International Mergers: Incentive and Welfare

by

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Abstract

Information asymmetry creates value and incentives for firms from different countries to merge. To demonstrate this point, we develop a model of international trade under oligopolistic competition and asymmetric information, in which domestic firms are informed of the local market demands, but foreign firms are not. By emphasizing two features of a merger between a domestic firm and a foreign firm, we show that the two firms always want to *share information*, but *output coordination* is not always profitable. We also examine how such a merger affects the non-merging firms' profits, consumer surplus, domestic and global welfare. The results are crucially determined by the extent of product differentiation.

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1. Introduction

International mergers have recently become prolific.[1] DaimlerChrysler is the most notable example in the auto industry.[2] An important question to ask is what are the benefits of international mergers over domestic mergers. A related question is why and when firms located in different countries have incentives to merge. We will explore these and other related issues in this paper, with a focus on output coordination and information sharing between merging firms.

A firm often has better information about the local market than the foreign market. For example, compared to a foreign firm, a domestic firm is more familiar with the local consumer tastes, rules and culture on the labor market, effective ways of advertising, distribution network, government regulations, and market interaction with suppliers, consumers and competing firms. Information asymmetry creates value and incentives for firms from different countries to merge. To demonstrate this point, we develop a model of international trade under oligopolistic competition (Cournot) and asymmetric information. There are n domestic firms and one foreign firm which produce differentiated products and compete in the domestic market.[3] The domestic firms are informed of the market demand, but the foreign firm is not. We emphasize two features of a merger between a domestic firm and the foreign firm: they coordinate production and they share demand information. In the absence of asymmetric information, a merger allows the two merging firms to choose output jointly to maximize their joint profit. This creates two conflicting effects to the merging firms. On the one hand, output coordination eliminates the negative competition externality between the merging firms, which is good for them. On the other hand, the non-merging domestic firms respond to the merger by raising their outputs, which is bad for the merging firms. We show that such an output-coordination merger is profitable for the merging firms if and only if the products are sufficiently differentiated.

In the presence of asymmetric information, a merger enables the two merging firms to share the information about market demand, in addition to coordinating their outputs. We show that

[1] According to UNCTAD (2000), the value of cross-border M&A (mergers and acquisitions) rose from less than $100 billion in 1987 to $720 billion in 1999.

[2] Other examples include the one between Ford and Mazda, the one between Renault and Nissan, and the one between GM and Saab.

[3] We focus on horizontal mergers, i.e., mergers between firms in the same industry. According to UNCTAD (2000), about 70 per cent in terms of value, or 50 per cent in terms of number, of cross-border M&As are horizontal.

information sharing gives the merging firms additional incentives to merge. That is, information sharing always facilitates mergers. Specifically, although mergers under asymmetric information may be still not profitable for the merging firms when the products are very similar, they are profitable under a *broader* range of product differentiation than mergers under symmetric information.

We also examine how mergers affect non-merging firms' profits and consumer surplus, and how they affect the domestic and global welfare. The results crucially depend on the extent of product differentiation. Policy implications can be drawn from this part of analysis. For example, we find that when demand uncertainty is large and market competition is intense, international mergers should be encouraged because they are socially desirable but not taken up by firms. Under the opposite condition, international mergers should be discouraged because firms have incentive to form such a merger, but which is not socially beneficial.

The present paper is closely related to two bodies of literature: the international trade literature on mergers and the industrial organization literature on mergers and information.

In the international trade literature, most studies are concerned about trade and competition policies in the presence of mergers. In particular, researchers in this area are interested in questions such as how trade policies and/or competition policies should respond to mergers, and what are the effects of mergers under various policy regimes. For example, Collie (2003) analyze optimal trade policies in the presence of a domestic merger, or a foreign merger. Richardson (1999) and Levinsohn (1997) study how trade liberalization affect optimal competition policies regarding domestic mergers. Ross (1988) examines how trade liberalization affects the price effects of domestic mergers and that of foreign mergers. Horn and Levinsohn(2001) explore the interactions between trade policy and merger policy. Unlike these studies, we focus on the incentives for an international merger and its welfare effects. Policy analysis can be conducted within such a framework as an extension of the present model.

Some researchers are also interested in incentives for mergers in the international setting. Long and Vousden (1995) investigate the effects of trade liberalization on both domestic and cross-border mergers. They show that the result depends on whether it is unilateral or bilateral liberalization and how large the cost saving can be generated from a merger. Horn and Persson (2001) examine the equilibrium structure of international oligopoly as a result of national or international mergers. Different from most studies in the IO literature on merger incentives, they treat mergers as a result of coalition formation. With such an approach, they find that international mergers may arise due to lower trade costs, contrary to the “tariff jumping” argument. While the above-mentioned two papers study trade policy and trade cost as an incentive or disincentive for international merger, we examine information asymmetry as an incentive for international mergers. Moreover, unlike Horn and Persson, we follow the traditional IO approach to model merger incentives. However, we believe using coalition formation approach to study mergers under asymmetric information would be an very interesting extension of the present paper.

Welfare is always an important issue to be studied in international trade. Head and Ries (1997) are mostly concerned about the welfare implication of mergers. By focusing on mergers that raise price and reduce world welfare, they show that whether the national government can be relied on to block a world welfare-reducing merger depends on whether the merger generates cost savings. While Head and Ries focus on the conflict between national competition agency and perceived world competition agency, Horn and Persson (2001) are interested in the conflict between the private and social incentives for merger. They find that private and social incentives for mergers may differ for weak merger synergy, but converge if synergy is strong. In the present paper, we also examine the welfare aspects of an international merger arising from asymmetric information. In particular, we derive conditions under which, industrial profit, consumer surplus, domestic welfare and global welfare will increase after the merger.

While there is already a large body of literature in industrial organization on mergers, studies concerning international mergers and/or asymmetric information are relatively few.[4] Closely related to the present paper are Gal-Or (1988), Das and Sengupta (2001), and Banal-Estanol (2002). Our paper has many distinguishing features, emphases and results, some of which are discussed below. Gal-Or (1988) shows that mergers *may* create informational disadvantages to the merging firms under Cournot competition, but always generate information advantages to the merging firms under Bertrand competition.[5] Our model differs from Gal-Or (1988) in two

[4] Church and Ware (2001, chapter 23) and Pepall et al (1998, chapter 8) are two sources of a summary of merger literature.

[5] Gal-Or (1988) builds her model on the deterministic model of Salant et al. (1983) and Deneckere and Davidson (1985). Salant et al. (1983) find that under Cournot competition, mergers are generally not profitable. In contrast, Deneckere and Davidson (1985) demonstrate that firms competing in prices

important aspects. First, while she considers the case where every firm has a partial private information about demand, we consider the case where all the domestic firms are fully informed and the foreign firm is not completely informed. Her case better describes information structure among domestic firms, but our case is closer to the information asymmetry between domestic and foreign firms. Because of this difference, we obtain a different result: the merging firms as a whole *always* benefit from information sharing even under Cournot competition. Second, although firms produce differentiated products, Gal-Or (1988) assumes that after the merger, only one product is produced. In contrast, we consider the case where after the merger, the merging firms continue to produce two differentiated products but coordinate their output levels.

Banal-Estanol (2002) investigates incentives to merge when firms have private information about costs and engage in quantity competition. Following Perry and Porter (1985), he assumes that in addition to sharing the cost information, a merger allows the merging firms to pool their capital and therefore use their plants in a more efficient way to produce the product. He finds that such a merger generates informational advantages only to the merging firms. We obtain the same result but for a different type of mergers, in which the merging firms share demand information and there is no reduction in costs.

