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An Economic Analysis of Collaboration Between Competing Firms

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I. Introduction

Decision makers need to understand the economics of collaboration in order to be able to evaluate the potential of collaborative technology. Collaboration between different actors may occur within a firm's boundary or across it. Throughout the paper the focus lies on collaboration across the boundaries of firms.

The economic effects of collaboration between firms located along different phases of the value chain (typically supplier-purchaser-relationships) have been studied in the literature extensively. Usually, transaction cost theory is applied to derive the "optimal" institutional structure (cf. Williamson (1975)). Basic institutional arrangements are hierarchy, market and network cooperations (cf. Clemons et al. (1993)). The use of collaborative technology may be especially useful in case of network cooperations. As Clemons et al. point out, the use of IT triggers a move towards such cooperations (move-to-the-middle-hypothesis). A more formal economic analysis of interorganizational systems is presented in Clemons/Kleindorfer (1992).

Collaboration between competing firms is a problem that has not yet been studied in such detail. As it is well-known, strategies of firms may be seen as a mixture of cost reduction, product differentiation and improvement of decision making and/or planning. Information technology may help a firm to create sustaining competitive advantages over competitors (examples are contained in Clemons (1991)). Sustainability is an important issue to defend investments from being imitated too quickly (see Kettinger et al. (1994)). Based on this observation it is not clear whether collaboration between competing firms is useful.

Generally, collaboration between competing firms may occur in many ways. Some examples are joint use of complex technological or marketing processes, bundling products or setting standards. Collaboration typically requires sharing information and know how, as well as resources.

In literature collaboration problems are usually studied with the help of methods from microeconomics and game theory. It turns out that the most important factors affecting the usefulness of collaboration are as follows:

- *Market structure*. If perfect competition prevails collaboration is of limited use. No single firm or proper subsets of firms may influence market prices and/or quantities. In a monopolistic environment there obviously is no room for collaboration. Consequently, the interesting market structure is an oligopoly. Depending on the kind of products offered and the way an equilibrium is obtained, price or quantity setting oligopolies may be distinguished (Bertrand or Cournot oligopolies, cf. Pindyck/Rubinfeld (1992, pp. 430) and Martin (1988)).
- *Product relationship*. Products offered may be substitutes or complements. In general, we would expect that products of competing firms are substitutes. Product differentiation, however, allows to vary the degree of possible substitution.
- *Distribution of knowledge and ability*. The distribution of knowledge and ability is closely related to the possibility of generating sustaining competitive advantages (cf. Choudhury/Sampler (1997)). If a firm has specific knowledge or specific abilities that competitors do not have it may use these skills to outperform competing firms.
- *Kind and degree of uncertainty faced by competing firms*. Basically we may distinguish uncertainty with respect to common or private variables. As an example consider demand parameters. They are called common or public variables since they directly affect profits but are not firm specific. On the other hand variable costs are an example of private variables (cf. Jin (1994, p. 323)). They are firm specific. Of course, knowledge of rival's variable costs may affect a firms own decisions since it may predict rival's behavior more precisely.
- *Risk preferences of competing firms*. It is assumed that decision makers are risk averse. Hence they would not maximize expected profits as if they were risk neutral but expected utility of profits.

The results obtained depend on the assumptions made about the factors identified above. They partially differ or even contradict each other. Important factor combinations have not yet been studied in detail. An example is the case of an oligopoly with differentiated products, demand uncertainty and risk averse managers. Note, that this seems to be the case that is mostly found in real life.

In this paper the case of differentiated products, demand uncertainty and risk averse managers will be studied in detail. For the sake of simplicity the analysis will be restricted to the case of two competing firms (duopoly). It is possible but tedious to extend the analysis to the case of more than two competitors.

The analysis is carried out with the help of a microeconomic model that will be presented in the third section. The basic assumption is that collaboration occurs through knowledge and information sharing, common information collection and/or interpretation. In order to share information, knowledge and know-how collaborative technology is usually applied.

Joint application development and joint use of resulting information systems, as well as interorganizational information systems in general are typically covered by such an analysis. Joint application development bundles development capabilities in an effort to reduce development costs. Typically specific know how and information is shared between the cooperating development partners. Hence, in case of competing developers, it is necessary to compare the benefits associated with reduced costs to possible disadvantages faced by disclosing information and know how. In this paper we will assume that information is shared via joint application development and/or joint use of such systems.

Note, that in our context collaboration may be characterized as being pre-competitive. It should not be mixed up with collusion which may be legally restricted or even forbidden.

A formal model will be developed in the sequel. Techniques from game theory allow to solve the corresponding optimization problems. The model will be analyzed in a simple setting in order to be able to derive closed-form solutions which may be handled more conveniently. Generalizations which make the model more realistic are of course possible and will be indicated. Usually, more general settings will not allow the derivation of closed-form solutions. Then numerical or simulation techniques have to be used. However, the results presented for the simple case will change only slightly in the more general cases.

To make the paper accessible to the "non-technical" reader the formal derivations have been placed in the appendix of the paper.

In the second section results obtained so far in literature will be reviewed. Section IV. discusses the results obtained with the help of the model developed in section III. Finally, section V. presents a conclusion.

