3 J_e(t,2)}{\partial t^3}$ does not depend on the value of t because $(1 - c - 4t)$ is always positive.[22] For any t, the sign of $\frac{\partial^3 J_e(t,2)}{\partial t^3}$ is always negative or always positive. Therefore, if $(\partial^2 J_e(t, 2))/(\partial t^2)$ is negative when $t = c/3$ and $t = c$, the sign of $(\partial^2 J_e(t, 2))/(\partial t^2)$ is negative for any t.

(1) $t = c/3$: Substituting $t = c/3$ into $(\partial^2 J_e(t, 2))/(\partial t^2)$, we have:

$$\left.\frac{\partial^2 J_e(t,2)}{\partial t^2}\right|_{t=c/3} = -\frac{(n+4)(4(27-27c-126c^2+179c^3)+3c(144-477c+422c^2)n)}{2(n+1)^2(3-4c)^3} < 0,$$

because $(27 - 27c - 126c^2 + 179c^3)$ and $(144 - 477c + 422c^2)$ are positive for any $c < 1/2$.

(2) $t = c$: Substituting $t = c$ into $(\partial^2 J_e(t, 2))/(\partial t^2)$, we have:

$$\left.\frac{\partial^2 J_e(t,2)}{\partial t^2}\right|_{t=c} = -\frac{(n+4)((3n+4)(1-8c^2)^{3/2}+(-H_b)(3-10c+9c^2)}{2(n+1)^2(1-8c^2)^{3/2}} < 0.$$

Therefore, $J_e(t, 2)$ is concave with respect to t. We now substitute $t = c/3$ (the lower bound of t) and $t = c$ (the upper bound of t) into $J_e(t, 2)$, then we have:

$$\begin{aligned} J_e\left(\frac{c}{3}, 2\right) &= \frac{8c^2}{9(n+1)} > 0, \\ J_e(c, 2) &= \frac{(n+4)(n-2(2+3n)c)(1-\sqrt{1-8c^2})-4n^2c^2}{8(n+1)^2}. \end{aligned}$$

If n and c are in the shaded area of Figure S4, $J_e(t, 2)$ is positive for any $t \in [c/3, c)$, otherwise there exists $\bar{t}''$ such that $J_e(t, 2) = 0$ and that for any $t \in [c/3, \bar{t}'')$, disclosure increases the profit of the incumbent firm because $J_e(t, 2)$ is concave. We can summarize this as the following proposition.

Proposition 4 *Suppose that $c \in (t, 3t)$ and that n is even and larger than or equal to 6. If $J_e(c, 2) > 0$, for any $t \in [c/3, c)$, the disclosure increases the profit of the incumbent firm. Otherwise, there exists $\bar{t}''$ such that $J_e(t, 2) = 0$, and for any $t \in (c/3, \bar{t}'')$, the disclosure increases the profit of the incumbent firm.*

[22] In this case, the quantity supplied by the incumbent firm in market B is $(2 - 2c - (n + 2h)t)/(2(n + 1))$. If this is positive, $(1 - c - 4t)$ is also positive.

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that given $k = n/2 - h$ entrant firms locate at A, $J_e(t, h)$ is minimized when $t = c/(2h - 1)$ or $t = c/(2h - 3)$.[23] $J_e(c/(2h - 1), h) = 4c^2h/((2h - 1)^2(n + 1)) > 0$. Therefore, if $J_e(c/(2h - 3), h)$ is positive for any c, h, and n, in the given range of t ($[c/(2h - 1), c/(2h - 3)]$), disclosure enhances the profit of the incumbent firm. Note that h is related to the value of t. As the value of h increases, the value of t decreases.

We now show two examples of these values. From Figures S5 and S6, we find that as the value of h increases, the condition that disclosure enhances the profit of the incumbent firm tends to hold. As mentioned earlier, as the value of h increases, the value of t decreases. That is, as the value of t becomes smaller, the condition tends to hold.

6.2 Entrant firms

We now consider the changes in the profits of the entrant firms. There are two types of entrants: those who locate in market A and those who locate in market B.

Suppose that k entrant firms locate at A and $n - (k + 1)$ firms locate at B ($k = 0, 1, 2, n - 1$) (note that the incumbent has already located at A). The profit of the incumbent firm (denoted as $\pi_I(k, \tau)$), the profit of the entrant firm locating at A (denoted as $\pi_A(k, \tau)$), and the profit of the firm locating at B (denoted as $\pi_B(k, \tau)$) are:

$$\begin{aligned}\pi_A(k,\tau) &= \frac{(1-2c+(n-k-1)\tau)^2}{(n+1)^2} + \frac{(1-c-(n-k)t)^2}{(n+1)^2},\\ \pi_B(k,\tau) &= \frac{(1-2c-(k+2)\tau)^2}{(n+1)^2} + \frac{(1-c+(k+1)t)^2}{(n+1)^2}.\end{aligned}$$

We have to distinguish two cases: n is odd; n is even. First, we consider the case in which n is odd, and then that in which n is even.

[23] We first differentiate $J_e(t, h)$ with respect to t three times. The sign of $(\partial^3 J_e(t, h))/(\partial t^3)$ does not depend on t but on the other parameters. This means that the sign $(\partial^3 J_e(t, h))/(\partial t^3)$ is always positive or always negative on the range of t $[c/(2h - 1), c/(2h - 3)]$. If the signs of $(\partial^2 J_e(t, h))/(\partial t^2)$ are negative at $t = c/(2h - 1)$ and $t = c/(2h - 3)$, the sign of $(\partial^2 J_e(t, h))/(\partial t^2)$ is always negative for any $t \in [c/(2h - 1), c/(2h - 3)]$. That is, $J_e(t, h)$ is concave with respect to t. Substituting $t = c/(2h - 1)$ and $t = c/(2h - 3)$ into $(\partial^2 J_e(t, h))/(\partial t^2)$, we have the values of $(\partial^2 J_e(t, h))/(\partial t^2)$ at $t = c/(2h - 1)$ and $t = c/(2h - 3)$. The numerators of the values are quadratic and concave functions with respect to n. Solving the quadratic equations $(\partial^2 J_e(t, h))/(\partial t^2)|_{t=c/(2h-1)} = 0$ and $(\partial^2 J_e(t, h))/(\partial t^2)|_{t=c/(2h-3)} = 0$ with respect to n, we find that for both equations the solutions are negative. Therefore, the values of $(\partial^2 J_e(t, h))/(\partial t^2)$ at $t = c/(2h - 1)$ and $t = c/(2h - 3)$ are negative, that is, $J_e(t, h)$ is a concave function with respect to t.

