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Cooperation and Competition in Markets with Network Externalities or Learning Curves

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Abstract

The related phenomena of learning curve and network effects are quite common in oligopolistic markets. In this context the present paper discusses the incentives of a technological leader to share its exclusive technology with potential competitors. An alliance may be preferable because partner firms jointly realize learning curve or network effects and, in some instances, because entry of another firm may be blocked. On the other hand competition between the alliance partners will be intensified. It is shown that the alliance solution will be chosen for medium values of learning curve or network effects. In almost all cases where firms decide to form an alliance this will enhance welfare.

Keywords: Alliances, Network externalities, Learning curve, Oligopoly

JEL–classification: L13, D43, L15

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1 Introduction

Timing is very important in oligopolistic markets. A firm that enters first not only achieves monopoly revenues until the entrance of the first competitor. It may also be able to obtain an enduring competitive advantage for the subsequent oligopoly competition. This result may be achieved by irreversible investments that allow the firm to behave like a Stackelberg leader. Being first is particullarily attractive in markets with dynamic learning effects or with network externalities. Dynamic learning effects result in a cost advantage for the early entrant. In a similar manner network externalities make the product of an incumbent more valuable to consumers. Both effects may render entry of potential competitors unattractive or at least reduce their market shares. In the present paper we develop a simple model that is suited for the analysis of both dynamic learning effect and network externalities. This model is than applied to analyze the incentives for an alliance between a technological leader (the incumbent) and potential competitors.

Dynamic learning effects are particularly pronounced in some high technology markets like microchip production. Here accumulated experience in production makes a firm more efficient in producing additional units which in turn yields lower unit costs. As unit costs are decreasing in cumulative output, this phenomenon is also labeled as "dynamic scale economies" (see e. g. *Baldwin/Krugman, 1988*). Dynamic learning effects imply that a firm must also consider the impact on future costs when deciding about the optimal output level for a given period. In an oligopolistic setting reducing future costs has a strategic dimension as it influences the competitive behavior of the other firms in the industry. In the economic literature dynamic learning is especially discussed in the context of international trade and competition, for example to deal with the impact of infant industry protection (see e. g. *Melitz, 2005*). In the management and marketing literature the concept is for example used to analyze pricing in markets for electronic products (see e. g. *Hossain, 2011*).

A related phenomenon of dynamic competition are network externalities (for an overview see *Shy, 2011* or *Katz/Shapiro, 1994*). In a market with network externalities the utility of a consumer depends on the number of consumers who buy the same or a compatible good. This positive externality in consumption can be either due to a direct impact on the quality of a good (e. g. a telecommunication infrastructure with a larger number of telephone extensions) or to indirect effects (e. g. availability of complementary products like application software for a operating system). In both cases this implies that consumers have a higher valuation for the good or service if the network is larger. From the point of view of the firm the higher valuation has a similar impact as a correspondent reduction of production costs. Therefore network externalities are also sometimes referred to as "demand side economies of scale".

There are quite a number of papers in the 1990s that discuss the strategic impacts of markets with network externalities and learning–by–doing.[1] While the literature is more spares in the last couple of years, there are for example two recent papers that deal with the impact of network externalities on the incentives to strategic managerial delegation (see *Hoernig 2012* and *Bhattacharjee/Pal, 2013*). The relatively small number of papers that deal with cooperation incentives mostly concentrate on two firms or restrict attention to a symmetric oligopoly.[2] However, asymmetries due to sequential market entry and cooperation are empirically important in such markets. For a proper understanding these issues need to be addressed. To my knowledge only *Axelrod et. al. (1995)* and *Economides (1996)* allow more than two firms in an asymmetric setting. *Axelrod et. al. (1995)* analyze the formation of standard setting alliances. In their static model firms are asymmetric with respect to the degree of rivalry relative to the different potential alliance partners. *Economides (1996)* is more closely related to present analysis. As in the present paper, he considers the incentives of a technological leader to share its technology. However, he restricts attention to markets with network externalities, assumes a "fulfilled expectations equilibrium"[3] and does not consider the possibility of market entry by firms with non–compatible technologies.

The paper proceeds as follows: In section 2 the basic structure of the formal model will be explained. Subsequently in 3 quantities and profits for the different possible alliance structures will be determined and it will be shown, how entry decisions might be affected by alliance formation. Based on the profits determined in section 3, the formation of alliances wil be analyzed in 4. Section 5 deals with the welfare impact of alliance formation and asks, whether the resulting equilibrium alliance structure is beneficial from a social point of view. The conclusion gives an overview over the main results and relates them to other work about alliances in markets with network externalities or learning curve effects.