Throughout the paper we will assume risk averse decision makers. Such decision makers prefer a secure payment of y\$ to a lottery that pays 0\$ with probability $^1/_2$ and $2y$\$ with probability $^1/_2$. On the first view, this seems to contradict common assumptions, e.g., in portfolio management. Here, investors, although risk averse, would choose their risky portfolios as if they were risk neutral. The reason for this is that risk (in portfolio theory the so-called unsystematic risk) may be diversified away. Investors only need to bare the systematic risk which can never be diversified away.

Hence, it seems natural to assume that a rational company maximizes its expected profits. In larger companies, however, decisions are usually delegated by absentee owners to managers. The compensation of such managers is very often tied to profits. This fact, as well as possible opportunistic behavior and asymmetric information, suggest that managers behave more or less risk averse (cf. Kao/Hughes (1993, p. 103)). Consequently, expected utility of profits is maximized instead of expected profits.

A first result of our analysis shows that maximization of expected utility may lead to different optimal actions than maximization of expected profits. While the latter in general is a simple optimization problem, maximization of expected utility requires knowledge of the utility function of the decision maker. Note, that this is a more difficult and complex problem.

If costs of information sharing are sufficiently low, information sharing in general is beneficial if development know how is equally distributed. This is an expected result since then development costs may be reduced. This result, however, changes significantly if know how for development is not equally distributed between the competitors. In this case situations occur that are well-known from the treatment of "prisoner-dilemma-situations" (for a treatment of this game-theoretic problem cf. Rasmussen (1995)). Results then strongly depend on the degree of risk aversion and the market structure and nearly all "prisoner-dilemma-situations" may be constructed by suitably choosing the model parameters. First mover and follower strategies are then optimal choices depending on risk aversion of the decision makers and market structure.

In some instances, the results obtained will be surprising and contradict common expectations. It can be shown, e.g., that the use of information to reduce uncertainty may be harmful for a company. Firms are paid for taking risks. If they try to reduce such risks profits and expected utility may decrease (even if risk is reduced at zero costs, see e.g. Palfrey (1982)).

Once again, such surprising results show the importance of understanding the economic effects of collaboration before deciding on investments in collaboration technologies.

II. Previous Work

In literature the effects of collaboration between competitors are not directly analyzed (except collusion). There is some literature on the effects of information sharing with respect to private or common variables. The question whether it pays off to share such information is important to analyze possible effects of collaboration with respect to information collection and/or sharing by means of suitable information systems.

Existing literature may be roughly classified into the categories homogeneous versus heterogeneous market environment, consideration of risk aversion or assumption of risk neutrality and analysis of uncertainty of private or common model parameters. Altogether, eight categories result by combining these classes.

In case of homogeneous products (no product differentiation) firms usually behave as price takers and set quantities accordingly. The most simple price-demand-function is linear and given by

$$p = a - b(q_1 + q_2).$$

Here a and b are parameters to be specified, p is the price that results if the i-th firms offers quantity q_i on the market. Uncertainty with respect to common (public) variables may be introduced by allowing a to be a random variable. Uncertainty with respect to private variables is introduced by treating the variable costs c_i of each firm as random variables.

If risk aversion of decision makers is not considered each firm maximizes expected profits. For the i-th firm profits in the most simple setting are given by

$$\Pi_i = (a - b(q_1 + q_2) - c_i)q_i.$$

Note, that in this simple setting fixed costs are not considered. Moreover, economies of scale (decreasing variable costs) are not possible.

In case of risk aversion decision makers do not maximize expected profits but the utility of expected profits. For the sake of computational simplicity constant absolute risk aversion is usually assumed. The utility function of the i-th decision maker is then given by

$$u_i(x) = 1 - \exp(-\gamma_i x).$$

The degree of risk aversion of the decision maker is measured by $\gamma_i > 0$. Higher values of this parameter result in a higher degree of risk aversion.

Fried (1984) investigates incentives for information production and disclosure in a duopolistic environment. The focus is on unknown variable costs. Variable costs have two components of uncertainty. First, there is a common component related to the economy, second, there is a firm-specific component. Fried assumes, that decisions are first made about information production and disclosure. The decision made by each firm is known and enforceable. Then four scenarios need to be analyzed: (1) Neither firm F_1 nor firm F_2 produces and discloses private information, (2) firm F_1 discloses while firm F_2 does not, (3) the roles of firm F_1 and F_2 in the second scenario are interchanged and (4) both firms produce and disclose information. Each scenario is analyzed in detail and a so-called Nash-equilibrium is determined. In such an equilibrium neither firm has an incentive to change its strategy. For details of Nash-equilibria refer to Rasmussen (1995, pp. 15–29 and pp. 276–279). When firm F_1 discloses information which firm F_2 does not have the result depends on how variable costs are composed of private and common factors. Disclosure of private cost components is usually beneficial, disclosure of common components generally does not pay off.

Gal-Or (1985) and Li (1985) study the effects of information sharing associated with an uncertain demand parameter a. When a firm observes a signal of low demand (this corresponds to a low value of the parameter a) disclosure of this information may prevent its competitor from overproducing. On the other hand, disclosure of a signal indicating high demand may result in a higher production of the competitor. Both authors investigated which effect was dominating. Their result suggests that information sharing is not an optimal strategy. Gal-Or assumed a normal distribution of the parameter a, Li allowed more general probability distributions. Li also analyzed the case of sharing private cost information and confirms the results of Fried.

To summarize, sharing information about private parameters pays off, sharing information about common parameters does not.

