ELECTRONIC COMMERCE AND COLLABORATION BETWEEN COMPETING FIRMS

Eberhard Stickel
Dept. of Information Systems, Viadrina University Frankfurt (Oder),
PO Box 776, 15207 Frankfurt (Oder), Germany
Phone: +49 335 5534 358, Fax: +49 335 5534 357,
eMail:stickel@euv-frankfurt-o.de

ABSTRACT

Investments in electronic commerce technology typically require large sums of money and the realisation of possible benefits is often highly uncertain. Possible investors may also be confronted with the so-called free-rider-problem. Innovators have to bear all development costs. Once standards are established followers (free-riders) may easily imitate the investment. Hence, innovators may not be able to build up sustaining competitive advantages that make their investments worthwhile. As a result, available technology may not be used in an efficient way. A typical prisoner's dilemma scenario prevails. Pre-competitive collaboration may be a possible solution to this problem. The term „pre-competitive" refers to the possibility of joint application development and/or sharing of information, knowledge and ability. It should not be confused with collusion which may be legally restricted or even forbidden. The goal of the paper is to analyse whether there are economic incentives for pre-competitive collaboration as sketched above. The analysis is carried out with the help of a microeconomic model and techniques from game theory.

INTRODUCTION

Investments in electronic commerce technology typically require large sums of money and the realisation of possible benefits is often highly uncertain. Possible investors may also be confronted with the so-called free-rider-problem. Innovators have to bear all development costs. Once standards are established followers (free-riders) may easily imitate the investment. Hence, innovators may not be able to build up sustaining competitive advantages that make their investments worthwhile. Sustainability, however, is of crucial importance if IT-investments are pursued with the goal of building up competitive advantages (Kettinger et al., 1994).
As a result, available technology may not be used in an efficient way since potential innovators may abstain from investment. This corresponds to a typical prisoner's dilemma situation.
A possible solution to this problem would be some sort of pre-competitive collaboration commitment between competing firms. Pre-competitive refers to the possibility of joint application development and/or sharing of information, knowledge and ability. Pre-competitive collaboration should not be confused with collusion which may be legally restricted or even forbidden (Tirole, 1997).
The goal of the paper is to analyse whether there are economic incentives for pre-competitive collaboration as sketched above. The analysis is carried out with the help of a microeconomic model and techniques from game theory.
Collaboration between firms that are located in different phases of the value chain (typically supplier-purchaser-relationships) is a quite well-studied problem. The institutional structure of supplier-purchaser-relationships has changed significantly over the last few years (Bauer & Stickel, 1996). More often coordination through markets and collaboration (network organisations, strategic alliances) instead of pure hierarchical coordination may be observed. The role of IT in this process was investigated in the literature. Malone et al. (1987) propose the so-called 'Move-to-the-Market'-hypothesis. Basically it is stated that complex products are more likely to be obtained through hierarchical than through market coordination due to communication costs. Since IT may decrease communication costs, Malone et al. argue that a shift towards market coordination should occur. Also, product specificity should decrease. Unfortunately, the authors do not investigate the specificity of IT-investments themselves. Highly specific IT-investments may allow opportunistic behaviour and may incur additional costs (agency costs). This increase may very well exceed the savings with respect to communication costs. More work on the subject was done by Clemons & Reddi (1994). They proposed the so-called 'Move-to-the-Middle'-hypothesis. It is argued that the use of IT involves a learning curve. Hence, long-term collaboration will be preferred to short-term market arrangements. Long-term collaboration will allow companies to longer enjoy the benefits of their IT-investments. Empirical research basically supports this hypothesis (Bauer & Stickel, 1996, p. 49).
The work mentioned above is concerned with issues of vertical integration and not with collaboration among competing firms (horizontal integration). The latter issue is addressed in the work presented here. It is investigated under what conditions information and/or knowledge sharing is beneficial.
Investments in electronic commerce technology typically are strategic investments. Such investments are considered to be long-term investments with the goal to exploit possible competitive advantages. According to the literature strategies of firms may be seen as a mixture of cost reduction, product differentiation and improvement of decision making and/or planning (Porter, 1985). The case of product differentiation will not be considered in this paper. As will be indicated, results are similar to the results presented here, however.

Investments in electronic commerce technology may have effects on costs. The primary focus, however, is associated with the demand side. Possible benefits include e.g. increased customer bonding, better customer services, anticipation of changes in demand and/or consumer behaviour. Generally, this implies better support for planning and decision making. Also note, that demand risk is one of the most important uncertainty factors faced by today's firms.

To keep our model simple, we necessarily have to abstract from reality. Based on the previous remarks we assume that the main focus of investments in electronic commerce technology lies on better support for planning and decision making on the demand side. This, in turn, may be viewed as decreasing uncertainty by means of suitable investments. Uncertainty is introduced into our model by means of stochastic demand parameters.

The possibility of cost reductions through investments in electronic commerce technology is addressed shortly in section 5.

The paper is organised as follows. In the next section the assumptions underlying the microeconomic model will be outlined in more detail. Also, a detailed literature review will be provided. Section 3 sketches the derivation of our results. Methods from game theory will be applied. The main steps will be motivated so that the presentation is also accessible to the non-technical specialist. The main conclusions will be drawn in the fourth section. Section 5 considers issues related to cost reductions. Finally we conclude by presenting a summary and pointing out further areas of possible research. For the sake of completeness and easier reference rather technical derivations have been placed in the appendix of the paper.

CONSTRUCTION OF THE MODEL AND LITERATURE REVIEW

A review of the microeconomic literature (see e.g. Fried, 1984, Gal-Or, 1985, Li, 1985, Hviid, 1989, Kao & Hughes, 1993) indicates that relevant factors affecting collaboration decisions between competitors are:

- *Market structure.* If perfect competition prevails collaboration is of no 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. In oligopolistic markets decisions of a firm may directly influence prices and quantities offered of the firm and its competitors.
- *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. In microeconomic theory homogeneous and heterogeneous markets are distinguished (see e.g. Pindyck & Rubinfeld, 1992, pp. 430-444). In homogeneous markets goods are perfect substitutes for each other. As a consequence, there is no product differentiation. In such markets usually quantities are set by competing firms. Then, a unique equilibrium price, which holds for all competing firms results. In heterogeneous markets firms usually set prices and apply a product differentiation strategy. Klemperer & Meyer (1986) have shown that generally price competition is preferred by firms in an oligopolostic market if the slope of their marginal cost curve is rather flat. For the sake of simplicity we will assume constant variable costs. Hence, 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. In markets with price competition, each firm acting in the market sells a certain quantity of the good offered, depending on prices set and consumer demand.
- *Risk preferences of competing firms.* In general decisions are delegated by absentee owners to managers. This is especially true in large companies. The compensation of such managers is usually tied to profits. This fact, as well as possible opportunistic behaviour and asymmetric information suggest that managers behave more or less risk averse (see e.g. Kao & Hughes, 1993). Hence, they will not maximise expected profits as if they were risk neutral but expected utility. A utility function basically accounts for the degree of risk associated with a certain payment stream (Copeland & Weston, 1983). For risk averse decision makers a secure payment h is always preferred to a random payment with expected value h. Hence, there is a positive risk premium. As can and will be shown the consideration of risk aversion significantly influences the results.
- *Kind and degree of uncertainty faced by competing firms.* Basically we may distinguish uncertainty with respect to common or private parameters. As an example consider demand parameters. They are called common variables since they are the same for all firms and directly affect profits of each firm. On the other hand variable costs are an example of private variables. They are unique to each competing firm (note however, that some components of variable costs may be considered as being common (e.g. costs influenced by the overall economy), while others (e.g. firm-specific production costs) typically are private).