6.2.1 Entrant firms locating in market A

We now discuss the profits of the firms locating in market A.

n is odd When n is odd, in any case, the number of firms in each market is different. Given that $k = (n-1)/2 - h$ ($h = 1, 2, 3, \ldots$) entrant firms locate in market A in the nondisclosure case ($c \in [2(h-1), 2ht)$), to induce an entrant firm that would locate in market A in the nondisclosure case to locate in market B, the incumbent sets τ at τ_o (which is defined in (24)):

$$\tau_o = \frac{-(1-2c) + \sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2}}{2h-1}.$$

The profit in the cases when the incumbent discloses its knowledge and sets τ_o and when it does not is:

$$\pi_A\left(\frac{n-1}{2} - (h+1), \tau_o\right) = \Big[(1+2h+n)\sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2} \quad (30)$$
$$-(n-2h+3)(1-2c)\Big]^2 \Big/ 4(2h-1)^2(n+1)^2$$
$$+\frac{(2-2c-(n+2h+3)t)^2}{4(n+1)^2},$$

$$\pi_A\left(\frac{n-1}{2} - h, t\right) = \frac{(2-4c+(n+2h-1)t)^2}{4(n+1)^2} + \frac{(2-2c-(n+2h+1)t)^2}{4(n+1)^2}. \quad (31)$$

If the difference between $\pi_A((n-1)/2 - (h+1), \tau_o)$ in (30) and $\pi_A((n-1)/2 - h, t)$ in (31) is positive, the know-how disclosure enhances the profits of entrant firms who locate in market A. We now define $J_o^A(t, h)$ as follows:

$$J_o^A(t,h) \equiv \pi_A\left(\frac{n-1}{2} - (h+1), \tau_o\right) - \pi_A\left(\frac{n-1}{2} - h, t\right).$$

We now check the three cases: (i) $h = 1$ ($c \in (0, 2t)$ or $t > c/2$), (ii) $h = 2$ ($c \in [2t, 4t)$ or $t \in (c/4, c/2]$), and (iii) h is larger than 2 ($c \in [2(h-1)t, 2ht)$ or $t \in (c/(2h), c/(2(h-1))]$).

First, we consider the case in which $h = 1$ ($c \in (0, 2t)$ or $t > c/2$). Differentiating $J_o^A(t, 1)$ with respect to t twice, we have (note that c and t are smaller than $1/2$):

$$\frac{\partial^2 J_o^A(t,1)}{\partial t^2} = -\frac{(n+3)(((1-2c)^2 + 2(1-c)t - 3t^2)^{3/2} - (1-2c)(4-14c+13c^2))}{2(n+1)((1-2c)^2 + 2(1-c)t - 3t^2)^{3/2}} < 0.$$

Therefore, $J_o^A(t,1)$ is concave with respect to t. We now substitute $t = c/2$ (the lower bound of t) into $J_o^A(t,1)$, then we have:

$$J_o^A\left(\frac{c}{2},1\right) = \frac{c^2}{2(n+1)} > 0.$$

We find that there exists $\tilde{t}$ such that $J_o^A(t,1) = 0$ and that for any $t \in [c/2, \bar{t})$, disclosure increases the profit of the incumbent firm because $J_o^A(t,1)$ is concave. We can summarize this as the following proposition.

Proposition 5 *Suppose that $c \in (0, 2t)$. There exists $\tilde{t}$ such that $J_o^A(t,1) = 0$. For any $t \in (c/2, \tilde{t})$, the disclosure increases the profit of the incumbent firm.*

Second, we consider the case in which $h = 2$ ($c \in [2t, 4t)$ or $c/4 < t \leq c/2$). Differentiating $J_o^A(t,2)$ with respect to t three times, we have:

$$\frac{\partial^3 J_o^A(t,2)}{\partial t^3} = -\frac{3(1-2c)(n+5)(8-26c+23c^2)(n-1)(1-c-5t)}{2(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{5/2}} < 0,$$
$$\frac{\partial^2 J_o^A(t,2)}{\partial t^2} = \frac{(n+5)[(1-2c)(8-26c+23c^2)(n-1)]}{6(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{3/2}} - \frac{8(n+5)(n+2)}{6(n+1)^2}.$$

We now show that the sign of $(\partial^2 J_o^A(t,2))/(\partial t^2)$ is negative in all cases. Substituting $t = c/4$ (the lower bound of t) into $(\partial^2 J_o^A(t,2))/(\partial t^2)$, we have:

$$\left.\frac{\partial^2 J_o^A(t,2)}{\partial t^2}\right|_{t=c/4} = -\frac{4(n+5)(2(32-136c+200c^2-103c^3)+c(32-100c+81c^2)n)}{(n+1)^2(4-5c)^3} < 0,$$

for any $c < 1/2$.

Because $\frac{\partial^3 J_o^A(t,2)}{\partial t^3}$ is negative, $(\partial^2 J_o^A(t,2))/(\partial t^2)$ is negative, that is, $J_o^A(t,2)$ is concave with respect to t. We now substitute $t = c/4$ (the lower bound of t) and $t = c/2$ (the upper bound of t) into $J_o^A(t,2)$, then we have:

$$J_o^A\left(\frac{c}{4},2\right) = \frac{c^2}{8(n+1)} > 0,$$
$$J_o^A\left(\frac{c}{2},2\right) = \frac{(n+5)(2-5c)(n+5)-(31+4n+n^2)c^2}{36(n+1)^2} - \frac{(n+5)(n-1)(1-2c)\sqrt{4-4c-11c^2}}{36(n+1)^2} < 0.$$

There exists $\tilde{t}'$ such that $J_o^A(t,2) = 0$ and that for any $t \in [c/4, \tilde{t}')$, disclosure increases the profit of the incumbent firm because $J_o^A(t,2)$ is concave. We can summarize this as the following proposition.