Unfortunately, these results change if risk aversion is considered. As it was already indicated, the delegation of decisions from owners to managers naturally introduces risk aversion.

Palfrey (1982) provided first insights into this situation. He showed that even the private use of information may be harmful. In particular, a firm that is less risk averse than its competitor(s) is rewarded for taking higher risks. If such a firm tries to reduce risk by using information the more risk averse competitor does not have, it is usually worse off afterwards.

More work on the subject stems from Hviid (1989) and Kao/Hughes (1993). Hviid investigates the incentives of a risk averse firm to share information. He showed that the results obtained in the case of risk neutrality need not to be true anymore. Hviid analyzed demand uncertainty and treated the parameter a as a random variable. Kao and Hughes extended the analysis of Hviid to the case of sharing firm-specific cost information.

To summarize, it can be shown that if risk aversion is considered there also may be incentives for collaboration. In most companies managers will behave as risk averters. This is the situation that usually prevails in practice.

We now turn to the case of heterogeneous products. In that case firms usually set prices. Now, each firm has its own price-demand function. In the most simple case we obtain for the i-th firm the expression

$$q_i = a - b(p_i + \delta(p_i - \bar{p})). \tag{1}$$

As in the homogeneous case a and b are parameters to be specified. δ models the degree of substitutability of the products offered in the market place. Small values of $\delta > 0$ correspond to a low degree of possible substitution (heterogeneous or highly differentiated products), high values to a high degree of substitution respectively (homogeneous products). $\bar{p}$ is the arithmetic mean of the prices of all competing firms.

Thus, it is obvious how the model extends to the case of an arbitrary oligopoly.

Gal-Or (1986) has analyzed information transmission in heterogeneous market environments for risk neutral decision makers. Uncertainty was introduced with respect to the variable costs of each firm. Uncertain costs are composed of two components, a firm-specific private and a common one. Note, that competition is based on prices now. This is why firms have an incentive to share information about common parameters. It does not pay off to share information about private parameters. This is in contrast to the homogeneous product case.

Gal-Or also analyzed the case of a heterogeneous oligopoly where quantities are set and prices are determined via the price-demand-function. The systems of price-demand-functions given in (1) is then inverted. Due to the stochastic nature of some parameters the two models are not equivalent (cf. Klemperer/Meyer (1986)). In that case firms will reveal firm-specific but not common information. This result is in line with the homogeneous case.

III. Model Building

In the following the probably most relevant case of a market with heterogeneous products where prices are set and decision makers are risk averse will be considered. The importance of heterogeneous markets and the assumption of risk aversion was already motivated.

Klemperer/Meyer (1986) have shown that generally price competition is preferred by firms in an oligopolostic market if the slope of the marginal cost curve is rather flat. Since we assume constant variable costs the slope of marginal costs is zero everywhere and the result of Klemperer and Meyer applies. Also note, that price competition prevails in a lot of interesting markets. Examples are the airline and automotive industry, as well as the financial services sector.

The starting point of our analysis is formula (1). By neglecting a constant factor (numéraire) in (1) we may assume without loss of generality that $b = 1$. Then, the demand-function of firm F_i may be rewritten as

$$q_i = a + \alpha p_j - \beta p_i, \tag{2}$$

with $0 < \alpha = \beta - 1$ and $i \neq j$. In the same way as the parameter δ in (1) α determines the degree of heterogeneity of the market under consideration. Uncertainty will be introduced to our model by treating α as a random variable. Hence, there is uncertainty about a common parameter. It is assumed that a has a normal distribution with mean μ and standard deviation σ. Both firms may predict the uncertain parameter a. This may be done e. g. by developing suitable information systems.

Since we are not interested in investigating the effects of different cost structures we suppose that both firms produce at the same variable costs. Then, we may set $c_i = 0 (i = 1,2)$ without loss of generality (see Lemma 1 of the appendix).

Decision makers have constant risk aversion. We assume that firm F_1 is less risk averse than firm F_2, i. e. $\gamma_1 < \gamma_2$.

Finally, both firms announce their prices simultaneously (case of Bertrand competition, cf. Pindyck/Rubinfeld (1992, pp. 441)). Otherwise, we would have first mover effects that may counterfeit the effects we wish to study. An extension of our analysis to the case where one firm prematurely announces prices is straightforward (see e. g. the case of Stackelberg competition, cf. Pindyck/Rubinfeld (1992, pp. 438–439)).

If $X(a,h)$ denotes the random payoff for a rational decision maker with risk aversion γ, uncertain state of nature a and possible action h the decision maker will choose h in order to maximize expected utility

$$\max_h E\{1 - \exp(-\gamma_i X(a,h))\}.$$

If $X(a,h)$ is normally distributed for each action h such a decision maker may as well maximize the expression

$$\max_h \left\{ E(X(a,h) - \frac{\gamma}{2}\mathrm{Var}(X(a,h)) \right\}. \tag{3}$$

The expression given in (3) is equal to the so-called certainty equivalent. It is the certain amount $D(h)$ such that the decision maker is indifferent between receiving $D(h)$ with certainty and receiving the uncertain payment $X(a,h)$ (cf. Copeland, Weston; 1983, p. 87). A derivation of (3) may be found in lemma 2 of the appendix by setting $c_2 = c_0 = 0$.