- *Distribution of knowledge and ability.* Knowledge and abilities to develop, adapt and use a certain technology may not be equally distributed. The interesting question is whether sustaining competitive advantages may or may not be built on specific knowledge and ability (see Choudhoury & Sampler, 1997 for a discussion of information specifity). It will be shown that under quite reasonable assumptions sharing of knowledge and ability between competitors is beneficial for all of them. Again it should be pointed out that collusion is not intended (e.g. price and/or quantity fixing). This incentive for sharing is a strong case for collaboration between competitors.

Note, that in particular competitive effects need to be monitored carefully. In the following the homogeneous product case where quantities are set and prices determined accordingly will be analysed. The analysis of the heterogeneous product case (i.e. the case of product differentiation) proceeds along the same lines but is technically more complicated. Results will be reported elsewhere in a short while. Note, however, that the spirit of the results does not change significantly in the heterogeneous product case (Stickel, 1998).

To simplify the analysis the case of two competing firms (duopoly) will be considered. It is assumed that both firms are risk averse and that the utility function of firm F_i is given by

$$(1) \qquad u_i(x) = 1 - \exp(-\alpha_i x)$$

for $i = 1,2$. This utility function corresponds to the case of constant risk aversion according to the Arrow-Pratt risk measure (Copeland & Weston, 1983 and Dossani et al., 1995). The smaller α_i the less risk averse is the corresponding firm F_i. In the limiting case as α_i tends to zero the case of a risk neutral decision maker is obtained. Throughout the paper we will assume that firm F_1 is less risk averse than firm F_2. Consequently, $\alpha_1 < \alpha_2$ holds.

The price-demand function faced by the two firms is given by

$$(2) \qquad p = a - (x_1 + x_2).$$

In (2) a is a stochastic demand parameter that introduces uncertainty into our model. Note, that the decision of a firm influences the price p and hence the optimal decision with respect to the quantity offered on the market by its competitor. The parameter a is assumed to be normally distributed with mean μ and standard deviation σ. Obviously, negative prices and quantities should be ruled out. This certainly requires positivity of a. From elementary statistics it is well-known, that the probability of a being negative is less than 0.5% if $\mu > 2.57\ \sigma$ holds (Pindyck & Rubinfeld, 1991, p. 31). Therefore, if the mean is large enough with respect to the standard deviation a may be assumed to be positive with near certainty (in fact the probability of error may be made arbitrarily small by increasing the mean and/or decreasing the standard deviation).

If variable costs of the i-th firm are denoted by c_i its profits are given by

$$\Pi_i(x_1, x_2) = px_i - c_i x_i = (a - x_1 - x_2 - c_i)x_i.$$

A risk neutral firm would maximise the expected value of this expression given the action x_j ($j \neq i$) of its competitor. A risk averse firm, however, would maximise its expected utility

$$Eu_i\left[\Pi_i(x_1, x_2)\right]$$

where u_i is given by (1). A formal analysis of this optimisation problem would be difficult due to the exponentials in (1). The normal distribution of the parameter a and the special form of the utility functions in (1) allow to restate the optimisation problem. The i-th firm maximises the objective function

$$(3) \qquad g_i(\Pi_i(x_1, x_2)) = E\Pi_i(x_1, x_2) - \frac{\alpha_i}{2} Var(\Pi_i(x_1, x_2)).$$

The expression in (3) is the so-called certainty equivalent of the corresponding expected utility. A decision maker is indifferent between a normally distributed payment stream with mean μ and standard deviation σ and a secure payment in the amount of the certainty equivalent (Copeland & Weston, 1983). Consequently, maximising expected utility and maximising the certainty equivalent will lead to the same optimal actions. Note, that the problem given by (3) is much simpler than the original problem. In particular, (3) allows the derivation of closed-form optimal solutions. This greatly simplifies the analysis.

We also assume that both firms produce at the same constant variable costs c. Hence, there is no cost leader. The cost leader usually is rewarded with higher profits and a higher market share. This effect may strengthen or weaken the effects we wish to study in this paper. Since our goal is to analyse incentives of pre-competitive collaboration and not primarily the effects of cost leadership the assumption of zero variable costs is certainly justified. It is then very easy to show, that $c = 0$ may be assumed without loss of generality (see the appendix, lemma 1 for a proof).

Finally, we assume that both firms announce their quantities x_i simultaneously. Hence, there is no early announcement by one of the competing firms. An early announcement is usually rewarded with a larger market share. Such effects may again strengthen or weaken the results presented in the paper. The assumption of

simultaneous price announcement allows to compute the so-called Cournot-equilibrium (Tirole, 1997, pp. 218-221). More details of this computation will be outlined later.
Both firms may now use information technology to reduce demand uncertainty. To be specific they may invest and eventually predict the stochastic parameter a. In that case all uncertainty is removed for the investing firm. Another possibility would be the use of IT to reduce production costs. The case of cost reductions is discussed briefly in section 5. The interested reader is referred to Stickel (1997) where a detailed treatment may be found.
The options faced by the competing firms lead to four possible scenarios:

1. None of the firms tries to reduce risk by predicting the stochastic parameter a (peace, scenario 1),
2. Firm F_1 tries to predict a, while firm F_2 does not do so (offense, scenario 2),
3. Firm F_2 tries to predict a, while firm F_1 does not do so (defense, scenario 3),
4. Both firms try to predict a (war, scenario 4).

n case only one firm invests the rival firm knows about this investment. Of course it does not know the results of the prediction (this may be changed by means of collaboration, however).
The model, although equipped with quite restrictive assumptions, is a quite flexible one. Various extensions, e.g. use of a more realistic price-demand-function or use of different distributions of a, are possible and will be indicated later in more detail. Most of these extensions do not alter the results presented in the third section, however.
Variants of the model used in this paper have been applied in the literature to study the problem of information transmission in a duopolistic (more generally oligopolistic) market environment.
Fried (1984) investigates incentives for information production and disclosure in a duopolistic environment. Firms are assumed to be risk neutral. The focus is on unknown variable costs. In Fried's paper variable costs have two components of uncertainty. First, there is a common component related to the economy, second, there is a firm-specific private component. Fried assumes, that decisions are first made about information production and disclosure. The decisions made by each firm are known and enforceable. Production decisions will be next. Fried shows that disclosure of private cost components usually is beneficial, while 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. Note, that this is a common parameter. As Fried, they assume risk neutrality of the competing firms. 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 dominates. 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 analysed the case of sharing private cost information and confirmed the results of Fried.
To summarise, sharing information about private parameters pays off, sharing information about common parameters does not.
These results change significantly if the assumption of risk neutrality is relaxed. As 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 it 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 may very well be worse off afterwards. Stickel (1995) has extended the analysis of Palfrey to all four possible scenarios and provided an explanation for the productivity paradox of information technology. The more risk averse firm F_2 has incentives to collect information and to reduce uncertainty. The less risk averse firm F_1 should then act as a follower. Its expected profits (and expected utility) will be lower than in the case when none of the firms collects information but slightly higher than in the case when only firm F_2 collects and uses information.
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 about the parameter a. It is assumed that information production in general is beneficial. He showed that the results obtained in the case of risk neutrality need not be true anymore. Basically, the results of Palfrey are confirmed. The main focus of Hviid's paper is on mechanisms to assure correct information transmission in case information sharing is beneficial. In particular Hviid investigates the roles of information brokers (the term used in his paper was auditor). Dynamics of decision making (analysis of all possible four scenarios) and costs, as well as incentives for information production and acquisition (e.g. costs to implement a suitable information system and to maintain it) are not considered, however. Kao and Hughes extend the analysis of Hviid to the case of sharing firm-specific cost information.
The case of heterogeneous goods is not treated in the literature as extensively as the case of homogeneous goods. In case of risk neutral decision makers the results published indicate that it now pays off to share information about common parameters while it is not beneficial to share information about private variables (Gal-Or, 1986).