Proposition 6 *Suppose that $c \in (2t, 4t)$. There exists $\tilde{t}'$ such that $J_o^A(t, 2) = 0$. For any $t \in (c/4, \tilde{t}')$, the disclosure increases the profit of the incumbent firm.*

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that, given that $k = (n-1)/2 - h$ entrant firms locate at A, $J_o(t, h)$ is minimized when $t = c/(2(h-1))$.[24] $J_o^A(c/(2h), h) = c^2/(2h^2(n+1)) > 0$. Therefore, we have the following result: *Suppose that $c \in (2(h-1)t, 2ht)$ and n is odd. There exists $\tilde{t}'_g$ such that $J_o^A(t, h) = 0$. For any $t \in (c/(2h), \tilde{t}'_g)$, the disclosure increases the profit of the incumbent firm.*

n is even Given that $k = n/2 - h$ entrant firms locate in market A in the nondisclosure case ($c \in [(2h-3)t, (2h-1)t)$) (when $h = 1$, the range is $(0, t)$), to induce an entrant firm who would locate in market A in the nondisclosure case to locate in market B, τ satisfies the following inequalities, the incumbent sets τ at τ_e:

$$\tau_e = \begin{cases} \dfrac{(1-c-t)t}{1-2c} & \text{if } h = 1, \\ \dfrac{-(1-2c) + \sqrt{(1-2c)^2 + 4(h-1)(1-c-ht)t}}{2(h-1)}, & \text{otherwise.} \end{cases}$$

The profit when the incumbent discloses its knowledge and sets τ_e and that when it does not do so is:

$$\pi_A\left(\frac{n}{2} - (h+1), \tau_e\right) = \begin{cases} \Big[(n+2h)\sqrt{(1-2c)^2 + 4(h-1)((1-c) - ht)t} \\ \quad -(n-2h+4)(1-2c)\Big]^2 \Big/ 16(h-1)^2(n+1)^2 \\ \qquad + \dfrac{(2-2c-(n+2(h+1))t)^2}{4(n+1)^2}, \ (h \neq 1) \\ \dfrac{(2-6c+5c^2-2(1-c)t+t^2)(4(1-2c)^2+(n+2)^2t^2)}{4(1-2c)^2(n+1)^2}, \ (h = 1), \end{cases} \tag{32}$$

$$\pi_A\left(\frac{n}{2} - h, t\right) = \frac{(2-4c+(n+2(h-1))t)^2}{4(n+1)^2} + \frac{(2-2c-(n+2h)t)^2}{4(n+1)^2}. \tag{33}$$

[24] We first differentiate $J_o^A(t, h)$ with respect to t three times. The sign of $(\partial^3 J_o^A(t, h))/(\partial t^3)$ does not depend on t but on the other parameters. This means that the sign $(\partial^3 J_o^A(t, h))/(\partial t^3)$ is always positive or always negative on the range of t $[c/(2h), c/(2(h-1))]$. If the signs of $(\partial^2 J_o^A(t, h))/(\partial t^2)$ are negative at $t = c/(2h)$ and $t = c/(2(h-1))$, the sign of $(\partial^2 J_o^A(t, h))/(\partial t^2)$ is always negative for any $t \in [c/(2h), c/(2(h-1))]$. That is, $J_o^A(t, h)$ is concave with respect to t. Substituting $t = c/(2h)$ and $t = c/(2(h-1))$ into $(\partial^2 J_o^A(t, h))/(\partial t^2)$, we have the values of $(\partial^2 J_o^A(t, h))/(\partial t^2)$ at $t = c/(2h)$ and $t = c/(2(h-1))$. The numerators of the values are quadratic and concave functions with respect to n. Solving the quadratic equations $(\partial^2 J_o^A(t, h))/(\partial t^2)|_{t=c/(2h)} = 0$ and $(\partial^2 J_o^A(t, h))/(\partial t^2)|_{t=c/(2(h-1))} = 0$ with respect to n, we find that under the both equations the solutions are negative. Therefore, the values of $(\partial^2 J_o^A(t, h))/(\partial t^2)$ at $t = c/(2h)$ and $t = c/(2(h-1))$ are negative, that is, $J_o^A(t, h)$ is concave function with respect to t.

If the difference between $\pi_I(n/2-(h+1),\tau_e)$ in (32) and $\pi_I(n/2-h,t)$ in (33) is positive, know-how disclosure enhances the profit of entrant firms locating in market A. We now define $J_e^A(t,h)$ as follows:

$$J_e^A(t,h) \equiv \pi_A\left(\frac{n}{2}-(h+1),\tau_e\right)-\pi_A\left(\frac{n}{2}-h,t\right).$$

We now check the three cases: (i) $h=1$ ($c\in(0,t)$ or $t>c$), (ii) $h=2$ ($c\in[t,3t)$ or $t\in(c/3,c]$), and (iii) h is larger than 2 ($c\in[(2h-3)t,(2h-1)t)$ or $t\in(c/(2h-1),c/(2h-3)]$).

First, we consider the case in which $h=1$ ($c\in(0,t)$ or $t>c$). $J_e^A(t,1)$ is:

$$J_e^A(t,1)=\frac{t\tilde{J}}{4(1-2c)^2(n+1)^2},$$

where $\tilde{J}\equiv 4c(1-2c)^2n+(n+2)(4+2(n-6)c-(3n-10)c^2)t-(2(1-c)-t)(n+2)^2t^2$. If $\tilde{J}$ is positive, then $J_e^A(t,1)$ is also positive. Differentiating $\tilde{J}$ with respect to t twice, we have:

$$\frac{\partial^2\tilde{J}}{\partial t^2}=-2(n+2)^2(2-2c-3t)<0.$$

$\tilde{J}$ is a concave function with respect to t. We now substitute $t=c$ (the lower bound of t) and $t=2(1-c)/(n+6)$ (a necessary condition that the quantities supplied by the firms are positive) into $\tilde{J}$, then we have:

$$\begin{aligned}
\tilde{J}_{t=c} &= 8c(1-2c)^2(n+1)>0,\\
\tilde{J}_{t=2(1-c)/(n+6)} &= \frac{16(1-c)(13-44c+40c^2)+48(3-2c-22c^2+30c^3)n}{(n+6)^3}\\
&\quad+\frac{4(5+55c-241c^2+235c^3)n^2+12c(5-17c+15c^2)n^3}{(n+6)^3}\\
&\quad+\frac{c(4-13c+11c^2)n^4}{(n+6)^3}.
\end{aligned}$$

After some calculus (we can show that the coefficients of n's are positive), we find that for any $c<1/2$ (this is a necessary condition that the quantities supplied by the firms are positive) and n, $\tilde{J}_{t=2(1-c)/(n+6)}$ is positive.