[1] Prominent examples are *Kristiansen/Thum (1997)* and *Matutes/Regibeau (1996)* for network externalities or *Cabral/Riordan (1997)* and *Petrakis/Rasmusen/Roy (1997)* for dynamic learning effects.

[2] See e. g. *Economides/Flyer (1995)* and *Bloch (1995)* for network externalities and *Petit/Tolwinski (1997)* for dynamic learning effects.

[3] The different approaches for the analysis of network externalities will be discussed in detail in section 2. See *Matutes/Regibeau (1996)* and *Shy (2011)* for an overview.

2 Basic structure of the formal model

The formal analysis of the incentives for cooperation in markets with network externalities and dynamic learning effects is performed in a two–period model based on *Fudenberg/Tirole (1983)*. The specific structure of the model has been chosen for two reasons. (i) Analyzing the formation of alliances in a setting with asymmetric firms is a quite complex problem. Therefore the dynamic aspect should be modeled as easy as possible. (ii) Network externalities and dynamic learning effects should be analyzed in the same kind of model. This allows working out the similarities as well as the differences.

It is assumed that firms compete in linear Cournot oligopoly. In the first period all active firms produce with identical and constant average costs c (which in turn implies constant marginal costs c). The demand side is given by a linear inverse demand function $p(X_{t_1}) = \alpha - X_{t_1}$. Cost and demand in the second period depend on the first period quantities x_{it_1} in the following manner:

- In the learning curve setting second period costs are reduced by λx_{it_1}, i. e. $c_{it_2} = c - \lambda x_{it_1}$.[4]
- Under network externalities it is assumed that products are incompatible as long as firms do not cooperate. However, products are homogenous insofar as consumers have identical valuations for products with the same network size. The valuation of a network is based on the quantity sold in t_1. This implies adaptive expectations: consumers expect a larger network size in t_2 if the network has been larger in t_1.[5] The inverse demand function for firm i in the second period is given by $p_{it_2}(X_{-it_2}, x_{it_2}) = (\alpha + \lambda x_{it_1}) - x_{it_2} - X_{-it_2}$ with X_{-it_j} denoting the aggregated production of the competitors of firm i that are active in period t_j.

[4] *Spence (1981)* assumes in his learning curve model constant elasticity of demand and "exponential learning". While this may be more realistic and easier to apply for empirical analysis, the present formulation has the advantage of being computationally much easier — in particular with asymmetric firms.

[5] The majority of papers dealing with network effects assume a "fulfilled expectation equilibrium", i. e. in equilibrium the actual size of the network equals the size that consumers (rationally) expected (the seminal paper on this approach is *Katz/Shapiro, 1985*). However, *Matutes/Regibeau (1996)* point out that there are also studies were firms can commit to a certain quantity ("commitment approach"), and others where consumers base their valuation on the current network size ("myopic approach" — see e. g. *Regibeau/Rockett, 1996*). The latter approach with adaptive expectations is used in the present paper because it is simpler and allows analyzing dynamic learning in the same model structure. How results are likely to be affected by working with rational expectations will be discussed in detail in the final section when comparing outcomes in the present paper with those obtained in *Economides (1996)*.

The objective function of a firm is given by total profits over both periods. In a full-fledged dynamic model the exact time of entry of a competitor is important for determining the relative advantage of the incumbent. This aspect cannot directly be addressed in a two–period model. Instead the parameter ρ that describes the relative importance of second period profits serves as a proxy. A higher value for ρ implies a smaller lag of the potential competitor.[6]

$$\pi_i = \pi_{it_1} + \rho\pi_{it_2} = x_{it_1}(\alpha - X_{t_1} - c) + \rho x_{it_2}(\alpha - X_{t_2} - c + \lambda x_{it_1}) \qquad (1)$$

To make the notation easier we assume in the following analysis that $\alpha = 1$ and $c = 0$. This normalization of "market size" to $\alpha - c = 1$ does not affect our results as only the relative size of profits is relevant for the alliance decision.

Until now it has been assumed that firms are symmetric and that each firm itself fabricates a product that is incompatible to the products of its competitors. To analyze the decision about alliance formation these assumptions will now be modified. (i) Firms are asymmetric with respect to the availability of the technology in the first period. (ii) The technology may be tranferred to another firm that will then produce a compatible product. (iii) Firms may produces together, which allows them to jointly realize dynamic learning effects. A market with three potential competitors is considered. Firm 1 is the technological leader that is able to already produce in t_1. Each of the other two firms can only enter in t_1 if it cooperates with the technological leader. Otherwise firm 2 or 3 can enter the market in t_2 with an incompatible product. When choosing technology transfer or joint production, the individual inverse demand functions (with network externalities) respectively the cost functions (with dynamic learning effects) of the firms in t_2 do not solely depend on their own output in the first period, but also on the output produced by alliance partners. The main difference between network externalities and learning curve effects lies in the fact that realizing dynamic learning effects is only possible if firms jointly produce the good — for example in a production joint venture. With network externalities it is sufficient to transfer the technology. In either case the profit function of an alliance member in t_2 is given by $\pi_{it_2} = x_{it_2}(1 - X_{t_2} + \lambda \sum_{i\in A} x_{it_1})$ with $A \subseteq \{1, 2, 3\}$.