To summarise, in case of homogeneous goods there seem to be incentives for sharing information about common variables if both decision makers are risk averse. Then there is room for (pre-competitive) collaboration in the form of information and/or knowledge sharing. It is left open in the literature, however, whether there are *any* incentives at all for information production if risk aversion is assumed. But collaboration issues need to be closely tied to investment incentives and decisions. This point will be analysed in more detail now.
Note, that the problem investigated is a key one in the area of electronic commerce investments. Firms have to decide whether it is beneficial to pursue often costly and highly uncertain IT-investments. Collaboration may be a way to reduce uncertainty and to share costs. This, in turn may influence the initial investment decision. Hence, the issues of investment incentives and collaboration may not be separated but should be studied together.

DERIVATION OF RESULTS

Within this section the model presented will be formally analysed. The section is rather mathematical and may be skipped by the non-technical reader. Important equations have been numbered and will be referenced later on.
We begin the analysis by considering the situation at the beginning (status quo, scenario 1). Both firms face uncertain demand introduced by means of the normally distributed parameter a. As was already indicated each firm maximises its objective function (3) given the quantity offered by its competitor. The result is a reaction function showing the optimal response of firm i to an arbitrary quantity set by firm j ($i \neq j$). To be specific, consider firm F_1. Its profits depending on a and x_2 are given by

$$\Pi_1(x_1,x_2) = px_1 = (a - x_1 - x_2)x_1.$$

The expected value of the profits is given by

$$(4) \qquad E\Pi_1(x_1,x_2) = (\mu - x_1 - x_2)x_1,$$

the variance by

$$(5) \qquad Var(\Pi_1(x_1,x_2)) = \sigma^2 x_1^2.$$

Combining (4) and (5) immediately yields the objective function of the first firm. It is given by

$$(6) \qquad g_1(x_1,x_2) = (\mu - x_1 - x_2)x_1 - \frac{\alpha_1}{2}\sigma^2 x_1^2.$$

In the next step (6) has to be maximised with respect to x_1 holding x_2 fixed. First order conditions for a maximum yield the reaction function

$$(7) \qquad x_1(x_2) = \frac{\mu - x_2}{2 + \alpha_1\sigma^2}.$$

The situation for F_2 is identical. By exchanging indices we immediately get its reaction function

$$(8) \qquad x_2(x_1) = \frac{\mu - x_1}{2 + \alpha_2\sigma^2}.$$

Up to now two reaction functions have been determined. In an ideal case (7) and (8) coincide. Suppose e.g. that F_2 sets a quantity x_2. From (7) the optimal answer of F_1 in the form of its quantity x_1 set may be computed. Using this in (8) yields another quantity x_2 which in an ideal case coincides with the earlier choice of F_2. Then an equilibrium would have been obtained. By assumption, prices are set simultaneously. An equilibrium may thus be computed by solving the two reaction functions simultaneously for the unknown quantities. This is easily done, since the reaction functions form a system of two linear equations in two unknowns. Equilibrium quantities are given by

$$(9) \qquad x_1 = \mu\frac{1+\alpha_2\sigma^2}{3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4}, \quad x_2 = \mu\frac{1+\alpha_1\sigma^2}{3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4}.$$

First note, that in equilibrium the quantities offered are positive and hence meaningful. Also, note, that the less risk averse firm offers a higher quantity and hence has higher (expected) sales, higher (expected) profits as well as a larger market share. To see this divide x_1 by x_2 and note that $\alpha_1 < \alpha_2$ by assumption. The ratio is larger than 1. From this we may conclude that there is a reward for taking risk. The less risk averse firm is rewarded by higher sales, higher expected profits and a larger market share than its more risk averse competitor.
From (9) and (6) expected profits and expected utilities (to be precise the certainty equivalent of expected utility) may be easily computed. For future reference the results are stated in equations (10) and (11). Here P_{ij} and C_{ij} denote expected profits and certainty equivalent for firm F_i in scenario j:

$$(10) \qquad P_{11} = \mu^2\frac{(1+\alpha_2\sigma^2)^2(1+\alpha_1\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2}, \quad P_{21} = \mu^2\frac{(1+\alpha_1\sigma^2)^2(1+\alpha_2\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2},$$

$$(11)\; C_{11} = \frac{1}{2}\mu^2 \frac{(1+\alpha_2\sigma^2)^2(2+\alpha_1\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2},\; C_{21} = \frac{1}{2}\mu^2 \frac{(1+\alpha_1\sigma^2)^2(2+\alpha_2\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2}.$$

This completes the analysis of the first scenario. Next, we assume that firm F_1 predicts a by introducing a suitable information system, while firm F_2 does not. The analysis basically proceeds as in the first case discussed previously.

For firm F_1 all uncertainty is removed. Let a^* denote the prediction of the parameter a. Given this prediction $\Pi_1(x_1,x_2)$ is no random variable anymore. Hence its variance is zero and F_1 simply maximises profits. This leads to the objective function

$$g_1(x_1,x_2) = (a^* - x_1 - x_2)x_1.$$

First order conditions for a maximum lead to the reaction function

$$(12) \qquad x_1(x_2,a^*) = \frac{1}{2}(a^* - x_2).$$

Profits for the second firm are given by

$$(13) \qquad \Pi_2(x_1(a),x_2) = (a - x_1(a) - x_2)x_2.$$

Taking expectations in (13) yields

$$E\Pi_2(x_1(a),x_2) = (\mu - x_1(\mu) - x_2)x_2.$$

Finally, we need to compute the variance of Π_2. For this we get

$$(14) \qquad Var(\Pi_2(x_1(a),x_2) = x_2^2 Var(a - x_1(a)) = x_2^2\left[\sigma^2 + Var(x_1(a)) - 2Cov(a,x_1(a))\right].$$

From (12) it follows

$$Var(x_1(a)) = \frac{1}{4}\sigma^2$$

and

$$Cov(a,x_1(a)) = \frac{1}{2}Cov(a,a) = \frac{1}{2}\sigma^2.$$

Collecting terms in (14) finally yields the objective function

$$(15) \qquad g_2(x_1(a),x_2) = (\mu - x_1(\mu) - x_2)x_2 - \frac{\alpha_2}{8}\sigma^2 x_2.$$

The difference in the objective function stems from the fact that F_2 knows about the prediction of F_1. It does not know the predicted value a^*, however. Since both firms announce their quantities offered simultaneously we may not substitute (12) in the formula for g_2. Otherwise we would assume that F_1 announces its quantities earlier than F_2 (cf. Pindyck & Rubinfeld, 1992, pp. 438-439).

Using first order conditions (15) is maximised with respect to x_2. After differentiation (12) is used and the equilibrium price

$$(16) \qquad x_2 = \frac{2\mu}{6+\alpha_2\sigma^2}$$

results. Using this in (12) yields the equilibrium

$$(17) \qquad x_1(a^*) = \frac{a^*(6+\alpha_2\sigma^2) - 2\mu}{2(6+\alpha_2\sigma^2)}.$$

On average F_1 charges the price

$$(18) \qquad Ex_1 = \frac{\mu(4+\alpha_2\sigma^2)}{2(6+\alpha_2\sigma^2)}.$$

Note again, that expected prices (16) and (18) of both firms are positive and hence meaningful. Also, if σ^2 is small enough the expression in (17) is positive with probability arbitrarily close to zero.