Proposition 7 *Suppose that $c\in(0,t)$ and that n is even. The disclosure increases the profits of the entrant firms locating in A.*

Second, we consider the case in which $h = 2$ ($c \in [t, 3t)$ or $c/3 < t \leq c$). Differentiating $J_e^A(t, 2)$ with respect to t three times, we have:

$$\frac{\partial^3 J_e^A(t,2)}{\partial t^3} = -\frac{3(1-2c)(3-10c+9c^2)n(n+4)(1-c-4t)}{(n+1)^2((1-2c)^2+4(1-c)t-8t^2)^{5/2}} < 0.$$

We now show that the sign of $(\partial^2 J_e^A(t,2))/(\partial t^2)$ is negative for any t. Substituting $t = c/3$ into $(\partial^2 J_e^A(t,2))/(\partial t^2)$, and then for any $c < 1/2$ we have:

$$\left.\frac{\partial^2 J_e^A(t,2)}{\partial t^2}\right|_{t=c/3} = -\frac{(n+4)(4(3-4c)^3+3c(36-117c+98c^2)n)}{2(n+1)^2(3-4c)^3} < 0.$$

Therefore, $J_e^A(t, 2)$ is concave with respect to t. We now substitute $t = c/3$ (the lower bound of t) and $t = c$ (the upper bound of t) into $J_e(t, 2)$, then we have:

$$\begin{aligned} J_e^A\left(\frac{c}{3}, 2\right) &= \frac{2c^2}{9(n+1)} > 0, \\ J_e^A(c, 2) &= \frac{n(n+4)(1-2c) - 4(n+2)^2c^2 - n(n+4)(1-2c)\sqrt{1-8c^2}}{8(n+1)^2} < 0. \end{aligned}$$

There exists $\tilde{t}''$ such that $J_e^A(t, 2) = 0$ and that for any $t \in [c/3, \tilde{t}'')$, the disclosure increases the profit of the incumbent firm because $J_e^A(t, 2)$ is concave. We can summarize this as the following proposition.

Proposition 8 *Suppose that $c \in (t, 3t)$ and that n is even. There exists $\tilde{t}''$ such that $J_e^A(t, 2) = 0$. For any $t \in (c/3, \tilde{t}'')$, the disclosure increases the profit of the incumbent firm.*

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that given $k = n/2 - h$ entrant firms locate at A, $J_e(t, h)$ is minimized when $t = c/(2(h-1))$.[25] $J_e^A(c/(2h-1), h) = 2c^2/((2h-1)^2(n+1)) > 0$. Therefore, we have the following result: *Suppose that $c \in ((2h-3)t, (2h-1)t)$ and n is even. There exists $\tilde{t}_g''$ such that $J_e^A(t, h) = 0$. For any $t \in (c/(2h-1), \tilde{t}_g'')$, the disclosure increases the profit of the incumbent firm.*

6.2.2 Entrant firms locating in market B

We now discuss the profits of the firms locating in market B.

[25] The procedure to prove it is similar to that in the odd case.

n is odd When n is odd, in any case, the number of firms in each market is different. Given that $k = (n-1)/2 - h$ $(h = 1, 2, 3, \ldots)$ entrant firms locate in market A in the nondisclosure case $(c \in [2(h-1), 2ht))$, to induce an entrant firm who would locate in market A in the nondisclosure case to locate in market B, the incumbent sets τ at τ_o:

$$\tau_o = \frac{-(1-2c) + \sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2}}{2h-1}.$$

We can easily show that this is smaller than t if and only if $c < 2ht$. The profit in which the incumbent discloses its knowledge and sets τ_o and that in which it does not are:

$$\begin{aligned}
\pi_B\left(\frac{n-1}{2} - (h+1), \tau_o\right) &= \Big[(1-2h+n)\sqrt{(1-2c)^2 + 2(2h-1)(1-c)t - (4h^2-1)t^2} \\
&\quad -(n+2h-1)(1-2c)\Big]^2 \Big/ 4(2h-1)^2(n+1)^2 \\
&\quad + \frac{(2-2c+(n-2h-1)t)^2}{4(n+1)^2}, \qquad (34)\\
\pi_B\left(\frac{n-1}{2} - h, t\right) &= \frac{(2-4c-(n-2h-3)t)^2}{4(n+1)^2} + \frac{(2-2c+(n-2h+1)t)^2}{4(n+1)^2}. \qquad (35)
\end{aligned}$$

If the difference between $\pi_B((n-1)/2-(h+1), \tau_o)$ in (34) and $\pi_B((n-1)/2-h, t)$ in (35) is negative, know-how disclosure diminishes the profits of the entrant firms who locate in market B. We now define $J_o^B(t, h)$ as follows:

$$J_o^B(t,h) \equiv \pi_B\left(\frac{n-1}{2} - (h+1)\right) - \pi_B\left(\frac{n-1}{2} - h\right).$$

We now check the cases (i) $h = 1$ $(c \in (0, 2t)$ or $t > c/2)$, (ii) $h = 2$ $(c \in [2t, 4t)$ or $t \in (c/4, c/2])$, and (iii) h is larger than 2 $(c \in [2(h-1)t, 2ht)$ or $t \in (c/(2h), c/(2(h-1))])$.