Das and Sengupta (2001) consider both the case of private information about demand and the case of private information about costs. They show that due to asymmetric information, demand uncertainty increases the likelihood of a merger, while cost uncertainty decreases the likelihood of a merger. Nonetheless, they argue that asymmetric information is always a *barrier* to mergers. In sharp contrast, we show that asymmetric information is always *conducive* to mergers. The reason for the different conclusions lies in the assumptions on how information is used in the two models. In their model, two firms bargain on a merger deal and each uses its private information to affect the bargaining outcome, but in our model, two firms share information when they merge. In their model, firms receive respective market information before they decide on a merger, but in our model, the reversed sequence is assumed. The two papers are also different in their focuses: while their paper looks at how the likelihood of a merger depends on cost asymmetries and bargaining inefficiencies, we are interested in how the merger incentives depend on product differentiation.

always have incentives to merge.

Unlike Das and Sengupta (2001), the present paper, along with Gal-Or (1988) and Banal-Estanol (2002), emphasize the information sharing feature of mergers, to which most previous literature has paid scant attention. Studies in the literature normally assume either that the merging firms coordinate their outputs (e.g., Salant et al., 1983), or that the merged entity enjoys cost synergy (e.g., Farrell and Shapiro, 1990). We believe that information sharing is an important element in many international mergers. Accordingly, we build our model on the literature on information sharing in oligopoly. Important contributions to this literature are made by Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984), Gal-Or (1985, 1986), Li (1985), Shapiro (1986) and Raith (1996). These papers concentrate on a firm's incentives to share its private information with competing firms, but they do not consider mergers. In particular, they show that firms competing in quantities are not willing to reveal their private information about market demand, but are willing to reveal their private information about production costs. Hence, it is interesting to know whether and how mergers affect firms' willingness to reveal information. We show that a merger makes a firm willing to share with its merging partner its private information about demand even under Cournot competition.[6]

The rest of the paper is organized as follows. In section 2, we present the basic model of international trade under oligopolistic competition and asymmetric information. In section 3, we focus on output-coordination mergers by assuming symmetric information. In section 4, we bring asymmetric information back to the model in order to examine the implications of asymmetric information on mergers. In section 5, we explore a merger's effects on the welfare of consumers, non-merging firms, domestic country and the world. Section 6 concludes the paper.

2. The Model

We consider an industry which consists of n domestic firms and one foreign firm.[7] The foreign firm competes against all the domestic firms in the domestic market by exporting its product to the market. The foreign firm is indexed by 0 and the domestic firms are indexed by $i \in N = \{1, 2, ..., n\}$. Hence, N is the set of all domestic firms, and $M \equiv \{0\} \cup N$ is the set of all

[6] Clearly it is less interesting to show that mergers make a firm willing to reveal its private information about costs under Cournot competition.

[7] Since this study focuses on the incentive to merge between an uninformed foreign firm and an informed domestic firm in an oligopolistic market, it should be clear later that our analysis and results should not be altered qualitatively if we allow more than one foreign firm to exist in the model.

firms. Assume that firms produce differentiated products and the market demand is given as

$$p_i = a + \theta - q_i - bQ_{-i}, \qquad i \in M,$$

where p_i is the price of product i, q_i is the output of product i, a is a constant which is assumed to be sufficiently large so that all firms produce positive amounts in equilibrium, $b \in (0,1)$ is a constant capturing the extent of product differentiation, and $Q_{-i} = \sum_{j \in M,\, j \neq i} q_j$ is the total output of all firms other than i. Moreover, θ is a random variable with zero mean and variance $\sigma^2 \equiv Var(\theta) = E(\theta^2)$.[8] Hence, σ^2 captures demand fluctuation. While all the domestic firms have complete information about the market demand, the foreign firm has only incomplete information to begin with.[9]

We consider a two-stage game as follows. In the first stage, one domestic firm, say firm 1 (without loss of generality), and the foreign firm together decide whether to merge. In the second stage, all firms compete in the market by choosing quantity, *à la* Cournot. During the transition from stage 1 to stage 2, all domestic firms receive the market demand information, i.e., they know the exact value of θ. We derive and analyze the subgame perfect Nash equilibrium (SPNE).

Because in this paper we focus on the implications of asymmetric demand information on international mergers, without loss of generality, we assume that all firms have zero marginal cost of production.[10] Without cost differential, we define a merger between the foreign firm and domestic firm 1 as that they share information and coordinate their output to maximize joint profit.

3. Mergers under Symmetric Information

In this section, we assume that all firms (including the foreign firm) have complete information about the market demand so as to focus on mergers for output coordination, called

[8]Implicitly we also assume that θ has finite support, say $[\theta_L, \theta_U]$, and a is large enough such that even at $\theta = \theta_L$, all firms have positive output. In this particular model, it turns out that we need to assume $\theta_L > -(2 + bn - b)a/(2 + bn)$.

[9]A firm often faces some barriers entering another country's market. We emphasize informational barriers in this model. The foreign firm has less information about the domestic demand than the domestic firms because it lacks knowledge of the domestic consumers' tastes, culture differences and other environments that affect demand for the product.

[10]It is worth pointing out that our focus on product differentiation with constant marginal costs is equivalent in analysis to an alternative case in which firms produce a homogeneous good but have increasing marginal costs.

output-coordination merger. When the foreign firm, denoted as F0, and domestic firm 1, denoted as F1, merge in the first stage, they make output decisions to maximize their joint profit.

As a benchmark, we derive the non-cooperative Cournot Nash equilibrium in the absence of the first-stage merger. The first-order conditions of F0 and the domestic firms are, respectively,

$$\begin{aligned} a + \theta - 2q_0 - bQ_{-0} &= 0, \\ a + \theta - 2q_i - bQ_{-i} &= 0, \qquad i \in N. \end{aligned}$$

It turns out all firms have the same equilibrium output and profit:

$$q^* = \frac{a+\theta}{2+bn} \qquad \text{and} \qquad \pi^* = \frac{(a+\theta)^2}{(2+bn)^2}. \tag{1}$$

Suppose now that F0 and F1 merge in the first stage. Then in the second stage the merged entity maintains the two separate product lines but chooses q_0 and q_1 to maximize the joint profit, $(p_0 q_0 + p_1 q_1)$. They choose q_0 and q_1 taking the non-merging firms' quantities $\{q_2, ..., q_n\}$ as given. That gives two first-order conditions:

$$\begin{aligned} a + \theta - 2q_0 - 2bq_1 - b\sum_2^n q_i &= 0, \\ a + \theta - 2q_1 - 2bq_0 - b\sum_2^n q_i &= 0. \end{aligned}$$

For non-merging firm i ($i = 2, \cdots n$), as in the usual Cournot game, their output follows the following first-order conditions:

$$a + \theta - 2q_i - bQ_{-i} = 0, \quad i \in \{2, ..., n\}.$$

By solving all the first-order conditions, we obtain the market equilibrium (superscript c denotes "complete information"):

$$q_0^c = q_1^c = \frac{(2-b)(a+\theta)}{2(2+bn-b^2)}, \qquad \pi_0^c = \pi_1^c = (1+b)(q_0^c)^2, \tag{2}$$

$$q_i^c = \frac{a+\theta}{2+bn-b^2}, \qquad \pi_i^c = (q_i^c)^2\,, \qquad i \in \{2, \cdots, n\}. \tag{3}$$

Direct comparison based on (1) and (3) yields the difference in total profits of the merged entity before and after the merger:

$$\Delta\pi^c \equiv (\pi_0^c + \pi_1^c) - (\pi^* + \pi^*) = \frac{b^2(a+\theta)^2 Y(n,b)}{2(2+bn)^2(2+bn-b^2)^2},$$

where $Y(n,b) \equiv n^2b^3 - (3n^2-4n+4)b^2 - 4(n-1)b + 4$. This allows us to establish the following result.

