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On the value of information sharing and cooperative price setting

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ABSTRACT

We consider a setting of two firms that sell substitutable products under price competition. We show that private signals enable firms to improve market forecast and earn higher profits. Provided that their private signals are not perfectly correlated, firms can benefit from sharing signals with each other. This is irrespective of product substitutability. Moreover, information sharing is a strategic complement to cooperative price setting to improve the profit performance of firms.

1. Introduction

The importance of information can never be overstated. Farmers in the agricultural industry, for instance, need weather and market information to make farming and pricing decisions. With the development of the telecommunication infrastructure, a few organizations such as farms.com and agriculture.com have begun to provide latest farming and market news through web portals to create values through infomediation. With the information obtained from various sources in addition to self-endowed signals, it is common for farmers to share them on various occasions through conversations in person or via social networks. In the industrial world, more and more firms have deployed information systems to collect market data. The access to and sharing of market information are of particular importance to the success of collaboration between firms, as exemplified by the alliance between IBM and Apple in the electronics industry, and the partnership between Renault and Nissan in the automobile industry. As stated in a recent OECD study, "*increased transparency in market as a result of information sharing can benefit consumers directly and the firms, resulting in an improved social welfare*" (Report No. DAF/COMP (2010) 37, July 11, 2011). Meanwhile, the cooperative business model has been widely adopted in practice. The Capper–Volstead Act provides legal protection from prosecution under antitrust laws to empower farmers to price and sell products by cooperative means. On the other hand, the rise of international cartels has made cooperation between competing entities across regions key to successful enforcement. Regional and bilateral trade agreements often involve specific provisions to facilitate cooperation. European Competition Network (ECN) provides a canonical example of regional agreement that facilitates consolidation by case coordination and information sharing, in addition to harmonization of leniency programs.

To investigate the economic value of information sharing and its interplay with cooperative decision making, we explicate a model of two firms that produce and sell substitutable products in uncertain markets under price competition. They each gain access to some private market signal, and can level their information statuses by sharing signals. We demonstrate that, irrespective of product substitutability, firms can benefit from sharing private signals, provided that the signals are not perfectly correlated. This complements the existing literature to show that market competition mode plays a role in the sustainability of information sharing. Moreover, we show information sharing is a strategic complement to cooperative price setting to improve firms' profits.

Literature review

This paper relates to the stream of literature on private information sharing. Most of this literature assumes that market competition is in quantity [2,4], in slightly different settings, show that it is the unique equilibrium for firms not to share demand signals. [10] shows that firms, each having a series of demand observations, will not share observations when products are perfect substitutes, but will share them when products are complements. Other papers on similar topics include [1,6,9], etc. [8] provides conditions under which firms have incentives to share demand information. [3] analyzes an oligopoly in which firms hold demand information and have identical convex cost functions, and shows that sharing information is Pareto optimal when cost functions are sufficiently convex. [5], under the assumption of binary demand and signals, show

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that firms have incentives to share signals after receiving them. With respect to this literature, we show that horizontal information sharing is sustainable when market competition is in price, irrespective of product substitutability. The mode of market competition then plays a crucial role in information structure. Moreover, we reveal that information sharing is a strategic complement to cooperative price setting to improve the firms' profit performance.

The remainder of this paper is organized as follows. The basic model is introduced in Section 2, and the equilibrium outcomes under various information structures and operating modes are presented in Section 3. We explore the effects of information sharing and cooperation in Section 4, and conclude the paper in Section 5. All the proofs can be found in an online supplement (Appendix A).

2. The model

We consider a setting in which two firms produce and sell differentiated products in uncertain markets. Firm i faces a demand function of:

$$q_i = a_i + \Xi - p_i + \beta p_{3-i}, \quad i = 1, 2, \tag{1}$$

where, $a_i > 0$ corresponds to market potential, and $\beta \in (0, 1)$ captures the level of product substitutability. The two products are independent as $\beta \longrightarrow 0$, but are prefect substitutes as $\beta \longrightarrow 1$. Ξ models the uncertainty in general market condition and follows normal distribution $N(0, u)$. Without loss of generality, we scale the firms' production costs to zero. Each firm has access to a noisy signal X_i that takes the form of $X_i = \Xi + S_i$, where S_i follows normal distribution $N(0, v)$. In addition, we make the following assumptions to facilitate exploration:

Assumption 1. The random variable (Ξ, S_i) is bi-variate normal $(\Xi, S_i) \sim N(0, 0, u, v, r)$, where $r = \text{Cov}(\Xi, S_i) \in \left[0, \sqrt{uv}\right]$. Hence, $X_i \sim N(0, u + v + 2r)$.

Assumption 2. The random variable (Ξ, X_1, X_2) is multi-variate normal, and $\text{Cov}(S_1, S_2) = \rho \in [0, v]$.