In our case profits of firm I are given by

$$\Pi_i(a) = p_i(a + \alpha p_j - \beta p_i). \tag{4}$$

Clearly, profits are normally distributed if a is normally distributed. Hence, decision makers may maximize a simpler expression. In particular, the omission of the exponential will permit the derivation of closed form solutions.

Four scenarios need to be analyzed in order to determine a game theoretic Nash-equilibrium:

1. None of the two firms develop the information system to predict a.
2. The less risk averse firm F_1 develops the information system, while firm F_2 does not.
3. The more risk averse firm F_2 develops the information system while F_1 does not.
4. Both firms develop the information system.

Next, we will outline the derivation of the solution to the problem of the first scenario. Both firms maximize the certainty equivalent of expected utility of their profits. First order conditions yield two reaction functions giving the optimal price of firm i as a function of the price set by firm $j (j \neq i)$. In our case the reaction functions are given by

$$p_1 = \frac{\mu + \alpha p_2}{2\beta + \gamma_1 \sigma^2}, \; p_2 = \frac{\mu + \alpha p_1}{2\beta + \gamma_2 \sigma^2}.$$

Note, that these are two equations in the unknowns p_1 and p_2. Solving this (linear) system yields equilibrium prices for both firms. After that it is straightforward to compute the value of the objective function (certainty equivalent of expected utility) and expected profits for each firm.

Also note, that in order to get positive quantities q_i some restrictions on the parameters β, γ_i, μ and σ need to hold. This is one of the problems associated with the assumed distribution of a. Given the parameters β, γ_i and μ the standard deviation σ may be chosen small enough such that prices remain positive. Moreover, σ may be chosen small enough such that with probability arbitrarily close to 1 the quantities q_i are positive.

The analysis of the second scenario is a bit different. Firm F_1 is now able to correctly predict the value of a. Thus, there is no uncertainty and the firm simply maximizes profits given the prediction $\hat{a}$. The result is the reaction function given by

$$p_1 = \frac{\hat{a} + \alpha p_2}{2\beta}. \tag{5}$$

The more risk averse firm knows that its competitor is able to predict the parameter a. Of course the result of the prediction is not known. Profits of firm F_2 are given by

$$\Pi_2(a) = (a + \alpha p_1(a) - \beta p_2) p_2.$$

Since a and also $p_1(a)$ are normally distributed F_2 may maximize the certainty equivalent of its profits instead of expected utility. The result of this maximization is given by

$$p_2 = \frac{2\beta(2\beta+\alpha)\mu}{\gamma_2\sigma^2(2\beta+\alpha)^2 + 4\beta(2\beta^2-\alpha^2)}.$$

This also constitutes the equilibrium price for F_2. Using this in (5) yields the equilibrium price for F_1. Again, we may easily compute expected profits for both firms and the certainty equivalent for firm F_2. For firm F_1 the computation of the certainty equivalent requires some further considerations. The reason is that profits of F_1 are a quadratic function of the parameter a. Then, profits do not have a normal distribution anymore and the certainty equivalent may not be computed with the help of formula (3). The necessary computations are outlined in the appendix.

The analysis of the third scenario is completely similar to the second one with the roles of the two firms interchanged. The analysis of the fourth scenario does not provide any further difficulties. The results obtained are contained in Table 1 (expected profits) and Table 2 (expected utilities) of the appendix.

IV. Discussion of Results

Suppose that $\alpha = 5, \mu = 10, \gamma_1 = 0.2$ and $\gamma_2 = 0.5$ holds. Fig. 1 shows the differences of the certainty equivalents $C_{i\_12} = C_{i1} - C_{i2}$ (solid line) and expected profits $D_{i\_12} = \hat{\Pi}_{i1} - \hat{\Pi}_{i2}$ (dotted line) for $i = 1{,}2$ and σ ranging from 0 to 3. The first index i refers to the i-th firm, the second index j to the scenario analyzed, correspondingly.

Fig. 2 shows the differences $C_{i\_13} = C_{i1} - C_{i3}$ (solid line) and $D_{i\_13} = \hat{\Pi}_{i1} - \hat{\Pi}_{i3}$ (dotted line) for the same range of the standard deviation. Higher values of σ are not considered, since negative quantities with non-neglectable probability may result.

Furthermore, at the beginning of our analysis we assume that there are no costs for information system development and information collection.

First note, that certainty equivalent and expected profits may suggest different behavior. This is best seen with $\sigma \approx 1.5$ in Fig. 4 for F_2. The certainty equivalents suggest that F_2 should not act as a follower (positive difference), while expected profits suggest the opposite in that case. This is due to the risk aversion of firm F_2. Also note, that both firms should

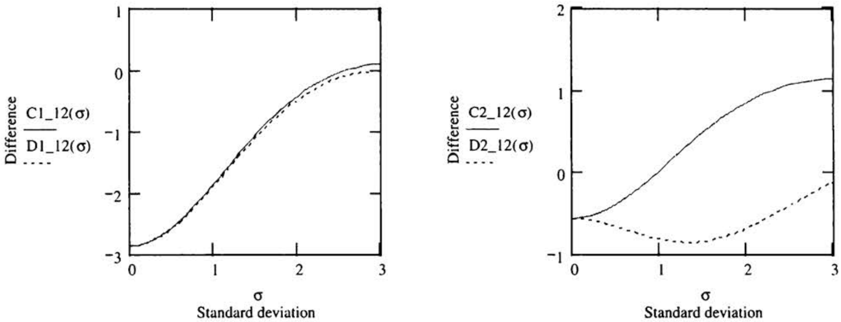

Figure 1: Comparison of Scenarios 1 and 2 for Firm F_1 (left) and Firm F_2 (right)