Proposition 1: *Suppose there is symmetric information among all firms.*

(i) *For any given n, there exists a unique $b_0(n) \in (0,1)$ such that for $b < b_0$, the SPNE is that a merger occurs in the first stage with the second-stage market outcomes $\{q_0^c, q_1^c, ..., q_n^c\}$, and for $b \geq b_0$, the SPNE is that a merger does not occur in the first stage and all firms produce q^* in the second stage. Moreover,* $\mathrm{d}b_0(n)/\mathrm{d}n < 0$.

(ii) *In comparison, $q_0^c = q_1^c < q^*$, $q_i^c > q^*$, and $\pi_i^c > \pi^*$ for $i \in \{2, \cdots n\}$.*

Proof: See the Appendix.

The above proposition says that a merger is more likely to be profitable for the two merging firms if products are more differentiated and the number of firms in the market is fewer. Moreover, after a merger, the two merging firms produce less than before, while the non-merging firms produce more and have higher profits than before.

F0 and F1 will merge if the merger can increase their joint profit. Without a merger, all firms behave just like in a usual Cournot Nash game in which they compete aggressively. Intensive competition creates negative externalities among each other. When F0 and F1 engage in an output-coordination merger, they have incentives to reduce or eliminate the negative externalities between themselves by producing less (see $q_0^c = q_1^c < q^*$). Due to strategic substitution, other non-merging firms will raise their output (see $q_i^c > q^*$), and they benefit from the reduced competition ($\pi_i^c > \pi^*$ for $i \in \{2, \cdots, n\}$). Although F0 and F1 benefit from internalizing the negative externalities between themselves, they also suffer a loss because the non-merging firms increase their output. Hence, output-coordination mergers do not guarantee a larger profit for the merged entity. Proposition 1 shows that when the products are sufficiently different (b is sufficiently low), output-coordination mergers bring the merged entity more benefit than harm, and when the products are not sufficiently different (b is large), output-coordination mergers bring the merged entity more harm than benefit.

The traditional result that mergers are not profitable under Cournot competition (see Salant et al., 1983) is a special case of Proposition 1 above for $b = 1$. Proposition 1 shows that mergers are profitable when products are sufficiently differentiated.

4. Mergers under Asymmetric Information

We now return to the asymmetric information case. In order to better understand the role of information sharing in international mergers, we assume in subsection 4.1 that when a merger occurs in the first stage, F1 shares its information with F0 but in the second stage they compete in the market as if they are still independent firms. We call this type of merger as *information-sharing merger*. In subsection 4.2, we will investigate individual firm's incentives for information revelation and acquisition without mergers. Finally (in subsection 4.3), we analyze *full degree mergers* in which F0 and F1 share information and coordinate output.

4.1. Merger for information sharing

As a benchmark, let us first derive the market equilibrium when $\theta = 0$ and all firms (including F0) know it. This is the usual Cournot game with complete information. By setting $\theta = 0$ in (1), we get the symmetric equilibrium output for each firm (superscript o indicates this benchmark case):

$$q^o = \frac{a}{2 + bn}. \tag{4}$$

■ **Second-stage analysis**. We now return to the original model with asymmetric information. Suppose there is no merger in the first stage. Then, we have the usual Cournot game with F0 having incomplete information in the second stage. Let us focus on the case in which without mergers none of the domestic firms can reveal their private information.[11] We will investigate in subsection 4.2 the informed firms' individual incentives to reveal private information and the uninformed firm's incentives to acquire information.

Given q_i for $i \in N$, F0 chooses q_0 to maximize its expected profit $\pi_0^e = (a - q_0 - bQ_{-0})q_0$. The first-order condition is

$$a - 2q_0 - bQ_{-0} = 0.$$

Given q_j for $j \in M_{-i}$, where $M_{-i} = M\backslash\{i\}$, firm i chooses q_i to maximize its profit $\pi_i = (a + \theta - q_i - bQ_{-i})q_i$. The first-order condition is

$$a + \theta - 2q_i - bQ_{-i} = 0, \qquad \forall \;\; i \in N \; .$$

[11] We will show that without a merger, the informed domestic firms have no incentive to reveal their information. But even if they are willing to give out information free of charge, there are problems such as verifiability that constrains information revelation. Mergers certainly overcomes those problems.

When solving all the first-order conditions above, F0 takes the expectation of the domestic firms' output and the domestic firms know this. The solution is (superscript u indicates that F0 is "uninformed"):

$$q_0^u = q^o \quad \text{and} \quad q^u = q^o + \frac{\theta}{2+bn-b}. \tag{5}$$

Without having more information about the realized demand, F0 chooses its output level as in the benchmark case. In contrast, the informed domestic firms adjust their output levels according to the realized demand. Their realized profits are, respectively,

$$\pi_0^u = \ (q_0^u)^2 + \frac{(2-b)a\theta}{(2+bn)(2+bn-b)} \quad \text{and} \quad \pi^u = (q^u)^2\,. \tag{6}$$

We next suppose F0 and F1 engage in an information-sharing merger in the first stage, in which F1 reveals the information to F0. Then, the second stage game becomes the usual Cournot game with complete information, i.e., all firms (including F0) know the realization θ. This has been derived in (1) and can be rewritten as (superscript s indicates "information-sharing"):

$$q_0^s = q^o + \frac{\theta}{(2+bn)} \quad \text{and} \quad q^s = q^o + \frac{\theta}{(2+bn)}, \tag{7}$$

and

$$\pi_0^s = (q_0^s)^2 \quad \text{and} \quad \pi^s = (q^s)^2\,. \tag{8}$$

■ **Information sharing and the first-stage analysis**. In the first stage, F0 and F1 decide whether to merge in order to share information. The necessary and sufficient condition for a merger is that the merged entity's expected profit must be greater than the sum of these two firms' expected profits without the merger. Using (6) and (8), the comparison is reduced to

$$(\pi_0^s + \pi^s) - (\pi_0^u + \pi^u) = \frac{\theta^2 Z(n,b)}{(2+bn)^2(2+bn-b)^2} + \frac{ab(nb-2)\theta}{(2+bn)^2(2+bn-b)}$$

where $Z(n,b) \equiv (2+bn-2b)^2 - 2b^2$. Note $\partial Z(n,b)/\partial n > 0$ and $Z(2,b) = 4-2b^2 > 0$ except at $b=1$. In the present model, we have $n \geq 2$ and so $Z(n,b) > 0$. As a result,

$$E\left[(\pi_0^s + \pi^s) - (\pi_0^u + \pi^u)\right] = \frac{\sigma^2 Z(n,b)}{(2+bn)^2(2+bn-b)^2} > 0. \tag{9}$$

That is, the collective profit of the merged entity is always higher than the sum of the two firms without the information-sharing merger. Provided that there is a mechanism for appropriate interfirm profit transfer, F0 and F1 always choose to merge.

Proposition 2: *Suppose that the merging firms (F0 and F1) only share information but do not coordinate output.*

(i) *The SPNE is characterized as below: F0 and F1 merge in the first stage, F0 produces* q_0^s *and every domestic firm produces* q^s*. The merged entity's profit is* $(\pi_0^s + \pi^s)$*, and every other domestic firm's profit is* π^s*.*

(ii) *For a larger* σ^2*, a smaller* n *(except when* $n = 2$*), or a smaller* b*, the net profit gains from the merger are larger. More precisely,*

$$\begin{aligned} \frac{\partial E\left[(\pi_0^s + \pi^s) - (\pi_0^u + \pi^u)\right]}{\partial \sigma^2} &> 0; \\ \frac{\partial E\left[(\pi_0^s + \pi^s) - (\pi_0^u + \pi^u)\right]}{\partial n} &< 0 \quad (\text{for } n \geq 3); \\ \frac{\partial E\left[(\pi_0^s + \pi^s) - (\pi_0^u + \pi^u)\right]}{\partial b} &< 0\ . \end{aligned}$$

Proof: See the Appendix.

We will explain the intuition for Proposition 2 at the end of subsection 4.3.