With these two assumptions, we can derive the conditional expectations and variances of $(\Xi|X_i = x_i)$ and $(\Xi|X_1 = x_1, X_2 = x_2)$, as shown in Lemma 1.

Lemma 1. *By Assumptions 1 and 2, given observed signals x_1, x_2, we have:*

$$E(\Xi|X_i = x_i) = \frac{u + r}{u + v + 2r} x_i,$$

$$E(\Xi|X_1 = x_1, X_2 = x_2) = \frac{u + r}{2u + v + 4r + \rho}(x_1 + x_2),$$

$$E\left(X_j|X_i = x_i\right) = \frac{u + \rho + 2r}{u + v + 2r} x_i;$$

$$\text{var}(\Xi|X_i = x_i) = u - \frac{(u + r)^2}{u + v + 2r}, \quad \textit{and}$$

$$\text{var}(\Xi|X_1 = x_1, X_2 = x_2) = u - \frac{2(u + r)^2}{2u + v + \rho + 4r}.$$

We adopt the following decision sequence to carry out investigation. First, the firms independently or cooperatively choose pricing policies. After observing private signals, they disclose them to each other if they have ex-ante agreed on information sharing, and apply the pre-determined policies to set prices by utilizing the available signals. Finally, demand uncertainty is fully revealed and the firms sell products to make profits.

Without information sharing and cooperative price setting, each firm i independently chooses pricing policy $p_i(\cdot)$ to maximize its expected profit:

$$\pi_i = E[\pi_i|X_i],$$

where,

$$\begin{aligned}\pi_i|\{X_i = x_i\} &= E\{[p_i(a_i + \Xi - p_i + \beta p_{3-i})]|X_i = x_i\} \\ &= p_i(x_i)[a_i + E(\Xi|X_i = x_i) - p_i(x_i) \\ &\quad + \beta E(p_{3-i}|X_i = x_i)].\end{aligned}$$

We will use pricing policy $p_i(\cdot)$ in the form of:

$$p_i(x_i) = R_{0i} + R_{1i}x_i, \quad i = 1, 2. \tag{2}$$

When the firms ex-ante agree to share signals, each firm i will gain access to both signals $\{X_1, X_2\}$, but will independently choose pricing policy $p_i(\cdot)$ to maximize its expected profit:

$$\pi_i = E[\pi_i|X_i, X_j],$$

where, $\pi_i|\{X_1 = x_1, X_2 = x_2\} = p_i[a_i + E(\Xi|X_1 = x_1, X_2 = x_2) - p_i + \beta E(p_{3-i}|X_1 = x_1, X_2 = x_2)]$.

For this situation, we will focus on the pricing policy $p_i(\cdot, \cdot)$ in the form of:

$$p_i(x_1, x_2) = Z_{0i} + Z_{1i}x_1 + Z_{2i}x_2, \quad i = 1, 2. \tag{3}$$

By Theorems 4 and 5 in [7], it suffices to consider pricing policies in the forms given in (2) and (3) for linear demand function, as given in (1). The coefficients R_{0i}, R_{1i}, Z_{0i}, Z_{1i}, and Z_{2i} are to be determined.

When firms cooperate in decision making, we adopt the Nash bargaining framework to analyze their pricing policies. This axiomatic approach bypasses the context-specific negotiation process to predict the reasonable outcome. Specifically, the firms choose pricing policies (p_1, p_2) and internal transfer payment t to maximize the Nash product of their net profit surpluses from cooperation:

$$N(p_1, p_2; t) = (\pi_1 - t - r_1)^{\theta}(\pi_2 + t - r_2)^{1-\theta}$$

$$\text{Subject to} \quad \pi_1 - t \geq r_1, \; \pi_2 + t \geq r_2.$$

$\theta \in (0, 1)$ and $1 - \theta$ indicate the respective bargaining powers endowed to firm 1 and firm 2. π_i is the expected profit of firm i under cooperation, and r_i is its disagreement profit. We use pricing policies in the forms of (2) and (3) when cooperating firms do not share signals and share signals respectively. The transfer payment t from firm 1 to firm 2, which can be positive or negative depending on the direction of the transfer, allocates total profit surplus between the two firms. The Nash bargaining solution represents a situation that cannot be improved to the interests of both firms, and guarantees each firm a profit surplus no less than its disagreement profit.

For ease of reference, we add superscript $k \in \{N, S, C, SC\}$ on the equilibrium outcomes, where N indicates that firms neither share signals nor cooperate in price setting, S indicates that firms share signals but independently make pricing decisions, C indicates that firms cooperate but do not share signals, and SC indicates that firms share signals and cooperate. With these notations, $r_i = \pi_i^N$ is firm i's disagreement profit by refusing to cooperate when firms do not share signals, and $r_i = \pi_i^S$ is its disagreement profit by refusing to cooperate when firms share signals.