First, we consider the case in which $h = 1$ $(c \in (0, 2t)$ or $t > c/2)$. Differentiating $J_o^B(t, 1)$ with respect to t twice, we have (note that c and t is smaller than $1/2$ and $t > c/2$):

$$\frac{\partial^2 J_o^B(t,1)}{\partial t^2} = -\frac{(n-1)(4((1-2c)^2 + 2(1-c)t - 3t^2)^{3/2} - (1-2c)(4-14c+13c^2))}{2(n+1)((1-2c)^2 + 2(1-c)t - 3t^2)^{3/2}} < 0.$$

We now substitute $t = c/2$ (the lower bound of t) into $J_o^B(t)$ and $\frac{\partial J_o^B(t)}{\partial t}$, then we have:

$$\begin{aligned}
\frac{\partial J_o^B(t,1)}{\partial t}\Big|_{\frac{c}{2}} &= -\frac{c(4+(n-7)c)}{2(2-3c)(n+1)} < 0,\\
J_o^B\left(\frac{c}{2}, 1\right) &= -\frac{c^2}{2(n+1)} < 0.
\end{aligned}$$

Because $\partial^2 J_o^B/\partial t^2 < 0$, $\partial J_o^B/\partial t$ is negative and then $J_o^B(t, 1)$ is negative for any $t(> c/2)$.

Proposition 9 *Suppose that $c \in (0, 2t)$ and that n is odd. The disclosure decreases the profit of the entrant firms locating at B.*

Second, we consider the case in which $h = 2$ ($c \in [2t, 4t)$ or $c/4 < t \leq c/2$). We now relabel $J_o^B(t, 2)$ as $J_o^B(c, 2)$. That is, we now treat J_o^B as a function with respect to c. Differentiating $J_o^B(c, 2)$ with respect to c three times, we have:

$$\begin{aligned}
\frac{\partial^3 J_o^B(c,2)}{\partial c^3} &= -\frac{3(n^2-9)(3-2c-10t)(4-23t)t^2}{2(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{5/2}} < 0, \\
\frac{\partial^2 J_o^B(c,2)}{\partial c^2} &= \frac{-(n^2-9)(8+72t-117t^2-180t^3)}{18(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{3/2}} \\
&\quad + \frac{(n^2-9)[6(8+36t-51t^2)c-48(2+3t)c^2+64c^3]}{18(n+1)^2((1-2c)^2+3(1-c)t-15t^2)^{3/2}} - \frac{4(n^2-9)}{9(n+1)^2}.
\end{aligned}$$

We now show that the sign of $(\partial^2 J_o^B(c,2))/(\partial c^2)$ is positive for any c. Substituting $c = 4t$ (the upper bound of c) into $(\partial^2 J_o^B(c,2))/(\partial c^2)$, we have:

$$\left.\frac{\partial^2 J_o^B(c,2)}{\partial c^2}\right|_{c=4t} = \frac{9(n^2-9)t^2(5-28t)}{18(n+1)^2(1-5t)^3} > 0, \text{ for any } t < 2/(9+n).$$

Note that $t < 2/(9+n)$ is a necessary condition that the quantity supplied by the firms are positive. $(\partial^2 J_o^B(c,2))/(\partial c^2)$ is positive, that is, $J_o^B(c,2)$ is convex with respect to c. We now substitute $c = 4t$ (the upper bound of c) and $c = 2t$ (the lower bound of c) into $J_o^B(c,2)$, then we have:

$$\begin{aligned}
J_o^B(4t,2) &= -\frac{2t^2}{n+1} < 0, \\
J_o^B(2t,2) &= \frac{(n^2-9)(1-5t)-2(n^2+27)t^2-(n^2-9)(1-4t)\sqrt{1-2t-11t^2}}{18(n+1)^2} < 0.
\end{aligned}$$

For any $t \in [c/4, c/2)$, disclosure decreases the profit of the entrant firms.

Proposition 9' *Suppose that $c \in (2t, 4t)$ and that n is odd. The disclosure decreases the profit of the entrant firms locating at B.*

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that given $k = (n-1)/2 - h$ entrant firms locate at A, $J_o^B(c, h)$ is a convex function with respect to c.[26] $J_o^B(2(h-1)t, h)$ and $J_o^B(2ht, h)$ are negative. Therefore, we have the following proposition.

[26] We first differentiate $J_o^B(c,h)$ with respect to c three times. The sign of $(\partial^3 J_o^B(c,h))/(\partial c^3)$ depends not on t but on the other parameters. This means that the sign $(\partial^3 J_o^B(c,h))/(\partial c^3)$ is always positive or always negative in the range of c

Proposition 9" *Suppose that $c \in (2(h-1)t, 2ht)$ and n is odd. The disclosure decreases the profits of entrant firms locating in market B.*

n is even Given that $k = n/2 - h$ entrant firms locate in market A in the nondisclosure case ($c \in [(2h-3)t, (2h-1)t)$), to induce an entrant firm that would locate in market A in the nondisclosure case to locate in market B, the incumbent sets τ at τ_e:

$$\tau_e = \begin{cases} \dfrac{(1-c-t)t}{1-2c} & \text{if } h = 1, \\ \dfrac{-(1-2c) + \sqrt{(1-2c)^2 + 4(h-1)(1-c-ht)t}}{2(h-1)}, & \text{otherwise.} \end{cases}$$

We can easily show that this is smaller than t if and only if $c < (2h-1)t$. The profit when the incumbent discloses its knowledge and sets τ at the above-mentioned level and that when it does not is:

$$\pi_B\left(\frac{n}{2} - (h+1), \tau_e\right) = \begin{cases} \Big[(n-2h+2)\sqrt{(1-2c)^2 + 4(h-1)((1-c)-ht)t} \\ \quad -(n+2h-2)(1-2c)\Big]^2 \Big/ 16(h-1)^2(n+1)^2 \\ \quad + \dfrac{(2-2c+(n-2h))t)^2}{4(n+1)^2}, \ (h \neq 1), \\ \dfrac{(2(1-2c)^2 - (1-c)nt + nt^2)^2}{4(1-2c)^2(n+1)^2} + \dfrac{(2(1-c)+(n-2)t)^2}{4(n+1)^2}, \ (h = 1), \end{cases} \tag{36}$$

$$\pi_B\left(\frac{n}{2} - h\right) = \frac{(2-4c-(n-2(h-2))t)^2}{4(n+1)^2} + \frac{(2-2c+(n-2h+2)t)^2}{4(n+1)^2}. \tag{37}$$