4.2. Incentives for information revelation and acquisition

Even without a merger, will any informed domestic firm voluntarily reveal its private information to the uninformed F0? Does the uninformed F0 benefit from getting more information? We search for answers to these questions in this subsection. Let us compare (6) and (8). It can be calculated that

$$\begin{aligned} \pi_0^s - \pi_0^u &= \frac{\theta^2}{(2+bn)^2} + \frac{nab^2\theta}{(2+bn)^2(2+bn-b)}, \\ \pi^s - \pi^u &= -\frac{b(4+2bn-b)\theta^2}{(2+bn)^2(2+bn-b)^2} - \frac{2ab\theta}{(2+bn)^2(2+bn-b)}. \end{aligned}$$

Recalling that $E(\theta) = 0$ and $E(\theta^2) = \sigma^2 > 0$, we immediately obtain

$$E\left(\pi_0^s - \pi_0^u\right) = \frac{\sigma^2}{(2+bn)^2} > 0, \tag{10}$$

$$E\left(\pi^s - \pi^u\right) = -\frac{b(4+2bn-b)\sigma^2}{(2+bn)^2(2+bn-b)^2} < 0. \tag{11}$$

Hence, we establish the following result.

Proposition 3: **(i)** *In the model with one uninformed foreign firm and n informed domestic firms, the foreign firm always wants to acquire the information about demand, but in the absence of a merger none of the domestic firms is willing to reveal the information.*

(ii) *For a larger σ^2 or a smaller n, the uninformed foreign firm's gain from acquiring information becomes larger and the loss to each informed domestic firm from revealing information, if it does, also becomes larger. For a smaller b, the foreign firm's gain is larger, but the domestic firms' loss may be larger or smaller. More precisely,*

$$\begin{aligned}
\frac{\partial E\left(\pi_0^s - \pi_0^u\right)}{\partial \sigma^2} &> 0, \quad \frac{\partial E\left(\pi_0^s - \pi_0^u\right)}{\partial n} < 0, \quad \frac{\partial E\left(\pi_0^s - \pi_0^u\right)}{\partial b} < 0; \\
\frac{\partial E\left(\pi^s - \pi^u\right)}{\partial \sigma^2} &< 0, \quad \frac{\partial E\left(\pi^s - \pi^u\right)}{\partial n} > 0, \\
\frac{\partial E\left(\pi^s - \pi^u\right)}{\partial b} &< 0 \text{ (for small } b\text{)}, \quad > 0 \text{ (for large } b\text{)}.
\end{aligned}$$

Proof: See the Appendix.

Hence, as indicated by part (i) of the proposition, information sharing benefits the uninformed firm, but hurts all informed firms. Without the information, F0 under-produces when actual demand is high, but over-produces when actual demand is low. With the information, however, it is able to produce more accurately according to demand, which creates a positive value to F0. In contrast, without revealing information, the informed domestic firms benefit from the foreign firm's underproduction (when demand is high, i.e., $\theta > 0$), but lose from its overproduction (when demand is low, i.e., $\theta < 0$). The gain of not revealing information more than compensates the loss. Hence, in the absence of an information-sharing merger in the first stage, no domestic firm will reveal information to F0 and the equilibrium is given by (5) and (6).

To further understand the effect of information sharing on profit changes, note that $\pi_0 = p_0 q_0$ for F0 and $\pi_i = p_i q_i$ for the domestic firms, where the price functions are $p_0 = a + \theta - q_0 - bnq$ and $p_i = a + \theta - q_i - b(n-1)q_j - bq_0$, respectively. Let us examine F0's profit change first. With demand fluctuation, F0's price also fluctuates but its output does not in the absence of information sharing. However, when it receives the information, F0 produces output according to the realized demand and so its output and price moves accordingly. Since q_0^s and p_0^s move in the same direction, the ability to move creates a positive value for F0, i.e., increases F0's expected profit. Its gain from information acquisition is *positively* correlated to the degree of price fluctuation under information sharing. Specifically, from F0's price function p_0, the fluctuation is captured by $\delta \equiv a + \theta - bnq^s = 2(a+\theta)/(2+bn)$.

In contrast, both the output and price of a domestic firm fluctuate as demand changes, with or without information sharing. However, due to F0's ability to adjust its output in the case of information sharing, a domestic firm's fluctuation of output and price is smaller with information sharing than without. This reduction in fluctuation lowers a domestic firm's expected profit. A domestic firm's loss from information revelation is *positively* correlated to the degree of the reduction in its price fluctuation. Basically, if demand fluctuates more, the private information for the informed domestic firms also becomes more valuable and it is also more desirable for F0 to acquire it.[12]

With the above understanding, we can then explain the intuition behind part (ii) of Proposition 2. First, for a larger σ^2, although both δ and total output fluctuation are larger, demand fluctuates more than in the case of a smaller σ^2. Hence both the gain by F0 and the loss to the domestic firms from information sharing are larger.

Second, for a larger n, both δ and total output fluctuation become smaller. That is, information sharing allows F0's price to fluctuate *less* with a larger n than with a smaller n, and reduces the domestic firms' price fluctuate *less* with a larger n than with a smaller n. Hence both the gain by F0 and the loss to the domestic firms from information sharing are smaller. It can also be understood by recognizing the fact that when n is very large, the private information to each firm becomes less valuable because many firms have the information and so the loss from revealing the information is small. Also it is less desirable to acquire the information by F0 since many firms have the information.

Lastly, for a larger b, δ becomes smaller. That is, information sharing makes F0's price fluctuation *less* with a larger b than with a smaller b. Hence, F0's gain from acquiring information also becomes smaller. In the contrary, for a larger b, total output fluctuation becomes larger

[12] Specifically, note $\Delta q_0 \equiv q_0^s - q_0^u = \theta/(2+bn)$, which is positively correlated to demand fluctuation. From a domestic firm's (say F1) price function p we see that fluctuation decreases after information sharing, hurting F1. However, since $\Delta q \equiv q^s - q^u = -b\theta/(2+bn)(2+bn-b)0$, which is negatively correlated to demand fluctuation, other domestic firms also adjust their production levels, making F1's price to fluctuate more. That benefits F1. Nonetheless, the overall fluctuation is reduced because in F1's price function $\Delta Q \equiv b(n-1)\Delta q + b\Delta q_0 = 2b\theta/(2+bn)(2+bn-b) > 0$, which is positively correlated to demand fluctuation.

(smaller) when b is small (large).[13] That is, information sharing could reduce a domestic firm's price fluctuation either *less* or *more* with a larger b than with a smaller b. Accordingly, the price fluctuation may become smaller or larger and the domestic firm's loss from revealing information may also become smaller or bigger.

Well established literature on information sharing in oligopoly has shown that firms have no incentives to reveal their private information about market demand if they compete in quantities (See, for example, Gal-Or, 1985).[14] Our Proposition 3 confirms this result and goes further to show that the uninformed firm has incentives to acquire the information. Moreover, it shows how various parameters (degree of demand fluctuation, market structure and product differentiation) affect the incentives. Our Proposition 2 adds to literature by showing that the uninformed firm's gain from information sharing outweighs the loss to an informed firm, which provides incentives for them to engage in an information-sharing merger.

The intuition behind such a result in Proposition 2 is as follows. Output fluctuates because of θ, and informed firms benefit from the fluctuation. Before the merger, however, F0 does not gain from the fluctuation. F1's gain is proportional to the degree of the fluctuation, by a factor of $1/[2+b(n-1)]^2$. After the information-sharing merger, each firm including F0 gains from the fluctuation by a factor of $1/(2+bn)^2$. Compared to the case without the merger, F1's gain is smaller, but F0's gain is larger with the merger. The final comparison pins down to that between $2/(2+bn)^2$ (for merger) and $1/[2+b(n-1)]^2$ (for no merger), which is equivalent to the sign of $Z(n,b)$. We have shown $Z(n,b) > 0$ except at $b=1$ and $n=2$, but $Z(2,1)=0$. That is, the total gain to the merging firms from output fluctuation is greater than F1's gain in the absence of mergers.