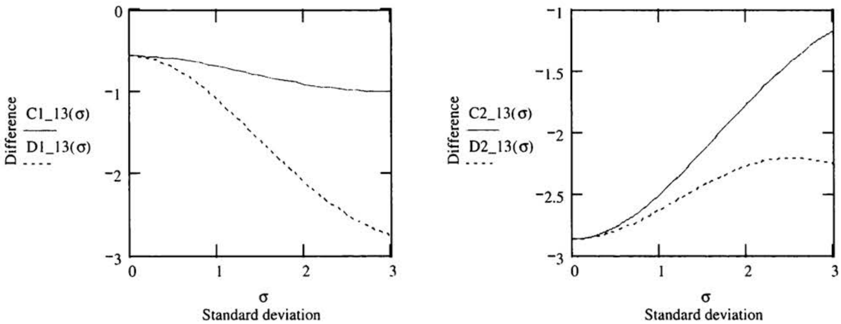

Figure 2: Comparison of Scenarios 1 and 3 for Firm F_1 (left) and Firm F_2 (right)

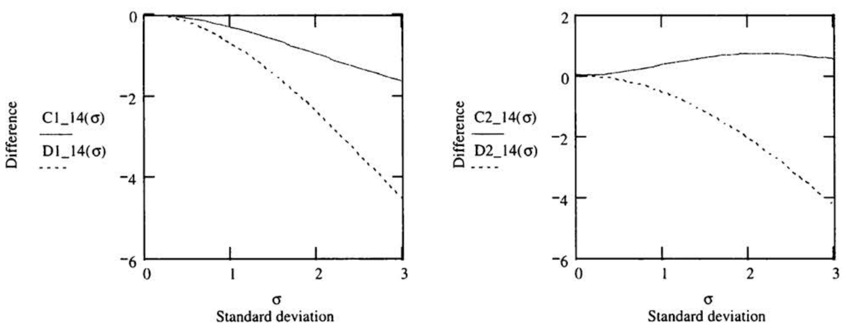

Figure 3: Comparison of Scenarios 1 and 4 for Firm F_1 (left) and Firm F_2 (right)

behave as first movers (see Fig. 1 and Fig. 2) and that the fourth scenario is optimal and will result as equilibrium for larger values of σ (e.g. $\sigma \geq 2$; see Fig. 3 and Fig. 4).

We now consider $\sigma \geq 2$. If development costs are sufficiently low, collaboration in the form of joint application development simply may halve these costs for each firm. This is beneficial for both firms. Suppose now that knowledge and ability are distributed in such a way that only firm F_1 may construct a suitable system to predict the stochastic parameter a. Firm F_1 would still be a first mover. This will lead us to the second scenario. Fig. 4 shows the differences in the certainty equivalents and expected profits for scenarios 2 and 4.

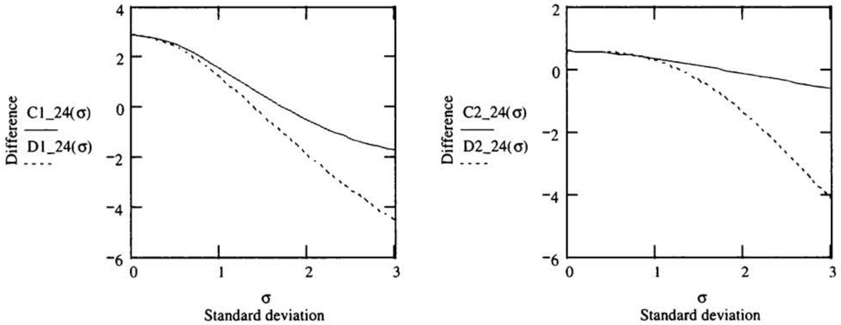

Figure 4: Comparison of Scenarios 2 and 4 for Firm F_1 (left) and Firm F_2 (right)

Firm F_1 has an incentive to communicate its predictions to F_2, since it may improve if F_2 is able to predict a, too. This shows that even if F_1 has unique knowledge and abilities it may pay off to share them with a competitor. This is a strong case for collaboration. Of course, F_1 should receive some kind of compensation (if costs are incurred this compensation should be at least one half of its development and/or periodic costs). Note, that this result is in line with the result of Gal-Or; 1986 for risk neutral decision makers since it pays to communicate common information. A reason for this might be that the risk aversion of the two firms is rather small. Then they nearly behave like risk neutral decision makers.

This hypothesis is supported if risk aversion of both firms is increased. Let e.g. $\gamma_1 = 1, \gamma_2 = 1.7$ and $\sigma = 2$. Then F_1 has no incentive to be a first mover. If costs are not considered F_2 should act as first mover. Hence, we reach the third scenario. F_1 also benefits from the actions of F_2. In fact, it should now act as a follower since it would further improve. This, however, would be bad for F_2. It would be worse off than in the first scenario. Anticipating this situation F_2 would probably abstain from development. If knowledge and ability is not equally distributed and F_2 has an advantage over F_1 it may use this advantage and start developing the system. In that case there is no incentive for collaboration since this would harm its expected utility. Now the result contradicts the result of Gal-Or; 1986.