If the difference between $\pi_B(n/2 - (h+1), \tau_e)$ in (36) and $\pi_B(n/2 - h, t)$ in (37) is negative, the know-how disclosure decreases the profit of the entrant firms locating at B. We now define $J_e^B(t,h)$ as follows:

$$J_e^A(t,h) \equiv \pi_B\left(\frac{n}{2} - (h+1), \tau_e\right) - \pi_B\left(\frac{n}{2} - h, t\right).$$

We now check the cases (i) $h = 1$ ($c \in (0, t)$ or $t > c$), (ii) $h = 2$ ($c \in [t, 3t)$ or $t \in (c/3, c]$), and (iii) h is larger than 2 ($c \in [(2h-3)t, (2h-1)t)$ or $t \in (c/(2h-1), c/(2h-3)]$).

$[2(h-1)t, 2ht]$. If the signs of $(\partial^2 J_o^B(c,h))/(\partial c^2)$ are positive at $c = 2(h-1)t$ and $t = 2ht$, the sign of $(\partial^2 J_o^B(c,h))/(\partial c^2)$ is always positive for any $c \in [2(h-1)t, 2ht]$. That is, $J_o^B(c,h)$ is convex with respect to c. Substituting $c = 2(h-1)t$ and $c = 2ht$ into $(\partial^2 J_o^B(c,h))/(\partial c^2)$, we have the values of $(\partial^2 J_o^B(c,h))/(\partial c^2)$ at $c = 2(h-1)t$ and $c = 2ht$. The numerators of the values contain the following quadratic form $B(t,h,c)(n-2h+2)(n+2h-2) > 0$ ($B(t,h,c)$ is a function of t and h and the value of B depends on c). Therefore, the values of $(\partial^2 J_o^B(c,h))/(\partial c^2)$ at $c = 2(h-1)t$ and $c = 2ht$ are positive, that is, $J_o^B(t,h)$ is a convex function with respect to c.

First, we consider the case in which $h = 1$ ($c \in (0, t)$ or $t > c$). $J_e^B(t, 1)$ is:

$$J_e^B(t,1) = \frac{t\hat{J}}{4(1-2c)^2(n+1)^2},$$

where $\hat{J} \equiv -4c(1-2c)^2(n+2) - n(4-2(n+8)c+(3n+16)c^2)t - 2(1-c)n^2t^2 + n^2t^3$. If $\hat{J}$ is negative, then $J_e^B(t, 1)$ is also negative. Differentiating $\hat{J}$ with respect to t twice, we have:

$$\frac{\partial^2 \hat{J}}{\partial t^2} = -2n^2(2-2c-3t) < 0. \tag{38}$$

$\hat{J}$ is a concave function with respect to t. We now substitute $t = c$ (the lower bound of t) into $\hat{J}$ and $\partial\hat{J}/\partial t$, then we have:

$$\begin{aligned} \hat{J}_{t=c} &= -\frac{2c^2}{1+n} < 0, \\ \frac{\partial \hat{J}}{\partial t}_{t=c} &= -2(1-2c)n(2-4c+cn) < 0. \end{aligned}$$

$\partial\hat{J}/\partial t$ is negative for any t and then $\hat{J}$ is negative.

Proposition 10 *Suppose that $c \in (0, t)$ and that n is even. The disclosure decreases the profits of the entrant firms locating in B.*

Second, we consider the case in which $h = 2$ ($c \in [t, 3t)$ or $c/3 < t \leq c$). We now relabel $J_e^B(t, 2)$ as $J_e^B(c, 2)$. Differentiating $J_e^B(c, 2)$ with respect to c three times, we have:

$$\frac{\partial^3 J_e^B(c,2)}{\partial c^3} = -\frac{3(n^2-4)(3-2c-8t)(2-9t)t^2}{(n+1)^2((1-2c)^2+4(1-c)t-8t^2)^{5/2}} > 0.$$

We now show that the sign of $(\partial^2 J_e^B(c, 2))/(\partial c^2)$ is positive in any case. Substituting $c = t$ into $(\partial^2 J_e^B(c, 2))/(\partial c^2)$, and then for any $t < 1/5$ we have:

$$\left.\frac{\partial^2 J_e^B(c,2)}{\partial c^2}\right|_{c=t} = -\frac{(n^2-4)(-2+29t^2-34t^3+2(1-8t^2)^{3/2})}{2(n+1)^2(1-8t^2)^{3/2}} > 0.$$

Therefore, $J_e^B(c, 2)$ is convex with respect to c. We now substitute $c = t$ (the lower bound of c) and $c = 3t$ (the upper bound of c) into $J_e^B(c, 2)$, then we have:

$$\begin{aligned} J_e^B(t,2) &= \frac{(n^2-4)(1-2t)(1-\sqrt{1-8t^2})-4n^2t^2}{8(n+1)^2} < 0, \\ J_e^B(3t,2) &= -\frac{2t^2}{n+1} < 0. \end{aligned}$$

Proposition 10' *Suppose that $c \in [t, 3t)$ and that n is even. The disclosure decreases the profits of entrant firms locating at B.*

Finally, we briefly discuss the case in which h is larger than two. After some calculus, we find that given $k = n/2 - h$ entrant firms locate at A, $J_e^B(c, h)$ is a convex function with respect to c.[27] $J_e^B((2h-3)t, h)$ and $J_e^B((2h-1)t, h)$ are negative. Therefore, we have the following proposition.