4.3. Merger for information sharing and output coordination

In this subsection, we examine the *full-degree merger* under asymmetric information, in which F1 reveals information to F0 and they choose their output levels to maximize the joint profit. We have already obtained the expressions of all the equilibrium quantities and profits before a

[13] We have $\partial \Delta Q/\partial b = 2\theta[4-b^2 n(n-1)]/(2+bn)^2(2+bn-b)^2$.

[14] However, both Kirby (1988) and Hwang (1994) show that firms may have a mutual incentive to share their information, depending on the properties of their cost and demand functions.

merger (as in subsection 4.1),

$$\begin{aligned} q_0^u &= \frac{a}{2+bn}, \ \ \pi_0^u = (q_0^u)^2 + \frac{(2-b)a\theta}{(2+bn)(2+bn-b)}, \\ q_1^u &= \frac{a}{2+bn} + \frac{\theta}{2+bn-b}, \ \ \pi_1^u = (q_1^n)^2, \end{aligned}$$

and after a merger (as in section 3),

$$\begin{aligned} q_0^c &= q_1^c = \frac{(2-b)(a+\theta)}{2(2+bn-b^2)}, \\ \pi_0^c &= \pi_1^c = (1+b)(q_0^c)^2. \end{aligned}$$

Thus, letting $\Delta\pi^a \equiv (\pi_0^c + \pi_1^c) - (\pi_0^u + \pi_1^u)$ denote the profit differential for the merged entity (superscript a indicating asymmetric information), we obtain

$$\Delta\pi^a = \frac{\theta^2 Z(n,b)}{(2+bn)^2(2+bn-b)^2} + \frac{a(nb^2-2b)\theta}{(2+bn)^2(2+bn-b)} + \frac{b^2(a+\theta)^2 Y(n,b)}{2(2+bn)^2(2+bn-b^2)^2}$$

where $Y(n,b)$ has been defined before in section 3 and $Z(n,b)$ in subsection 4.1. After taking expectation, we have

$$E(\Delta\pi^a) = \frac{1}{(2+bn)^2}\left[\frac{\sigma^2 Z(n,b)}{(2+bn-b)^2} + \frac{b^2(a^2+\sigma^2)Y(n,b)}{2(2+bn-b^2)^2}\right].$$

We can show (in the Appendix) that for any given n (≥ 2) there exists a unique $b_1(n) \in (0,1)$ such that

$$\begin{cases} E(\Delta\pi^a) > 0 & \text{for all} \quad b \in [0, b_1) \\ E(\Delta\pi^a) = 0 & \text{at} \quad b = b_1 \\ E(\Delta\pi^a) < 0 & \text{for all} \quad b \in (b_1, 1]. \end{cases} \tag{12}$$

Moreover, $b_1(n) > b_0(n)$, where $b_0(n)$ is defined in section 3. Based on this result, we establish the following proposition.

Proposition 4: *The SPNE under asymmetric information is as follows. For any given n, there exists a unique $b_1(n) \in (b_0(n), 1)$. If $b < b_1$, then F0 and F1 merge in the first stage, with the second-stage market outcomes $\{q_0^c, q_1^c, ..., q_n^c\}$ as given in (2) and (3). If $b \geq b_1$, then F0 and F1 do not merge in the first stage, with the second-stage market outcomes $\{q_0^u, q_1^u, ..., q_n^u\}$ as given in (5).*

Proof: See the Appendix.

Proposition 4 says that a merger is profitable if and only if products sufficiently differentiated. Since $b_1 > b_0$, a merger occurs more often under asymmetric information than under symmetric information.

5. Welfare Analysis

We have so far examined firms' incentives to merge and now we investigate the welfare implications of mergers under asymmetric information. In particular, we want to know how mergers affect the total industrial profit, consumer surplus, and social welfare. Since we deal with international merger, we must distinguish between domestic welfare and global welfare. Results are summarized in a table at the end of this section.

■ **Industrial profit**. In previous sections, we have shown that under certain conditions, mergers are profitable, which means that the joint profit of the merging firms, i.e., F0 and F1, is increased after the merger. The non-merging firms, however, can be affected differently.

Look at the information-sharing merger first. Eq.(11) indicates that every non-merging firm's profit drops after F1 reveals the information to F0. Although F0's profit gain outweighs F1's profit loss, as shown below, the gain may be smaller or larger than the total loss to all informed firms, depending on the extent of product differentiation. From (10) and (11), we obtain the difference between total industry profit under the information-sharing merger, denoted as Π_S, and total industrial profit before the merger, denoted as Π_N,

$$E(\Pi_S - \Pi_N) = \frac{[4(1-b) - (n^2+n-1)b^2]\sigma^2}{(2+bn)^2(2+bn-b)^2}. \tag{13}$$

Note that $E(\Pi_S - \Pi_N)$ is a continuous function of b. It decreases in b, and is positive at $b = 0$ but negative at $b = 1$. Hence, in a market with one uninformed foreign firm and n informed domestic firms, if an informed domestic firm reveals the information about demand to the foreign firm, the total industrial profit increases (decreases) if the extent of product differentiation is below (above) a certain level.

Next, we examine the effect of the output-coordination merger under symmetric information. The analysis in section 3, in particular Proposition 1, has shown that all non-merging firms benefit from the competition-reducing output-coordination merger, but the joint profit of F0 and F1 is not always increased after the merger. However, because the market competition is reduced, the total industrial profit increases, as shown by the following difference between total profit under output coordination, denoted as Π_M, and total profit under symmetric information but without output coordination, i.e., Π_S.

$$E(\Pi_M - \Pi_S) = \frac{b^2(a^2+\sigma^2)[b(4-3b+b^2)n^2 + 2(2-b)^2 n - 4 + 4b - 2b^2]}{2(2+bn)^2(2+bn-b^2)^2} \geq 0. \tag{14}$$

Strict inequality holds except at $b = 0$. The above analysis can be summarized below.

Lemma. *In a market with one uninformed foreign firm and n informed domestic firms, an output coordination merger between a domestic firm and the foreign firm always increases the total industrial profit, while an information sharing merger increases the total industrial profit if and only if products are sufficiently differentiated.*

Finally, we examine the net effect of the merger under asymmetric information. To this end, we need to compare Π_M and Π_N. We summarize the comparison in the following proposition.

Proposition 5. *In a market with one uninformed foreign firm and n informed domestic firms, if a domestic firm and the foreign firm merge to share information and coordinate output, the total industrial profit increases, under a reasonable assumption that the market is not too competitive (more precisely, $n < 20$).*[15]

Proof: See the Appendix.

■ **Consumer surplus**. Next, we look at the changes of consumer surplus due to a merger. In the beginning of section 2, we have specified the demand functions, which can be derived from a representative consumer's utility function as given below:

$$\begin{aligned} U &= (a+\theta)\sum_i q_i - \frac{1}{2}\sum_i q_i^2 - \frac{b}{2}\sum_i \sum_{j\neq i} q_i q_j \\ &= (a+\theta)\sum_i q_i - \frac{1}{2}\sum_i q_i^2 - \frac{b}{2}\left[\left(\sum_i q_i\right)^2 - \sum_i q_i^2\right]. \end{aligned}$$

Hence consumer surplus is defined as the net benefit from consumption: $CS \equiv U - \sum_{i=0}^{n} p_i q_i$. By comparing the consumer surplus without any merger (CS_N) to the consumer surplus under the information-sharing merger (CS_S), we obtain

$$E(CS_S - CS_N) = \frac{b^2(3-b)n^2 + b(8-5b+b^2)n + (2-b)^2}{2(2+bn)^2(2+bn-b)^2}\sigma^2 > 0.$$

Hence, information sharing between the firms unambiguously benefits consumers. By comparing the consumer surplus under the information-sharing merger (CS_S) to the consumer surplus under

[15] We can also prove that "Demand fluctuation is not too severe (more precisely $\sigma^2/a^2 < 0.44$) and market is not too competitive (more precisely $n \leq 36$)" is another sufficient condition for industrial profit to increase.

the full-degree merger (CS_M), we also have

$$E(CS_M - CS_S) = \frac{b(a^2+\sigma^2)F_1}{4(2+bn)^2(2+bn-b^2)^2} < 0,$$

because $F_1 \equiv -b^2(8-5b+b^2)n^2 - 2b(3+b)(2-b)^2 n - 2(8-6b-2b^2+b^3) < 0$. The reason is simple: output coordination reduces market competition, which hurts the consumers.