In order to compare the results to the ones in scenario 1 we need to take expectations. Note, that uncertainty for the first firm is only resolved in a single period. To decide about the benefits of a suitable IT-investment that allows information production more periods need to be considered. Thus, over time there still is uncertainty for both firms. Expected profits of both firms may be easily computed. We get

$$(19) \qquad P_{12} = \frac{(\mu^2+\sigma^2)(4+\alpha_2\sigma^2)^2 + 4\sigma^2(5+\alpha_2\sigma^2)}{4(6+\alpha_2\sigma^2)^2},\; P_{22} = \mu^2\frac{(4+\alpha_2\sigma^2)}{(6+\alpha_2\sigma^2)^2}.$$

The certainty equivalent for the second firm is also easily derived. A straightforward computation yields

$$(20) \qquad C_{22} = \mu^2 \frac{(8+\alpha_2\sigma^2)}{2(6+\alpha_2\sigma^2)^2}.$$

The situation for firm F_1 is a little bit more tricky and complicated. The utility function given by (1) was substituted by the objective function (3). It was argued that the maximisation of (3) is equivalent to the maximisation of expected utility. This is true since (3) is the corresponding certainty equivalent in case that the underlying random variable is normally distributed. Clearly this holds for a. In the first scenario profits and objective functions have been linear functions of a. This is also true for the profits of firm F_2 and the objective functions of both firms in the second scenario. Hence, instead of computing expected utility of normally distributed profits we might as well use (3) with expected value and variance of the profits. Profits of firm F_1 in scenario 2 are quadratic functions of a, however. To be specific, we have

$$(21) \qquad \Pi_1(a^*) = \frac{(6a^* + a^*\alpha_2\sigma^2 - 2\mu)^2}{4(6+\alpha_2\sigma^2)^2}.$$

Clearly, $\Pi_1(a^*)$ is not normally distributed any more. It is still possible, however, to compute the certainty equivalent of (21). Then it is possible to compare the outcomes of scenario 1 and scenario 2 for firm F_1, too. The important formula that allows to derive the certainty equivalent of (21) is stated in the appendix (lemma 2). The result of an application of this formula to (21) is

$$(22) \qquad C_{12} = \mu^2 \frac{(4+\alpha_2\sigma^2)^2}{2(2+\alpha_1\sigma^2)(6+\alpha_2\sigma^2)^2} + \frac{1}{2\alpha_1}\ln\left(1+\frac{\alpha_1\sigma^2}{2}\right).$$

In (22) ln() denotes the natural logarithm.

This completes the analysis of scenario 2. Scenario 3 is symmetric to scenario 2. In order to get results we may simply switch the roles of firm F_1 and F_2. In the formulas only indices need to be interchanged.

Finally, in the fourth scenario both firms are able to ex ante predict the parameter a. In a single period all uncertainty is removed. Hence, a symmetric solution with the same prices and expected profits should be expected. The objective function of the i-th firm is given by

$$g_i(x_1, x_2, a^*) = (a^* - x_1 - x_2)x_i.$$

The computation of the reaction function yields

$$x_1(x_2, a^*) = \frac{1}{2}(a^* - x_2), \quad x_2(x_1, a^*) = \frac{1}{2}(a^* - x_1)$$

which clearly are symmetric. Equilibrium prices are given by

$$x_1(a^*) = x_2(a^*) = \frac{a^*}{3}.$$

The profit functions of both firms are

$$\Pi_1(a) = \Pi_2(a) = \frac{a^2}{9}.$$

Hence,

$$(23) \qquad P_{14} = P_{24} = E\left(\frac{a^2}{9}\right) = \frac{1}{9}(\mu^2 + \sigma^2).$$

It remains to compute the certainty equivalent. An application of lemma 2 of the appendix yields

$$(24) \qquad C_{i4} = \frac{\mu^2}{9+2\alpha_i\sigma^2} + \frac{1}{2\alpha_i}\ln\left(1+\frac{2}{9}\alpha_i\sigma^2\right).$$

This completes the analysis of scenario 4.

DISCUSSION OF RESULTS

For easier reference we will collect together expected profits and expected utilities for the four scenarios analysed. Table 1 contains expected profits, table 2 the certainty equivalents.

$$P_{11} = \mu^2 \frac{(1+\alpha_2\sigma^2)^2(1+\alpha_1\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2} \quad P_{21} = \mu^2 \frac{(1+\alpha_1\sigma^2)^2(1+\alpha_2\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2}$$

$$P_{12} = \frac{(\mu^2+\sigma^2)(4+\alpha_2\sigma^2)^2+4\sigma^2(5+\alpha_2\sigma^2)}{4(6+\alpha_2\sigma^2)^2} \quad P_{22} = \mu^2\frac{(4+\alpha_2\sigma^2)}{(6+\alpha_2\sigma^2)^2}$$

$$P_{13} = \mu^2\frac{(4+\alpha_1\sigma^2)}{(6+\alpha_1\sigma^2)^2} \quad P_{23} = \frac{(\mu^2+\sigma^2)(4+\alpha_1\sigma^2)^2+4\sigma^2(5+\alpha_1\sigma^2)}{4(6+\alpha_1\sigma^2)^2}$$

$$P_{14} = P_{24} = \frac{1}{9}(\mu^2+\sigma^2).$$

Table 1: Expected profits P_{ij} for firm i in scenario j

$$C_{11} = \frac{1}{2}\mu^2 \frac{(1+\alpha_2\sigma^2)^2(2+\alpha_1\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2} \quad C_{21} = \frac{1}{2}\mu^2 \frac{(1+\alpha_1\sigma^2)^2(2+\alpha_2\sigma^2)}{(3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4)^2}$$

$$C_{12} = \mu^2\frac{(4+\alpha_2\sigma^2)^2}{2(2+\alpha_1\sigma^2)(6+\alpha_2\sigma^2)^2} + \frac{1}{2\alpha_1}\ln\left(1+\frac{\alpha_1\sigma^2}{2}\right) \quad C_{22} = \mu^2\frac{(8+\alpha_2\sigma^2)}{2(6+\alpha_2\sigma^2)^2}$$

$$C_{13} = \mu^2\frac{(8+\alpha_1\sigma^2)}{2(6+\alpha_1\sigma^2)^2} \quad C_{23} = \mu^2\frac{(4+\alpha_1\sigma^2)^2}{2(2+\alpha_2\sigma^2)(6+\alpha_1\sigma^2)^2} + \frac{1}{2\alpha_2}\ln\left(1+\frac{\alpha_2\sigma^2}{2}\right)$$

$$C_{14} = \frac{\mu^2}{9+2\alpha_1\sigma^2} + \frac{1}{2\alpha_1}\ln\left(1+\frac{2}{9}\alpha_1\sigma^2\right) \quad C_{24} = \frac{\mu^2}{9+2\alpha_2\sigma^2} + \frac{1}{2\alpha_2}\ln\left(1+\frac{2}{9}\alpha_2\sigma^2\right)$$

Table 2: Certainty equivalents C_{ij} for firm i in scenario j

Note, that both firms decide on the basis of their certainty equivalents. Instead of performing a formal analysis of the differences in various scenarios we will graph the certainty equivalents and expected profits for selected parameters μ, σ, α_1 and α_2. The results derived will hold in general, however.