Table 1

Certainty Equivalents for $\gamma_1 = 1$, $\gamma_2 = 1.7$ and $\sigma = 2$, Firm F_1 (left), Firm F_2 (right)

Firm 1/Firm 2	no development	development	Firm 1/Firm 2	no development	development
no development	5.957	6.327	no development	5.450	5.967
development	5.670	6.527	development	4.672	4.883

If development and/or periodic costs are incurred results may of course change. The certainty equivalent is additive in certain payments. Consequently, the existence of such costs would shift the curves upward in Fig. 1 for F_1, in Fig. 2 for F_2 and in Fig. 3 for both of them. In Fig. 4 there would be an upward shift for F_2. If costs are high enough it may not pay off at all to develop a suitable system. If costs remain small the effects of an upward shift do not change the results.

V. Conclusion

The case of duopolistic competition in a heterogeneous market environment with risk averse decision makers has been analyzed. The two firms had the opportunity to predict a common stochastic parameter a, in order to reduce uncertainty. It has been investigated whether it pays to collaborate in predicting this parameter. Collaboration may be done by means of joint system development and/or by information sharing. It can be shown that collaboration may or may not be a good strategy depending on the kind of market structure, the risk aversion of managers, the size of necessary investments and the distribution of knowledge and ability. It was shown that even if one of the firm has knowledge or abilities its competitor does not have it might pay to share these assets with the competitor. This is a somehow surprising result since knowledge and ability are usually seen as important assets that may allow to gain sustaining competitive advantages.

The presented model may be extended in a variety of ways in order to make it more realistic. Other distributions of a may be used. In particular it makes sense to restrict a to a certain interval $[A, B]$. Then the use of a beta-distribution would allow to model nearly arbitrary distributions of a with a single peak. The results remain the same but closed-form solutions may not be derived anymore. Of course it is possible to use other price-demand and/or utility functions too. Numerical simulations have been carried out with quadratic demand and utility functions. Again, the spirit of the results does not change. Another line of generalization is to use firm-specific parameters β_i. Again, this does not significantly change the results. Finally we may investigate the effects of different cost structures, as well as the effects of announcing prices earlier than the competitor. In general, a firm with lower variable costs or a firm that announces its decisions earlier, faces an advantage. Depending on which firm has lower costs or announces earlier the results presented may be offset by these effects.

For decision makers it is important to understand the economical effects of collaboration. Factors that need to be analyzed have been identified in the paper. Moreover, decision makers should use models from game theory in order to anticipate rival's behavior. Of course the simple model that was presented in this paper is only a first step towards more sophisticated simulation approaches with more realistic assumptions and data used.

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Appendix

Lemma 1

If both firms have the same variable costs c we may assume without loss of generality that $c = 0$ holds.

Proof.

Profits of the i-th firm are given by

$$\Pi_i = (p_i - c)(a + \alpha p_j - \beta p_i).$$

Substituting $\hat{p}_k = p_k - c$ for $k = 1{,}2$ and using $\beta = \alpha + 1$ yields

$$\Pi_i = \hat{p}_i(a + \alpha\hat{p}_j - \beta\hat{p}_i + \alpha c - \beta c) = \hat{p}_i(a - c + \alpha\hat{p}_j - \beta\hat{p}_i).$$

This is the problem with zero variable costs if a is assumed to have a normal distribution with mean $\mu - c$ and variance σ^2. ◆

Lemma 2

Let a have a normal distribution with mean μ and standard deviation σ. Suppose further that a decision maker has constant risk aversion γ. The certainty equivalent C of this decision maker for the payoff $c_2a^2 + c_1a + c_0$ is then given by

$$C = \frac{1}{2\gamma}\ln\left[1 + 2c_2\gamma\sigma^2\right] + c_0 + \frac{2c_2\mu^2 + 2c_1\mu - c_1^2\gamma\sigma^2}{2(1 + 2c_2\gamma\sigma^2)}.$$

Proof.

For the density of a normal distribution with mean μ and standard deviation σ we have

$$\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{\infty}\exp(-\frac{1}{2}(\frac{x-\mu}{\sigma})^2)dx = 1.$$

Expected utility R of our decision maker is given by

$$\begin{aligned} R &= \frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{\infty}\exp(-\frac{1}{2}(\frac{a-\mu}{\sigma})^2)\left[1-\exp(-\gamma(c_2a^2+c_1a+c_0)\right]da \\ &= 1-\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{\infty}\exp(-\frac{1}{2}(\frac{a-\mu}{\sigma})^2)\exp(-\gamma(c_2a^2+c_1a+c_0)da = 1-I. \end{aligned}$$

Using standard techniques from calculus the last integral I may be evaluated to get

$$I = (1+2c_2\gamma\sigma^2)^{-1/2}\exp(-\gamma(c_0+\frac{2c_2\mu^2+2c_1\mu-c_1^2\gamma\sigma^2}{2(1+2c_2\gamma\sigma^2)})).$$

By assumption the utility function of our decision maker is given by

$$u(x) = 1-\exp(-\gamma x).$$

Consequently

$$x = -\frac{\ln(1-u(x))}{\gamma}.$$

For the certainty equivalent this yields

$$C = u^{-1}(R) = u^{-1}(1-I) = -\frac{\ln(I)}{\gamma}.$$

From this the claim readily follows. ◆

Lemma 2 may be used to compute the certainty equivalent for firm F_1 in scenarios 2 and 4 and for firm F_2 in scenarios 3 and 4. Expected profits are quadratic functions of a. To see this, note, that by (4) the right factor is a linear function of a. In scenarios 2 and 4 for the first and scenarios 3 and 4 for the second firm $p_1(a)$ and $p_2(a)$ are also linear functions of a. Then, the product in (4) is a quadratic function of a and may be rewritten in the form $c_2a^2 + c_1a + c_0$ with suitable constants $c_i(i = 0, 1, 2)$.