The combined effect of the merger under asymmetric information is the result of the two conflicting forces above. By calculation, we have

$$E(CS_M - CS_N) = \frac{F_2\sigma^2}{4(2+bn-b)^2(2+bn-b^2)^2} + \frac{F_1 ba^2}{4(2+bn)^2(2+bn-b^2)^2},$$

where $F_2 \equiv (1-b)[b^2(b^2-4b+6)n^2 + 2b(8-9b+2b^2)n + (2-2b-b^2)(2-b)^2] > 0$. With simulation, we can see the pattern of the consumer surplus changes from a merger: *Given σ^2/a^2 and n, there exists a critical level of b such that the consumer surplus is higher (lower) after the merger if b* is *smaller (larger) than the critical level.*[16]

Figure 1 gives three examples, in which the calculated critical point is a function of n, based on $\sigma^2/a^2 = 0.2$, $\sigma^2/a^2 = 0.4$, and $\sigma^2/a^2 = 0.6$, respectively.

<Figure 1 is here>

■ **Global welfare**. Global welfare consists of consumer surplus and all producers' profits. Since we have assumed that production costs are zero, the global welfare is simply equal to U.

We are interested in knowing how mergers change global welfare. In the case of no merger, the equilibrium quantities of consumption are given by (4) and (5). Substituting these results in U yields the global welfare before merger:

$$U_N = \frac{(n+1)(3+bn)a^2}{2(2+bn)^2} + \frac{(3n+bn^2+2-b)a\theta}{(2+bn)(2+bn-b)} + \frac{n(3+bn-b)}{2(2+bn-b)^2}\theta^2.$$

Suppose F0 and F1 engage in the information-sharing merger. Then, the equilibrium quantities of consumption are given by (7), substituting which in U yields the global welfare under the information-sharing merger:

$$U_S = \frac{(n+1)(3+bn)(a+\theta)^2}{2(2+bn)^2}.$$

[16]Details of the simulation results are available from the authors upon request.

Finally, let us calculate the global welfare under the full-degree merge. The equilibrium quantities of consumption are given by (2) and (3), substituting which in U yields

$$U_M = \frac{[2bn^2 + (6 + 2b - 4b^2)n + 6 - 4b - 5b^2 + 3b^3](a + \theta)^2}{4(2 + bn - b^2)^2}.$$

In order to understand the effects of the full-degree merger on global welfare, let us examine the separate effects of information sharing and output coordination. First,

$$E(U_S - U_N) = \frac{b^2(1 - b)n^2 + b(8 - 7b + b^2)n + 3(2 - b)^2}{2(2 + bn)^2(2 + bn - b)^2}\sigma^2.$$

Note that the numerator is increasing in n and at $n = 2$, it is equal to $12 + 4b - 7b^2 - 2b^3 > 0$. Hence, $E(U_S - U_N) > 0$. That is, information sharing increases global welfare.

Next,

$$U_M - U_S = -\frac{bG_1}{4(2 + bn)^2(2 + bn - b^2)^2}(a + \theta)^2,$$

where $G_1 \equiv b^3(1 - b)n^2 + 2b(4 - 3b^2 + b^3)n + 16 - 4b - 12b^2 + 6b^3$. Note that $\partial G_1/\partial n > 0$ and $G_1|_{n=2} = 16 + 12b - 12b^2 - 2b^3 > 0$. Hence $G_1 > 0$ for any n and $E(U_M - U_S) < 0$. Output coordination reduces global welfare because it lowers market competition.

As information sharing has a positive effect and output coordination has a negative effect on global welfare, the net effect of the full-degree merger under asymmetric information then depends on the relative degree of these conflicting effects. By calculation, we have

$$E(U_M - U_N) = \frac{G_2}{4(2 + bn)^2(2 + bn - b^2)^2(2 + bn - b)^2},$$

where

$$G_2 \equiv -a^2b(2 + bn - b)^2G_1 + (1 - b)(2 + bn)^2H\sigma^2,$$

and

$$H \equiv b^2(2 - b^2)n^2 + 2b(8 - 3b - 4b^2 + 2b^3)n + (2 - b)^2(6 + 2b - 3b^2) > 0.$$

Hence, $\text{sgn}[E(U_M - U_N)] = \text{sgn}(G_2)$. It is clear that $G_2 < 0$ if σ^2 is sufficiently low (in which case, the positive benefits from information sharing are small), and $G_2 > 0$ if σ^2 is sufficiently large (in which case, the positive benefits from information sharing are large).

With simulation, we can see another pattern of the global welfare changes brought about by a merger: *Given σ^2/a^2 and n, there exists a critical level of b such that the global welfare is higher (lower) after the merger if b is smaller (larger) than the critical level.*[17]

[17]Details of the simulation are available from the authors upon request.

Figure 2 gives three examples, in which the calculated critical point is a function of n, based on $\sigma^2/a^2 = 0.2$, $\sigma^2/a^2 = 0.4$, and $\sigma^2/a^2 = 0.6$, respectively.

<Figure 2 is here>

■ **Policy implications**. Let us next investigate whether private incentives to merge is compatible with social incentives. Because it is hard to obtain a clear-cut result, we rely on three numerical examples to illustrate the basic points. First, suppose $\sigma^2/a^2 = 0.6$ and $n = 15$. By calculation, we obtain that $\Delta\pi^a > 0$ if and only if $b \leq 0.61$ and $E(U_M - U_N) > 0$ if and only if $b \leq 0.66$. This indicates that (a) whenever the two firms decide to merge, the merger increases the global welfare, and (b) it is possible that a merger raises the global welfare but the firms do not have incentives to merge, which is the case when $b \in (0.61, 0.66]$.

Second, suppose $\sigma^2/a^2 = 0.3$ and $n = 15$. Then, we have $\Delta\pi^a > 0$ if and only if $b \leq 0.48$ and $E(U_M - U_N) > 0$ if and only if $b \leq 0.46$. That is, when the two firms merge, the global welfare increases in some cases but decreases in others. Hence, sometimes merger should be encouraged and sometimes discouraged. The same qualitative conclusion holds in a third example in which $\sigma^2/a^2 = 0.6$ and $n = 8$. In this case, we have $\Delta\pi^a > 0$ if and only if $b \leq 0.64$ and $E(U_M - U_N) > 0$ if and only if $b \leq 0.61$.

We can draw a hypothesis from the above analysis: *When demand uncertainty is large and market competition is intense, international merger should be encouraged (because mergers are socially desirable but some are not taken up by firms); however, when demand uncertainty is very small and market competition is very weak, international mergers should be discouraged (because mergers occur, but are not socially beneficial).*

■ **Domestic welfare**. Finally, let us look at the domestic country's welfare, which is the global welfare excluding F0's profit. We will just focus our discussion on the welfare change due to the full-degree merger under asymmetric information. The domestic welfare before the merger is $W_N = U_N - \pi_0^u$, where π_0^u is given by (6). The domestic welfare after the merger is $W_M = U_M - \pi_0^c - \pi_1^c + \pi^u + \lambda[(\pi_0^c + \pi_1^c) - (\pi_0^u + \pi^u)]$, where π_i^c are given by (2), π^u is given by (6), and $\lambda \in [0, 1]$. The result in the square bracket measures the increase in the joint profit of F0 and F1 due to a merger and λ captures the share of this profit increase received by firm 1 (through bargaining or some mechanism imbedded in the merger negotiation, which we do not specify). Hence, the welfare effect of the merger can be specified as $W_M - W_N$.