Proposition 10" *Suppose that $c \in [(2h-3)t, (2h-1)t)$ and n is even. The disclosure decreases the profits of entrant firms locating in market B.*

6.3 Interdependent demand

In this subsection, we calculate a case in which the products in markets A and B are interdependent. To consider this case, we set the inverse demand functions in the markets as follows:

$$p_A = 1 - Q_A - \gamma Q_B, \quad p_B = 1 - Q_B - \gamma Q_A,$$

where Q_i $(i = A, B)$ is the total quantity supplied by the firms in market i $(i = A, B)$, and γ is the degree of product differentiation between the products. In the basic setting, we have assumed that $\gamma = 0$, that is, the products are independent.

We now suppose that there exist an incumbent firm and four entrant firms, that is, 5 firms exist. In this case, the incumbent firm and one entrant firm locate in market A, and the rest of the entrant firms are located in market B.

Before the incumbent firm discloses its know-how, one entrant firm locates in A and three entrant firms locate in B. We can easily show that the location pattern appears as an equilibrium outcome if $c < 2t$. The profit of the incumbent firm (denoted as $\pi_I(1, t)$), the profit of the entrant firm locating at A (denoted as $\pi_A(1, t)$), and the profit of the firm locating at B (denoted as $\pi_B(1, t)$) are:

$$\begin{aligned}\pi_I(1,t) &= \frac{(1+4c+3t)(1+4c+3t-(1-c-4t)\gamma)}{36(1-\gamma^2)} \\ &\quad + \frac{(1-c-4t)(1-c-4t-(1+4c+3t)\gamma)}{36(1-\gamma^2)}, \\ \pi_A(1,t) &= \frac{(1-2c+3t)(1-2c+3t-(1-c-4t)\gamma)}{36(1-\gamma^2)}\end{aligned}$$

[27] The procedure to prove this is similar to that in the odd case.

$$
\begin{aligned}
& +\frac{(1-c-4t)(1-c-4t-(1-2c+3t)\gamma)}{36(1-\gamma^2)}, \\
\pi_B(1,t) \quad = \quad & \frac{(1-2c-3t)(1-2c-3t-(1-c+2t)\gamma)}{36(1-\gamma^2)} \\
& +\frac{(1-c+2t)(1-c+2t-(1-2c-3t)\gamma)}{36(1-\gamma^2)}.
\end{aligned}
$$

We now suppose that the entrant firm locating in A moves to market B because of the disclosure. In this case, the incumbent firm locates in market A, and all the entrant firms locate in market B. The profit of the incumbent firm and the profit of the entrant firms are:

$$
\begin{aligned}
\pi_I(0,\tau) \quad = \quad & \frac{(1+4c+4\tau)(1+4c+4\tau-(1-c-5t)\gamma)}{36(1-\gamma^2)} \\
& +\frac{(1-c-5t)(1-c-5t-(1+4c+4\tau)\gamma)}{36(1-\gamma^2)}, \\
\pi_B(0,\tau) \quad = \quad & \frac{(1-2c-2\tau)(1-2c-2\tau-(1-c+t)\gamma)}{36(1-\gamma^2)} \\
& +\frac{(1-c+t)(1-c+t-(1-2c-2\tau)\gamma)}{36(1-\gamma^2)}.
\end{aligned}
$$

We now show the condition that the entrant firm locating in market A under the nondisclosure case moves to market B following the disclosure. The condition is:

$$
\begin{aligned}
& \pi_B(0,\tau) - \pi_A(1,t) \geq 0 \;\Leftrightarrow\; \tau \leq J_\gamma - (1-2c-(1-c-2t)\gamma), \\
& \quad \text{where } J_\gamma \equiv \sqrt{(1-2c-(1-c-2t)\gamma)^2 + t(2-2c-3t-2(1-2c)\gamma)}.
\end{aligned}
$$

We now define the upper bound of τ as τ_γ:

$$
\tau_\gamma \equiv J_\gamma - (1-2c-(1-c-2t)\gamma).
$$

The difference between $\pi_I(0,\tau_\gamma)$ and $\pi_I(1,t)$ is:

$$
\begin{aligned}
& \frac{4(1-2c)(1-4c)-(4-9c)t+8t^2-(8(1-c)(1-3c)-(8-29c)t+4t^2)\gamma}{6(1-\gamma^2)} \\
& +\frac{4(1-c-t)(1-c-2t)\gamma^2-2(1-4c-(1-c-t)\gamma)J_\gamma}{6(1-\gamma^2)}.
\end{aligned}
$$

We now consider the relation between the degree of product differentiation and the profitability of know-how disclosure. Differentiating τ_γ with respect to γ, we have:

$$
\frac{\partial \tau_\gamma}{\partial \gamma} = \frac{(1-c-2t)J_\gamma - \{(1-2c)(1-c-t)-(1-c-2t)^2\gamma\}}{J_\gamma}.
$$

After some calculus, we find that this is negative.[28] As the degree of differentiation decreases, the incumbent firm sets the level of τ lower.

[28] Because $c < 2t$ and t is smaller than $1/4$ (the former condition is that one of the entrant firms locates in market A under the nondisclosure case, and the latter condition is a necessary condition that the quantities supplied by the firms are positive), $(1-2c)(1-c-t)-(1-c-2t)^2\gamma$ is positive for any $\gamma \in (-1,1)$. Because $\{(1-2c)(1-c-t)-(1-c-2t)^2\gamma\}^2 - ((1-c-2t)J_\gamma)^2 = (2t-c)t(2-3c-2t)(2-2c-3t) > 0$, $\frac{\partial \tau_\gamma}{\partial \gamma}$ is negative.