Table 1

Expected Profits of Firms ($\hat{\Pi}_{ij}$: Expected profits of firm F_i in scenario j)

$$\hat{\Pi}_{11} = \frac{\mu^2(\beta + \gamma_1\sigma^2)(2\beta + \alpha + \gamma_2 o^2)^2}{(4\beta^2 - \alpha^2 + 2\beta\sigma^2(\gamma_1 + \gamma_2) + \gamma_1\gamma_2\sigma^4)^2}$$

$$\hat{\Pi}_{12} = \frac{\sigma^2}{4\beta} + \mu^2 \frac{(2\beta(4\beta^2 + 2\alpha\beta - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)^2}{4\beta(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)^2}$$

$$\hat{\Pi}_{13} = \frac{\mu^2(2\beta + \alpha)^2((2\beta + \alpha)^2\gamma_1\sigma^2 + 2\beta(2\beta^2 - \alpha^2))}{(4\beta(\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)^2} \qquad \hat{\Pi}_{14} = \frac{\beta(\mu^2 + \sigma^2)}{(2\beta - \alpha)^2}$$

$$\hat{\Pi}_{21} = \frac{\mu^2(\beta + \gamma_2\sigma^2)(2\beta + \alpha + \gamma_1 o^2)^2}{(4\beta^2 - \alpha^2 + 2\beta\sigma^2(\gamma_1 + \gamma_2) + \gamma_1\gamma_2\sigma^4)^2}$$

$$\hat{\Pi}_{22} = \frac{\mu^2(2\beta + \alpha)^2((2\beta + \alpha)^2\gamma_2\sigma^2 + 2\beta(2\beta^2 - \alpha^2))}{(4\beta(\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)^2}$$

$$\hat{\Pi}_{23} = \frac{\sigma^2}{4\beta} + \mu^2 \frac{(2\beta(4\beta^2 + 2\alpha\beta - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)^2}{4\beta(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)^2} \qquad \hat{\Pi}_{24} = \frac{\beta(\mu^2 + \sigma^2)}{(2\beta - \alpha)^2}$$

Table 2

Certainty Equivalents of Firms (C_{ij}: Certainty equivalent of firm F_i in scenario j)

$$C_{11} = \frac{\mu^2(2\beta + \gamma_1\sigma^2)(2\beta + \alpha + \gamma_2\sigma^2)^2}{2(4\beta^2 - \alpha^2 + 2\beta\sigma^2(\gamma_1 + \gamma_2) + \gamma_1\gamma_2\sigma^4)^2} \qquad C_{13} = \frac{\mu^2(2\beta + \alpha)^2}{2(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)}$$

$$C_{12} = \frac{1}{2\gamma_1}\ln\left[1 + \frac{\gamma_1\sigma^2}{2\beta}\right] + \frac{\mu^2(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)^2}{2(2\beta + \gamma_1\sigma^2)(2\beta(4\beta^2 + 2\alpha\beta - \alpha^2) + (2\beta + \alpha)^2\gamma_1\sigma^2)^2}$$

$$C_{14} = \frac{1}{2\gamma_1}\ln\left[1 + \frac{2\beta\gamma_1\sigma^2}{(2\beta - \alpha)^2}\right] + \frac{\beta\mu^2}{2\beta\gamma_1\sigma^2 + (2\beta - \alpha)^2}$$

$$C_{21} = \frac{\mu^2(2\beta + \gamma_2\sigma^2)(2\beta + \alpha + \gamma_1\sigma^2)^2}{2(4\beta^2 - \alpha^2 + 2\beta\sigma^2(\gamma_1 + \gamma_2) + \gamma_1\gamma_2\sigma^4)^2} \qquad C_{22} = \frac{\mu^2(2\beta + \alpha)^2}{2(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)}$$

$$C_{23} = \frac{1}{2\gamma_2}\ln\left[1 + \frac{\gamma_2\sigma^2}{2\beta}\right] + \frac{\mu^2(4\beta(2\beta^2 - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)^2}{2(2\beta + \gamma_1\sigma^2)(2\beta(4\beta^2 + 2\alpha\beta - \alpha^2) + (2\beta + \alpha)^2\gamma_2\sigma^2)^2}$$

$$C_{24} = \frac{1}{2\gamma_2}\ln\left[1 + \frac{2\beta\gamma_1\sigma^2}{(2\beta - \alpha)^2}\right] + \frac{\beta\mu^2}{2\beta\gamma_2\sigma^2 + (2\beta - \alpha)^2}$$