Note that if $\lambda = 1$, then $W_M - W_N = U_M - U_N$, which has been discussed above. The worst situation for the domestic welfare is when $\lambda = 0$. In this case, we have the following result from simulation: *Given* σ^2/a^2 *and* n, *there exists a critical level of* b *such that the domestic welfare is higher* (*lower*) *after the merger if* b is *smaller* (*larger*) *than the critical level.*

Figure 3 gives three examples, in which the calculated critical point is a function of n, based on $\sigma^2/a^2 = 0.2$, $\sigma^2/a^2 = 0.4$, and $\sigma^2/a^2 = 0.6$, respectively.

<Figure 3 is here>

■ **Summary**. We summarize the results of this section in the following table, where + indicates an increase and − a decrease.

Merger	industrial profit	consumer surplus	global welfare	domestic welfare
output-coordination	+	−	−	
information-sharing	+ for small b	+	+	
full-degree	+	+ for small b	+ for small b	+ for small b

6. Concluding Remarks

We have investigated international mergers under asymmetric information by concentrating on two features of a merger, i.e., output coordination and information sharing. We have shown that the foreign firm and a domestic firm always want to *share information*, but *output coordination* is not always profitable, depending on the extent of product differentiation. We have also examined how such a merger affects the non-merging firms' profits, consumer surplus, domestic welfare and global welfare. The extent of product differentiation plays a critical role.

Firms from different countries have different incentives to merge as opposed to firms in the same countries. Because a foreign firm is less likely to be as well informed as a domestic firm about demand in a domestic market, we have emphasized the incentives to share information on market demand in this paper. Firms from different countries also have different corporate cultures, management styles, technologies and market shares. It is interesting to investigate how these differences affect incentives for international mergers.

Appendix

A. Proof of Proposition 1.

Hereafter let a function with a subscript represent partial differentiation, e.g., $Y_b \equiv \partial Y(n,b)/\partial b$. Since $Y_b = 3n^2b^2 - 2(3n^2-4n+4)b - 4(n-1) = -[3n^2b+4(n-1)](1-b) - nb(3n-4) - 4b < 0$, $Y(n,0) = 4 > 0$ and $Y(n,1) = 4-2n^2 < 0$, there is a unique $b_0(n) \in (0,1)$ such that $Y(n,b) > 0$ if and only if $b < b_0(n)$. Note that $b_0(n)$ is defined by $Y(n,b_0) = 0$. By differentiating this condition and rearranging terms, we obtain

$$\frac{\mathrm{d}b_0(n)}{\mathrm{d}n} = -\frac{2b\,[nb(3-b)+2(1-b)]}{(3n^2b+4n-4)(1-b)+b(3n^2-4n+4)} < 0.$$

Note that $\Delta\pi^c$ and $Y(n,b)$ have the same sign. This completes the proof for part (i).

The proof for part (ii) is straightforward. □

B. Proof of Proposition 2.

Part (i). This part is in the text preceding the proposition, particularly (9).

Part (ii). Differentiating (9), denoting $H \equiv E\left[(\pi_0^s+\pi^s)-(\pi_0^u+\pi^u)\right]$, yields

$$\begin{aligned}
\frac{\partial H}{\partial b} &= -2\sigma^2\frac{n(n-1)b[(n^2-4n+2)b^2+6(n-2)b+12]+8(n+1)}{(2+bn)^3(2+bn-b)^3} < 0, \\
\frac{\partial H}{\partial n} &= -2b\sigma^2\frac{[2(n-1)^3-n^3]b^3+6(n^2-4n+2)b^2+12(n-2)b+8}{(2+bn)^3(2+bn-b)^3} < 0 \quad \text{for } n \geq 3.
\end{aligned}$$

When $n = 2$, $\partial H/\partial n$ is increasing in b and the root is $b = 0.7$. □

C. Proof of Proposition 3.

Part (i). This part is proven by (11).

Part (ii). The following results are immediately obtained by inspecting (10) and (11): $\partial E(\pi_0^s-\pi_0^u)/\partial\sigma^2 > 0$, $\partial E(\pi_0^s-\pi_0^u)/\partial n < 0$, $\partial E(\pi_0^s-\pi_0^u)/\partial b < 0$, and $\partial E(\pi^s-\pi^u)/\partial\sigma^2 < 0$.

Differentiating (11) with respect to n yields

$$\frac{\partial E(\pi^s-\pi^u)}{\partial n} = \frac{2\sigma^2b^2\left[3b^2n(n-1)+(b-3)^2+3+12bn\right]}{(2+bn)^3(2+bn-b)^3} > 0.$$

Differentiating (11) with respect to n yields

$$\frac{\partial E(\pi^s-\pi^u)}{\partial b} = \frac{2n(n-1)(6+2bn-b)b^2-16}{(2+bn)^3(2+bn-b)^3}\sigma^2.$$

It can be shown that the numerator is increasing in $b \in [0,1]$ and it has a unique root at $\frac{2}{2n-1}\left(\sqrt[3]{\frac{n}{n-1}}+\sqrt[3]{\frac{n-1}{n}}-1\right) \in (0,1)$. $\square$

D. Proof of Proposition 4.

It is clear that the sign of $E(\Delta\pi^a)$ is the same as $X(n,b)$, where $X(n,b) \equiv 2(2+bn-b^2)^2 Z(n,b) + (1+a^2/\sigma^2)b^2(2+bn-b)^2 Y(n,b)$. In what follows, we will examine the sign of $X(n,b)$.

First, recall that $Z_n > 0$ and $Z(n,b) > 0$ for all $n \geq 2$. Also, $Z_b = 2(n-2)^2 b + 4(n-2-b)$. So $Z_b < 0$ for $n \in \{2, 3\}$ but $Z_b > 0$ for all $n > 3$.

Second, recall that the property of $Y(n,b)$ has been derived in the proof of Proposition 1 (See Appendix A).

From the analysis of the three functions $X(n,b)$, $Y(n,b)$ and $Z(n,b)$, we immediately obtain the first result:

$$X(n,b) > 0 \quad \text{for all} \quad b \leq b_0.$$

Finally, let us examine the property of $X(n,b)$ in the region of $b \in (b_0, 1]$, within which $Y(n,b) < 0$.

Because $X(n,b_0) = 2(2+bn-b^2)^2 z > 0$, $X(n,1) = -2(k-1)(n^2-2)(n+1)^2 < 0$, and $X(n,b)$ is continuous in b, there exists a $b_1 \in (b_0, 1)$ such that $X(n,b_1) = 0$. We argue that b_1 is the only solution to $X(n,b) = 0$. We will prove this by contradiction.

Suppose there are multiple solutions to $X(n,b) = 0$. We let b_1 denote the smallest one. Then $X(n,b)$ must be decreasing at $b = b_1$, i.e., $X_b(n,b_1) < 0$. Moreover, there is at least another solution (the second smallest one) called $b_2 \in (b_1, 1)$ such that $X(n,b_2) = 0$ and $X(n,b)$ is increasing at $b = b_2$, i.e., $X_b(n,b_2) > 0$.