Let $\alpha_1 = 0.4$, $\alpha_2 = 0.7$, $\mu = 15$ be given. Fig. 1 shows the differences $C_{i1} - C_{i2}$ as a function of the standard deviation σ. Due to the non-negativity constraints it does not make sense to consider values of $\sigma > 5$.

For small and medium risks which correspond to small values of σ there is no incentive for firm F_1 to be a first mover. Moreover, the competitor of F_1 would benefit, although it does not undertake any investments. If risk increases and development as well as maintenance costs are small enough the situation changes. Then F_1 may have first mover advantages.

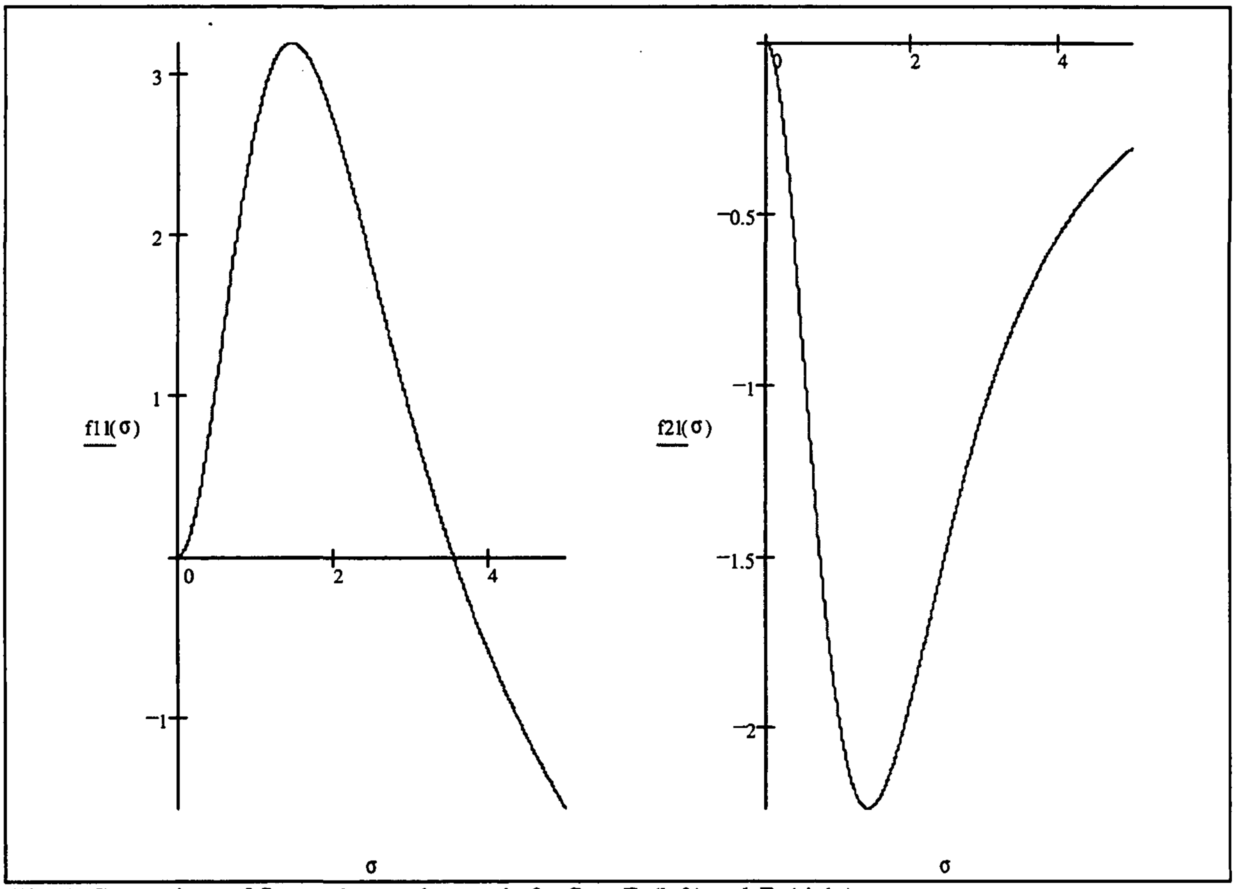

Fig. 1: Comparison of first and second scenario for firm F_1 (left) and F_2 (right)

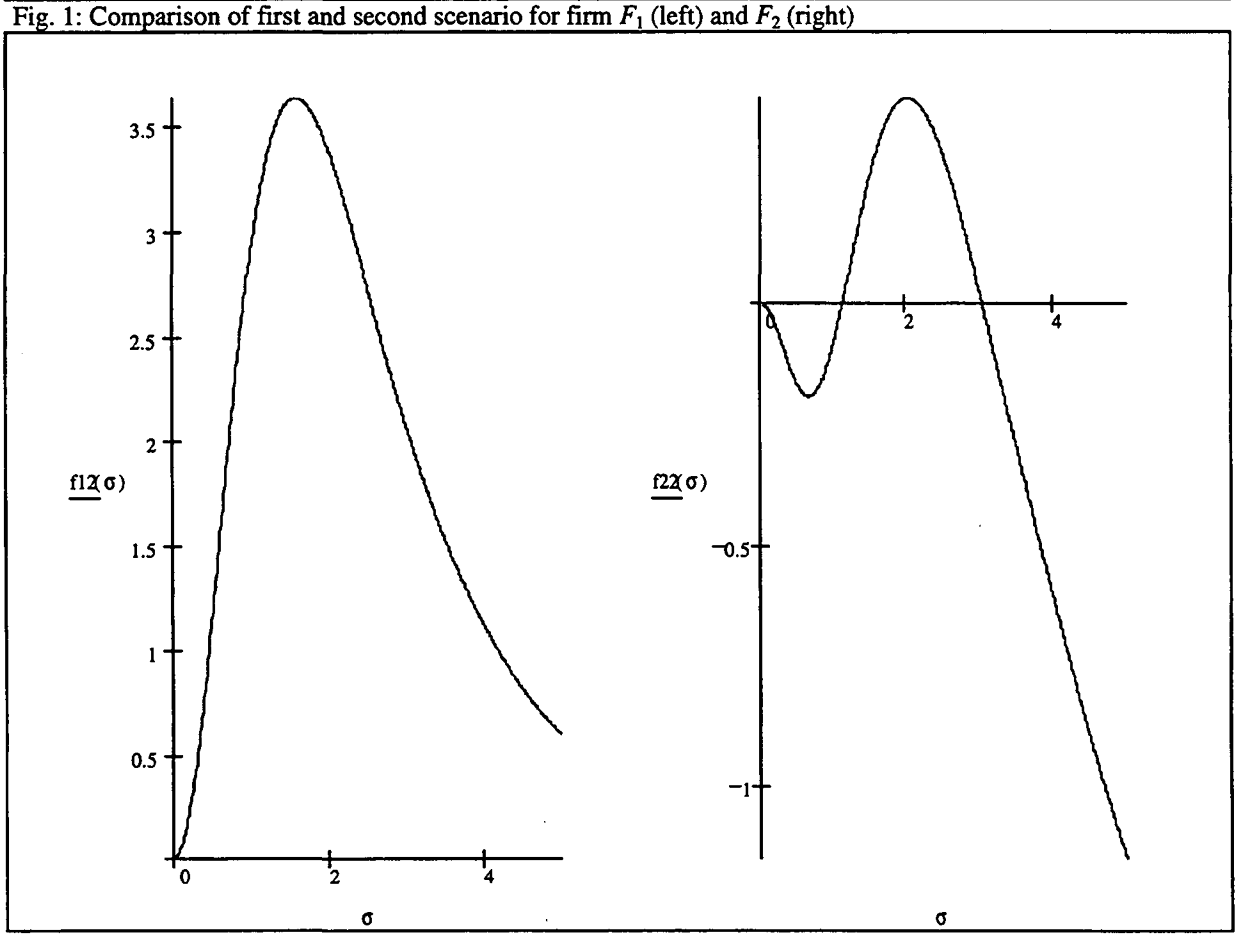

Fig. 2: Comparison of first and third scenario for firm F_1 (left) and F_2 (right)

Fig. 2 compares scenario 1 to scenario 3 by considering the differences C_{i1}-C_{i3}. The second firm has first mover advantages for smaller and larger risks if development and maintenance costs are small enough. For medium risks the first mover advantages disappear.