Summary

An Economic Analysis of Collaboration Between Competing Firms

To understand adoption of collaborative systems, it is of great importance to know about economical effects of collaboration itself. Decision makers should be able to value potential drawbacks and advantages of collaboration. Based on this estimation, the potential of collaborative technology may be determined. Throughout the paper we are interested in the effects of collaboration across a firm's boundary. There is vast literature on economical effects of collaboration among companies situated along different phases of the value chain. At least in economical terms this seems to be a well understood problem. The situation is different with respect to collaboration between competing companies. Strategies of firms may be seen as a mixture of cost reduction, product differentiation and improvement of decision making and/or planning. In this context information technology may help a firm to create sustaining competitive advantages over competitors. It is less clear whether collaboration is of any use in such an environment. According to the economics literature, the most important factors affecting benefits of collaboration are market structure, kind and degree of uncertainty faced by the firms, their risk preferences and the type(s) of product(s) offered (homogeneous or heterogeneous products). The results reported depend on the way these factors are combined. They partially contradict each other. In this paper we will analyze the most relevant case of an oligopoly with differentiated products, demand uncertainty and risk averse managers. This combination has not yet been examined in detail, although it is the most realistic case. We will present a microeconomic model and use techniques from game theory for the analysis. The way the model is constructed will allow the derivation of closed-form solutions. Results indicating whether collaboration in various areas makes sense will be obtained. This makes it possible to judge the potential of available collaborative technology. The simple model presented may be extended in a variety of ways. Some directions for possible generalization are indicated. (JEL C0, C70, L10)

Zusammenfassung

Eine ökonomische Analyse der Kooperation zwischen Wettbewerbern

Kooperation spielt nicht zuletzt unter dem Aspekt ständig steigender Entwicklungskosten eine wichtige Rolle bei der Entwicklung von Informationssystemen. Entscheidungsträger sollten deshalb die ökonomischen Effekte derartiger Entwicklungspartnerschaften verstehen, um rationale Entscheidungen zu fällen. Im Rahmen der Arbeit werden die ökonomischen Effekte von Entwicklungspartnerschaften zwischen Wettbewerbern detailliert analysiert. Bei der gemeinsamen Entwicklungsarbeit wird natürlich oft wertvolles Wissen an Konkurrenten weitergegeben. Dies spricht gegen Kooperation, während das Einsparen von Entwicklungskosten eher dafür spricht. Insofern ist nicht klar, ob Kooperationen zwischen Wettbewerbern sinnvoll sein können. In der Literatur werden zahlreiche Modelle diskutiert. Die wichtigsten Faktoren, die eine Kooperationsentscheidung beeinflussen, sind dabei Markt- und Produktstruktur, Art und Umfang der vorherrschenden Unsicherheit sowie die Risikopräferenzen der Entscheidungsträger. Die in der Literatur diskutierten Ergebnisse unterscheiden sich dabei je nachdem, wie man diese Faktoren kombiniert. Der aus Sicht der Praxis wichtigste Fall liegt bei oligopolistischer Marktstruktur, heterogenen Produkten und risikoaversen Entscheidungsträgern, die Nutzenmaximierung betreiben, vor. Dieser Fall wurde nicht zuletzt aufgrund seiner Komplexität bisher nicht umfassend analysiert und ist Gegenstand dieser Arbeit. Die Analyse erfolgt anhand eines formalen Optimierungsmodells, das die Bestimmung von geschlossenen Lösungen erlaubt. Das Modell kann in verschiedene Richtungen erweitert und so besser an die Realität angepasst werden.

Résumé

Une analyse économique de la coopération entre des firmes concurrentes

Pour comprendre l'adoption des systèmes de coopération, il est d'une grande importance de connaître les effets économiques de la coopération elle-même. Les preneurs de décision devraient être capable d'évaluer les inconvénients et les avantages de la coopération. Sur base de cette estimation, le potentiel de la coopé-

ration technologique pourrait être déterminé. Dans ce travail, l'auteur s'intéresse aux effets de la coopération à travers un partenariat de firmes. Il existe une vaste littérature sur les effets économiques de la coopération entre les firmes des différentes phases de la chaîne de valeur. Au moins en termes économiques, ceci semble être un problème bien compris. La situation est différente pour ce qui est de la coopération entre les firmes concurrentes. Les stratégies peuvent être considérées comme un mélange de réduction de coûts, différentiation de produits et amélioration de la prise de décision et/ou du planning. Dans ce contexte, la technologie de l'information peut aider une firme à créer des avantages compétitifs soutenus sur les concurrents. Il est moins clair si la coopération est d'une quelconque utilité dans un tel environnement. Selon la littérature économique, les facteurs les plus importants affectant les bénéfices de la coopération sont la structure du marché, la forme et le degré d'incertitude à laquelle font face les firmes, leurs préférences pour le risque et le(s) type(s) de produit(s) offert(s) – produits homogènes ou hétérogènes. Les résultats rapportés dépendent de la manière dont ces facteurs sont combinés. Ils se contredisent en partie les uns les autres. Dans ce travail, l'auteur analyse le cas le plus intéressant d'un oligopole avec des produits différenciés, une incertitude de la demande et des managers averses aux risques. Cette combinaison n'a pas encore été analysée en détail, bien que ce soit le cas le plus réaliste. L'auteur présente un modèle micro-économique et utilise pour l'analyse des techniques de la théorie des jeux. La manière dont le modèle est construit permettra la dérivation de solutions de forme fermée (closed-form solutions). On obtiendra des résultats indiquant si la coopération dans différents domaines a du sens ou non. Ceci permet de juger le potentiel de la coopération technologique disponible. Le modèle simple présenté peut être étendu de différentes manières et être ainsi mieux adapté à la réalité.