Denoting $f(n,b) = 2(2+bn-b^2)^2 Z(n,b)$, and $g(n,b) = b^2(2+bn-b)^2 Y(n,b)$, we have $X(n,b) = f(n,b) + (1+a^2/\sigma^2) g(n,b)$ and

$$X_b = f_b + (1+a^2/\sigma^2) g_b = f_b + \frac{g_b}{g(n,b)}\left[(1+a^2/\sigma^2) g(n,b)\right] = f_b + \frac{g_b}{g(n,b)}\left[X(n,b) - f(n,b)\right].$$

Since $X(n,b_2) = 0$, we find that $X_b(n,b_2) = f_b(n,b_2) - \frac{g_b(n,b_2) f(n,b_2)}{g(n,b_2)}$. After some manipulation, we get

$$X_b(n,b_2) = \frac{2(2+b_2 n - b_2^2)(2+b_2 n)}{b_2(2+b_2 n - b_2)}\left(\frac{h(n,b_2)}{Y(n,b_2)} - 32\right),$$

where $h(n,b) \equiv \sum_{i=0}^{7} w_i b^i$, whereas $w_0 = 64$, $w_1 = 32(5-3n)$, $w_2 = 16(6n^2-16n+5)$, $w_3 = 8(20n^3-71n^2+90n-42) > 0$, $w_4 = 52n^4-308n^3+576n^2-504n+224 > 0$ if $n \geq 4$, $w_5 = 6n^5-60n^4+164n^3-192n^2+132n-64 > 0$ if and only if $n \geq 7$, $w_6 = -3n^5+15n^4-14n^3+4 > 0$ if $n = 2,3$, and finally, $w_7 = n(n-1)(n^2-4n+2) > 0$ if $n \geq 4$.

Now let $h1(n,b) \equiv \frac{1}{16}\sum_{i=0}^{2} w_i b^i = 6b^2n^2 - 2b(3+8b)n + (5b^2+10b+4)$. Since $h1(n,b)$ is quadratic in n, it achieves minimum at $n = (3+8b)/6b$, at which $h1 = \frac{1}{6}(15+12b-34b^2) > 0$. Hence, $h1(n,b) > 0$.

Now let $h2 \equiv \sum_{i=3}^{7} w_i b^i$. For $n \geq 7$, since all coefficients of b^{th} except w_6 are positive, and $w_4+w_5+w_6 > 0$, we know that $h2 > \sum_{i=4}^{6} w_i b^i > (w_4+w_5+w_6)b^6 > 0$. For $4 \leq n < 7$, we know $w_5 < 0$ and $w_6 < 0$, but yet $w_3+w_5+w_6 > 0$. For $n = 3$, $w_4 < 0, w_5 < 0$ and $w_7 < 0$, but $w_3+w_4+w_5+w_7 = 448 > 0$. Therefore, $h2 > 0$ for all $n \geq 3$.

The above two paragraphs together show that $h(n,b) = 16h1(n,b) + h2(n,b) > 0$ for $n \geq 3$ and $b \in (b_0, 1]$. Because $Y(n,b_2) < 0$, $\frac{h(n,b_2)}{Y(n,b_2)} - 32 < 0$, which implies that $X_b(n,b_2) < 0$ for $n \geq 3$.

At $n = 2$, we have $h(n,b) - 32Y(n,b) = -4b^7+36b^6-24b^5-112b^4-16b^3+208b^2+96b-64 > 0$ for $b > b_0 = 0.555$. Hence, $X_b(n,b_2) < 0$ at $n = 2$.

Thus, we have shown $X_b(n,b_2) < 0$ for all $n \geq 2$, which contradicts the supposition of having b_2 as the second smallest solution to $X(n,b) = 0$, with $X_b(n,b_2) < 0$.

This proves (12) and Proposition 4. $\square$

E. Proof of Proposition 5.

Using (13) and (14), we obtain

$$E(\Pi_M - \Pi_N) = \frac{\sigma^2}{(2+bn)^2(2+bn-b)^2}\left[g_1 + kb^2g_2\right],$$

where $g_1 \equiv (2-b)^2 - (n^2+n)b^2$, $g_2 \equiv (2-b)^2(bn^2+2n-1) + b^2(n^2-1)$, and $k = [(a^2+\sigma^2)/2\sigma^2][(2+bn-b)/(2+bn-b^2)]^2$.

Since $\sigma^2 < a^2$, $(a^2+\sigma^2)/2\sigma^2 > 1$. The function $(2+bn-b)^2/(2+bn-b^2)^2$ is increasing in n, but has a U-shape in b. Noting this, we can then easily get $(2+bn-b)^2/(2+bn-b^2)^2 > 0.825$ for all $n \geq 2$ and $b \in [0,1]$. Thus, $k > 0.825 > 33/40$.

Because $g_2 > 0$, we know $E(\Pi_M - \Pi_N) > 0$ if we can show $3g_1 + 4b^2g_2 > 0$. Letting $x(n) \equiv x_2n^2 + x_1n + x_0 = 40g_1 + 33b^2g_2$, we have $b^2(-40+132b-99b^2+33b^3)$, $x_1 = 2b^2(112-132b+33b^2)$,

$x_0 = 160 - 160b - 92b^2 + 132b^3 - 66b^4$. We find that x_2 is positive when $b > 0.4.17$, $x_2 = 0$ if $b = 0.417$, x_1 is always positive, and x_0 is positive when $b < 0.871$. Hence, for $b \in [0.417, 1]$, x is increasing in n and $x(2) = 160 - 160b + 196b^2 + 132b^3 - 330b^4 + 132b^6 > 0$. This shows that $x > 0$ for $b \in (0.417, 1]$.

For $b \in [0, 0.417)$, $x(n) > 0$ if and only if $n < n^* = \left(-x_1 + \sqrt{x_1^2 - 4x_0x_2}\right)/2x_2$. Computer calculation can verify that $n^* \geq 19.4$. This shows that $x > 0$ for $b \in [0, 0.4.17)$ and $n < 20$. □

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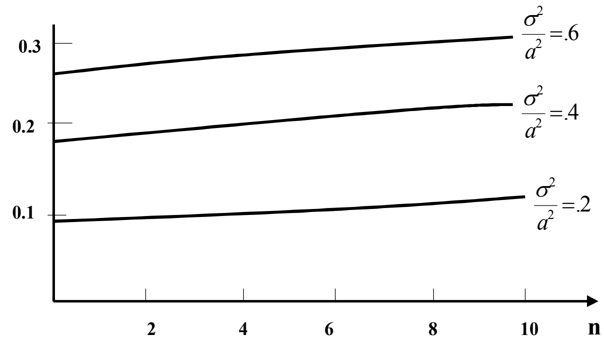

Figure 1: **Critical Level of b for Consumer Surplus**

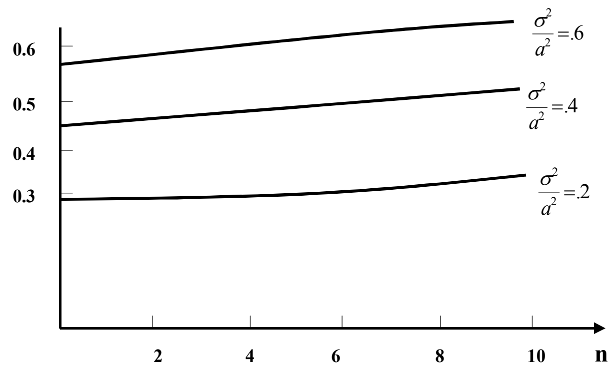

Figure 2: **Critical Level of b for Global Welare**

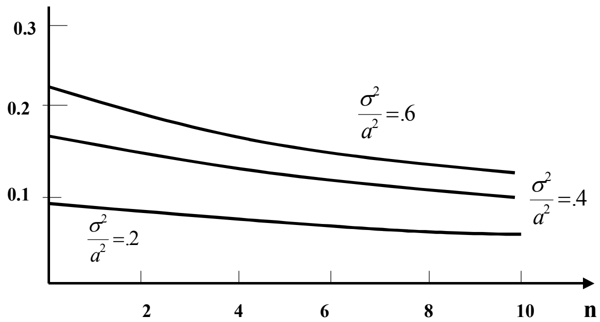

Figure 3: **Critical Level of b for Domestic Welfare**