By comparing the graphs in Fig. 1 and Fig. 2 it is evident, that for medium risks (around σ =2) none of the firms has first mover advantages even if development and maintenance costs are zero.

Next, we will compare the first to the fourth scenario. Fig. 3 visualises the differences C_{i1}-C_{i4} for the two firms. For larger risks both firms benefit, for smaller risks only the more risk averse firm does (this result holds in general if the difference in risk aversion of the firms is not too small, otherwise there is an interval [0,σ*] with small σ* such that firm F_2 does not benefit for risks within that interval).

Finally Fig. 4 compares the third to the fourth scenario by graphing the differences C_{i3}-C_{i4}. Except for small risks F_1 always benefits and consequently should act as a follower.

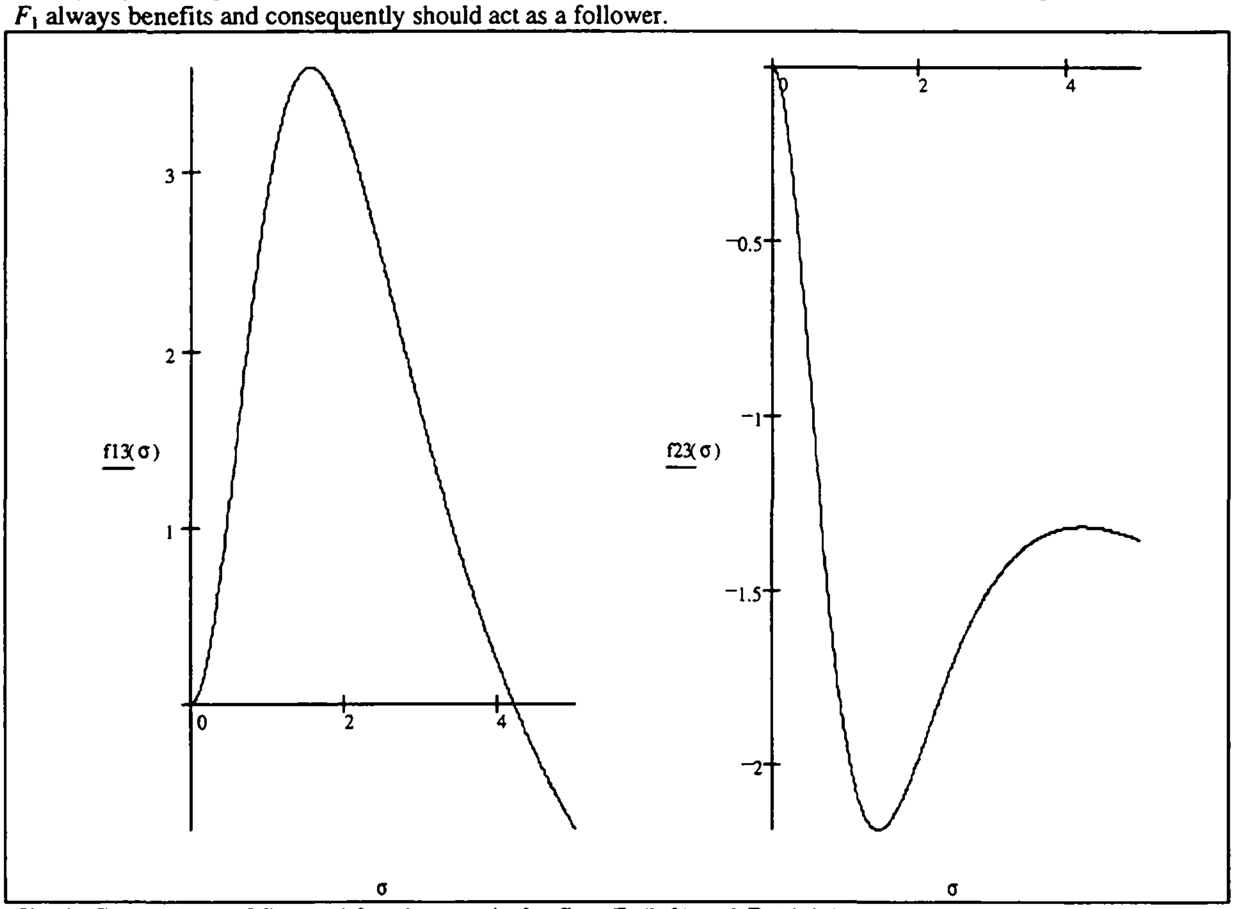

Fig. 3: Comparison of first and fourth scenario for firm F_1 (left) and F_2 (right)

The last observations made have some interesting consequences. Neglecting development and maintenance costs, if the differences in risk aversion are sufficiently high the second firm should always try to be a first mover. Firm F_1 should then be a follower except if risks are small. Then the fourth scenario would constitute an equilibrium (in game theory this is called a Nash equilibrium, none of the firms has an incentive to change its behaviour, cf. Pindyck & Rubinfeld, 1992, pp. 431-435 and 470-476). For small risks the third scenario would constitute an equilibrium.