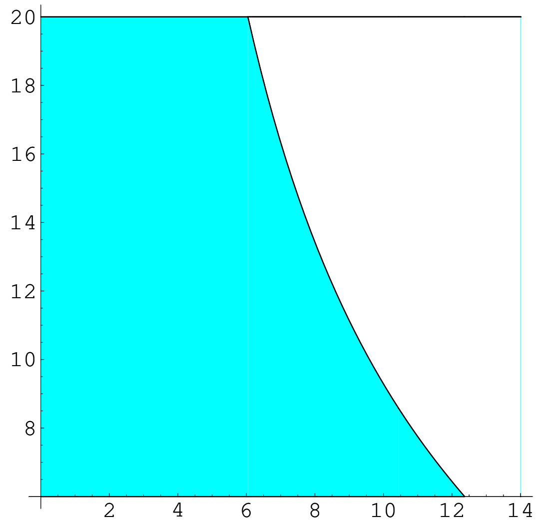

Figure S1: Know-how disclosure is profitable for the incumbent firm (n is odd)

(Horizontal: $100c$, Vertical: n, the shaded area: the profitable area for the incumbent)

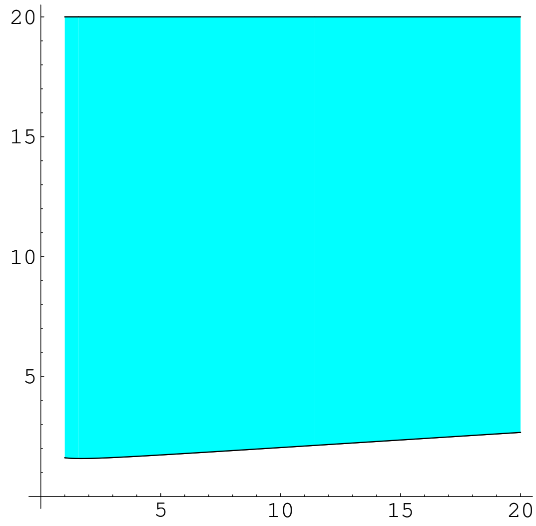

Figure S2: Know-how disclosure is profitable for the incumbent firm (n is odd, $c = 0.1$)

(Horizontal: n, Vertical: h, the shaded area: the profitable area for the incumbent)

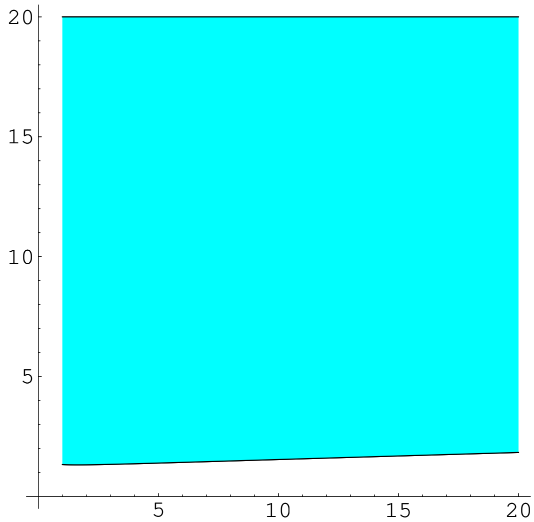

Figure S3: Know-how disclosure is profitable for the incumbent firm (n is odd, $c = 0.05$)

(Horizontal: n, Vertical: h, the shaded area: the profitable area for the incumbent)

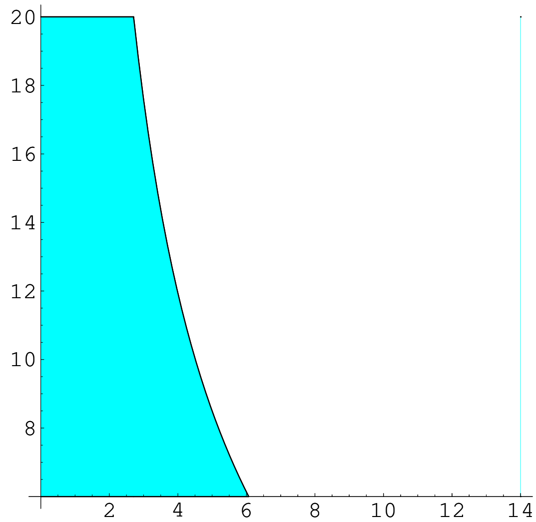

Figure S4: Know-how disclosure is profitable for the incumbent firm (n is even)

(Horizontal: $100c$, Vertical: n, the shaded area: the profitable area for the incumbent)

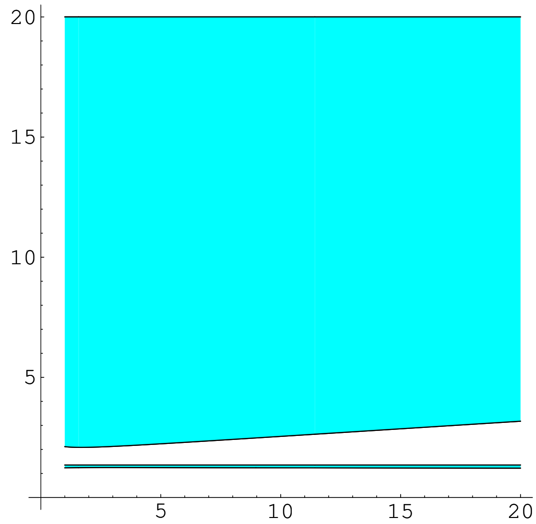

Figure S5: Know-how disclosure is profitable for the incumbent firm (n is even, $c = 0.1$)

(Horizontal: n, Vertical: h, the shaded area: the profitable area for the incumbent)

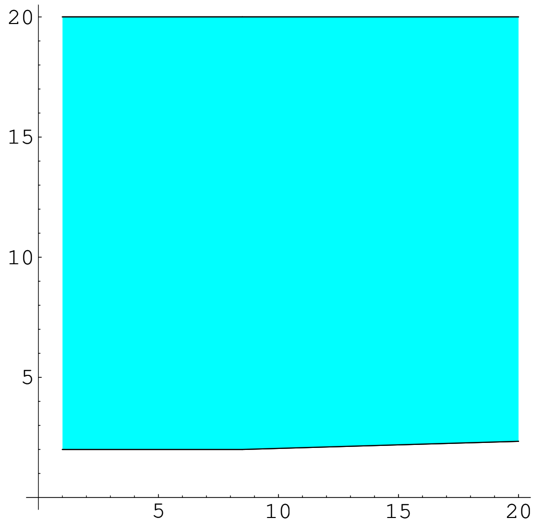

Figure S6: Know-how disclosure is profitable for the incumbent firm (n is even, $c = 0.05$)

(Horizontal: n, Vertical: h, the shaded area: the profitable area for the incumbent)