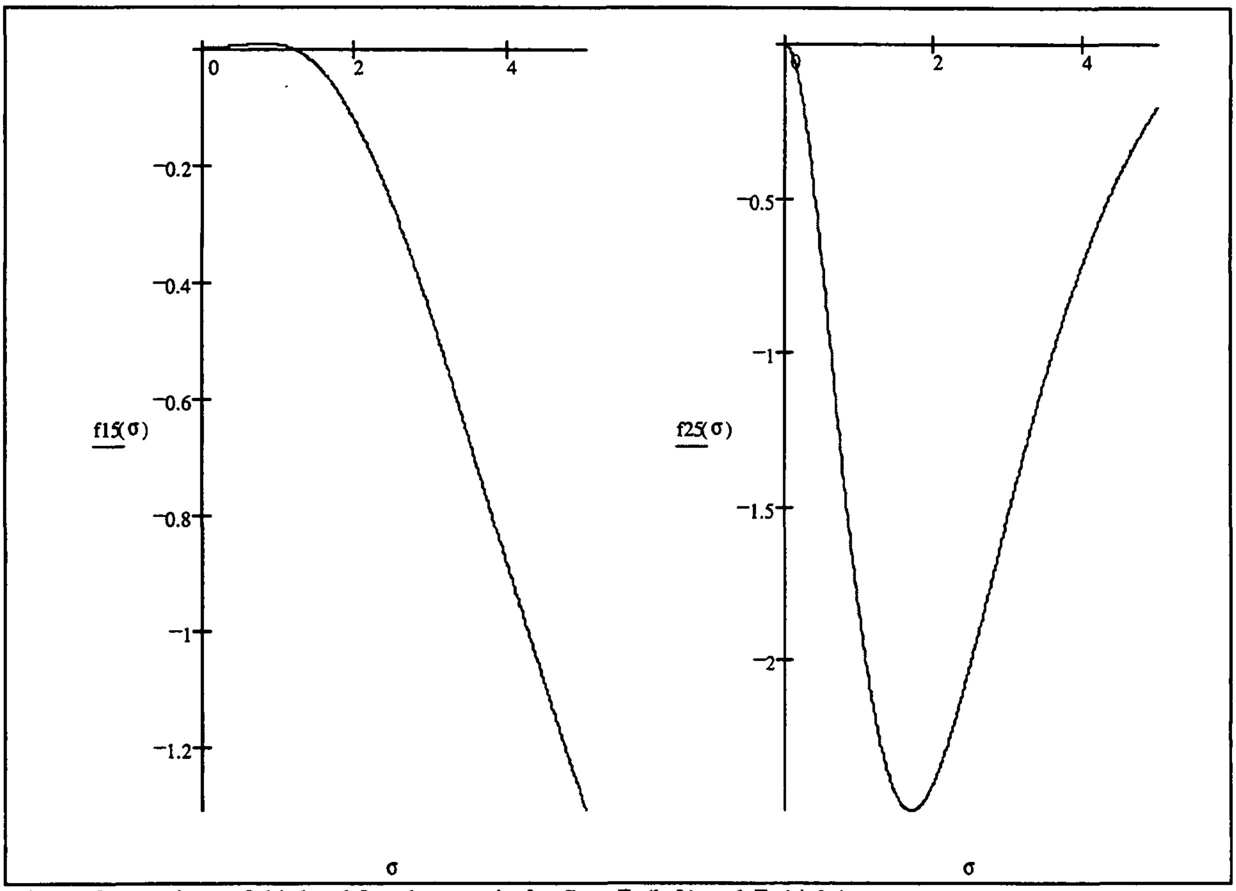

Fig. 4: Comparison of third and fourth scenario for firm F_1 (left) and F_2 (right)

We will now continue to analyse the cases presented in Fig. 1 to Fig. 4. Our goal is to indicate possible incentives for collaboration. For the sake of simplicity we consider specific examples by choosing suitable values of the parameter σ. The other parameters remain unchanged as in Fig. 1 to Fig. 4 ($\alpha_1 = 0.4$, $\alpha_2 = 0.7$, $\mu = 15$).
Table 3 contains the certainty equivalents of the two firms for the case of small σ. Note, that neither development nor maintenance costs are considered. The certainty equivalent is linear in secure payments. Hence to get the certainty equivalent in the presence of costs we merely have to deduct these costs from the corresponding numbers.

Scenario/Firm	F_1	F_2
Scenario 1	25.981	21.593
Scenario 2	24.010	23.099
Scenario 3	23.879	21.778
Scenario 4	23.871	23.048

Table 3: Results for $\sigma = 0.75$ without consideration of costs

Only the more risk averse firm F_2 has first mover advantages. If it invests the third scenario is reached. F_1 should not follow, however. Thus the fourth scenario which is the best possible situation for the second firm is not reached.
We now consider costs. It is assumed that the costs are incurred periodically (a single investment may be transformed into an annuity with a suitable number of periods). Scenario 3 will be obtained as long as the development/maintenance costs of the second firm are less than $\Delta_2 = 21.778\text{-}21.593 = 0.185$. The second firm has a strong incentive to reach the fourth scenario. This would increase the certainty equivalent by 1.270 units per period. A possible strategy would be to share the development efforts with the first firm and to compensate this firm for the losses of 0.008 units associated with the use of the system. The second firm has collaboration incentives as longs as its investment costs are lower than 1.447 (difference of fourth and first scenario minus the minimum transfer payment necessary to compensate the first firm for moving from the third to the fourth scenario).
Up to now we have assumed that IT-use is merely a matter of costs. Suppose next, that knowledge and ability with respect to developing a suitable system and/or using a specific technology are not equally distributed.

Assume that the first firm has a competitive advantage. In that case F_1 has no incentive to share its knowledge. Of course, it will not invest and use the new technology. Note, that the first scenario is optimal for this firm. Then the status quo will prevail as long as F_2 is not able to efficiently use the technology. Collaboration will not occur since there are no (economic) incentives.

Scenario/Firm	F_1	F_2
Scenario 1	22.065	13.773
Scenario 2	19.394	15.690
Scenario 3	18.698	13.350
Scenario 4	18.823	15.757

Table 4: Results for $\sigma = 2$ without consideration of costs

Next we increase σ by setting $\sigma = 2$. Table 4 contains the results with zero costs. None of the firms has first mover advantages. It was indicated above that the more risk averse firm should nevertheless invest. Then, the third scenario is reached. Now F_1 should follow and we reach the fourth scenario. Scenario 4 will be obtained as long as the development/maintenance costs of the first firm are less than Δ_1 = 18.823-18.698 = 0.125 (difference between scenario 4 and scenario 3; there is an incentive to be a follower) and the costs of the second firm are less than Δ_2 = 15.757-13.773 = 1.984 (difference between scenario 4 and scenario 1). Collaboration would make sense in order to cut down development costs.

Suppose next, that knowledge and ability with respect to using the new technology are not equally distributed. Assume that the second firm has a competitive advantage. It may develop the system at costs below Δ_2, while a similar development project would cost F_1 more than Δ_1. It is important to note that F_2 has incentives to transfer its know-how to firm F_1. Otherwise it would get stuck in the third scenario which is worse than the original status quo. On the other hand F_1 should accept the know-how transfer since it may improve. Obviously transfer payments in either direction are possible. This is a strong incentive for collaboration among competitors.

If the first firm has a competitive advantage it will not use its know-how and it will not transfer it. Again, the status quo will prevail as long as F_2 is not able to efficiently use the new technology. As in the previous case there is no incentive for collaboration.

Scenario/Firm	F_1	F_2
Scenario 1	11.650	6.735
Scenario 2	12.253	7.301
Scenario 3	10.536	7.343
Scenario 4	11.427	8.058

Table 5: Results for $\sigma = 4$ without consideration of costs

Finally, we set $\sigma = 4$. Table 5 contains the results for this case. Again, both firms face first mover advantages as long as costs remain below Δ_1 = 0.603 and Δ_2 = 0.608. Suppose firm F_1 has a competitive advantage in developing and/or maintaining a suitable information system. This firm has no incentive to share its know-how since the second scenario is the best possible world for this firm. The opposite statement holds if firm F_2 has a similar competitive advantage. This firm has vital interest in reaching the fourth scenario.

Before concluding this section the effects of technology use on consumers are analysed. As was shown the third and fourth scenarios are candidates for an equilibrium. Hence, quantities offered by the two firms need to be compared to the quantities offered at the beginning. Higher quantities result in lower prices and vice versa. Hence, consumers benefit if and only if quantities offered increase.

For the first scenario the total quantity offered may be computed using (9). This yields

$$(25) \qquad q_1 = \mu \frac{2+(\alpha_1+\alpha_2)\sigma^2}{3+2(\alpha_1+\alpha_2)\sigma^2+\alpha_1\alpha_2\sigma^4}.$$

Similar computations for the third (q_3) and fourth scenario (q_4) using expected quantities give

$$(26) \qquad q_3 = \frac{\mu(8+\alpha_1\sigma^2)}{2(6+\alpha_1\sigma^2)}, \quad q_4 = \frac{2}{3}\mu.$$

By computing the differences of the expressions in (25) and (26) it is possible to show that

$$q_4 > q_3 > q_1$$

holds. Hence, consumers always benefit from the use of the technology by the competing firms. Clearly, pre-competitive collaboration should be encouraged from a consumer's point of view. This once more demonstrates the difference between pre-competitive collaboration (which is beneficial for consumers) and collusion where prices and/or quantities are fixed or negotiated, respectively. The latter, generally is not beneficial for consumers.

EFFECTS OF COST REDUCTION

In this section the effects of cost reduction by using suitable information technology in a homogeneous duopolistic market environment are analysed. The starting point is the price-demand function (2). Now a is assumed to be fixed and consequently non-random. Suppose that the i-th firm produces at variable costs c_i. Its objective function is then given by

$$g_i(x_1, x_2) = (a - x_1 - x_2 - c_i)x_i.$$

Using first order conditions for a maximum the corresponding reaction functions are given by

$$x_1(x_2) = \frac{1}{2}(a - c_1 - x_2), \quad x_2(x_1) = \frac{1}{2}(a - c_2 - x_1).$$

From this we may compute equilibrium quantities. The result is

$$(27) \qquad x_1 = \frac{1}{3}(a + c_2 - 2c_1), \quad x_2 = \frac{1}{3}(a + c_1 - 2c_2).$$

We assume that the quantities in (27) are positive (this amounts to the assumption that a is sufficiently large with respect to variable costs). From (27) it is obvious that the firm that produces with lower costs has a higher market share and consequently also higher profits (since there is no uncertainty the certainty equivalent corresponds to profits). Profits for the firms are given by

$$(28) \qquad P_{11} = \frac{1}{9}(a + c_2 - 2c_1)^2, \quad P_{21} = \frac{1}{9}(a + c_1 - 2c_2)^2.$$

Consider next the case of cost reductions. Suppose the first firm is able to reduce costs by an amount of Δ. Then its profits will increase while the profits of the competitor decrease as (28) reveals. If one of the firms has a competitive advantage there is no incentive to share its know-how with its competitor. If knowledge and ability are equally distributed, profits of both firms increase if each firm is able to lower costs by an amount of Δ. Then, collaboration would be useful in order to cut down development costs.
In contrast to the situation in section 4 the results are as one would expect. Competitive advantages should be exploited, knowledge and ability become a strategic resource that should not be shared. In such cases firms will be extremely cautious when it comes to possible (pre-competitive) collaboration.
It is interesting to note that consumers benefit from cost reductions. Addition of the equilibrium quantities in (27) yields

$$x_1 + x_2 = \frac{1}{3}(2a - c_2 - c_1).$$

Hence, cost reductions lead to an overall increase in supply and consequently to lower prices. This corresponds to the result of section 4.

SUMMARY AND CONCLUSION

The use of electronic commerce technology may affect cost structures and/or demand/supply parameters. Decisions of two firms acting in a homogeneous duopolistic market environment have been analysed. It was investigated whether economic incentives for pre-competitive collaboration exist.
If the focus is primarily on cost reductions firms will be very cautious when the issue of collaboration arises. Know-how and ability are resources that allow to build up sustaining competitive advantages. Only if these resources are equally distributed between the competing firms collaboration is useful. Then development and/or maintenance costs may be split and therefore reduced.
The case where technology primarily influences the demand side is the more interesting one. The influence on the demand side was modelled with the help of a stochastic demand parameter. Using available technology the firms were able to reduce uncertainty and hence to exactly predict the uncertain parameter. The results derived are surprising in some cases. It was shown that situations are possible, where it is beneficial to share know-how with a competitor. Know-how refers to knowledge and ability about the technology under investigation and should not be confused with collusion. The term pre-competitive was used to characterise this form of collaboration between competing firms. Whether collaboration makes sense depends primarily on the market structure and the degree of risk aversion of the two firms.
Various situations with different parameters have been analysed. In some situations technology use was beneficial for both firms, in some situations only the more risk averse firm had benefits. Generally, the less risk averse firm has less incentives to share know-how than the more risk averse firm. An explanation for this

observation may be the fact that the less risk averse firm is rewarded for taking excess risks. Hence, its strategy should be the protection of its market dominance.

The results presented have interesting implications on the diffusion of electronic commerce technology. It indicates which kind of parameters may be important to firms in order to decide on the use of electronic commerce technology. An empirical validation of the model, eg. by considering case studies, is an important topic of future research.

Generally, consumers benefit from technology use. Total quantities offered increase and as a consequence price decreases. Hence, consumers receive more goods at lower prices.

In the paper the homogeneous duopoly case was analysed. In the same way the case of competition in a heterogeneous market environment may be tackled. The analysis is more complicated, the spirit of the results, that will be reported elsewhere, remains the same (Stickel, 1998).

The model presented, although very simple, may be extended in a variety of ways. It may be extended to the case of an arbitrary oligopoly. The results basically remain the same, except that we get an ordering of the firms according to their degree of risk aversion. The firm that has the least risk aversion is in the same situation as F_1, the firm with the highest degree of risk aversion resembles F_2. The assumptions about the distribution of the parameter a may be relaxed. The results hold for arbitrary single peaked distributions (eg. a beta distribution on the finite interval $[A,B]$). Also, more general utility functions may be used as long as an ordering with respect to risk aversion is possible. Then, in most cases, closed-form solutions may not be computed any more. Instead, numerical techniques need to be used. It is also possible to consider more general demand function. Simulations with more complex demand functions (eg. quadratic ones) have been carried out without changing the results. As was already indicated in the text different variable costs, as well as the case of a market leader who announces quantities earlier than its competitor may be considered. Cost effects and effects due to market leadership may „overlay“ the results presented and may strengthen or weaken the effects described.

The derivations relied on the existence of a Cournot-equilibrium. Other price mechanisms are possible and studied in the literature. Caldas & Coelho (1994) eg. use organisational learning concepts together with artificial economic agents. It remains to be explored whether these concepts change our results.

The model constructed allowed the consideration of different time periods. These time periods were treated as being independent. Hence there was zero correlation between parameter values of a in different time periods. Usually, this cannot be expected to hold in reality. Small demand in period t is usually followed by a small demand in period t+1. This implies that there is some sort of correlation. If such assumptions are introduced decision makers are equipped with so-called real options (Dixit & Pindyck, 1994). Investments may eg. be deferred, speeded up, slowed down or abandoned. Flexibility usually implies higher benefits of investments. Influences on the results presented may result. This interesting topic is the subject of current research.

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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. Suppose both firms have the same variable costs c. The profits of the i-th firm are given by

$$\Pi_i(x_1, x_2) = px_i - cx_i = (a - x_1 - x_2 - c)x_i.$$

Put $a^* = a - c$. Then a modified optimisation problem with a stochastic parameter a^* instead of a and variable costs $c = 0$ results (note that a^* is independent of i). The parameter a^* has a normal distribution with mean $\mu - c$ and unchanged standard deviation σ. This demonstrates the equivalence of the problems with and without zero variable costs. ◆

Lemma 2. Let a have a normal distribution with mean μ and standard deviation σ. Suppose further that a decision maker has a utility function as given in (1) with 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

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

$$= 1 - \frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{\infty}\exp(-\frac{1}{2}(\frac{a-\mu}{\sigma})^2)\exp(-\gamma(c_2a^2 + c_1a + c_0)da = 1 - I.$$

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. ◆