When determining the output quantity x_{it_1} firm i not only considers the impact on profits in t_1 but also both the "dynamic" impact on demand respectively cost in t_2 and the "strategic" impact on the competitive position in t_2. What also has to be considered

[6] The two–stage game only deals with the dynamic competition after entry of the competitors in reduced form. Nevertheless the basic result — higher market shares and profits for the firms which enter first — would be the same in an explicitly dynamic model. However, when interpreting the results one has to consider that a higher value of ρ also amplifies network externalities and dynamic learning effects. The dynamic incentives for production in t_1 therefore depend on both ρ *and* λ.

is the possibility that a sufficiently high quantity in t_1 may render market entry of a potential competitor in t_2 unattractive. Based on these consideration, the subgame–perfect Nash equilibria for a given alliance structure can be determined. The resulting profits for different alliance structures must then be calculated to derive the equilibrium of the complete game. Here three cases must be distinguished: No alliance, an alliance between the technological leader and one follower ("two firm alliance"), and an alliance between all firms ("three firm alliance").

In contrast to *Economides (1996)*, in the present setting a costless technology transfer can never be profitable for the technological leader. This is due to the fact that the valuation in the second period is only influenced by the actual production in the first period and not by the number of firms that supply a compatible technology. Therefore in an alliance there must be side payments to the technological leader.[7] An alliance will only be formed if not only joint profits but also industry profits will be maximized. This is due to the fact that whenever a two–firm alliance would not maximize industry profits, the remaining firm would be able to bribe one of the alliance members to leave the alliance by an appropriate side payment. An alliance structure is therefore only stable if industry profits are maximized (see *Morasch, 1994* for a similar approach when dealing with the formation cooperative ventures in reasearch and development).

3 Alliance structure and market outcome

Before it is possible to deal with the incentives for alliance formation, equilibrium quantities and resulting profits must be determined for all possible alliance structures. Here it has to be considered that a technological leader as well as a two–firm alliance might have an incentive to choose first period quantities which render (additional) entry in the second period unattractive. Therefore it is necessary to determine the parameter spaces for ρ und λ that yield entry blocking by a technological leader and by a tow–firm alliance, respectively. Based on this it is then possible to determine quantities and profits for different alliance structures for the different parameter spaces.

[7] In the case of network externalities this may be achieved by license fees. In the learning curve setting the technological leader may have a lower share in the financial requirements for the establishment of the joint venture. To keep the analysis as simple as possible we will assume lump sum side payments. For the impact of output dependent royalty fees in a technology transfer setting see e. g. *Farrell/Gallini (1988)*. The strategic impact of output based transfers in a production joint venture is analyzed in *Morasch (2000)*.

3.1 Market outcome without alliances

The technological leader will always produce in t_1. He would prefer to be a monopolist in both periods. While this is easily achieved in period one by not licensing his technology, market entry in the second period can only be blocked by appropriately large output in t_1. However, this strategy is not always preferable as it results in lower profits in the first period. As will be shown, blocking entry is only attractive for relatively pronounced network externalities or learning curve effects. Two threshold values are of interest:

- Which parameter combination of λ and ρ ensures that entry is already blocked if the monopolist chooses a quantity that maximizes first period profits?
- Where is the threshold for active entry blocking, i. e. the technological leader prefers to produce a higher quantity in t_1 in order to avoid oligopoly competition in t_2?

To identify the threshold values it is necessary to first determine the subgame–perfect equilibria for (i) monopoly in both periods as well as for (ii) monopoly in the first and oligopoly in the second period and also the entry blocking first period quantity. Monopoly in both periods will be considered first as it is the easiest case without any strategic incentives. However, even here the monopolist must take into account that the quantity chosen in the first period not only affects first period profits but also demand or cost in the second period. The optimal quantities must therefore be calculated by backward induction. In a first step the profit maximizing output in t_2 is determined for a given $\bar{x}_{1t_1}$ Based on this, total profits may be written as a function of the first period quantity only and thus the profit maximizing $x_{1t_1}^{MM}$ can be calculated.[8] From maximizing $\pi_{1t_2}^{M} = (1 + \lambda\bar{x}_{1t_1} - x_{1t_2})x_{1t_2}$ the expression $x_{1t_2}^{M}(x_{1t_1}) = (1 + \lambda x_{1t_1})/2$ is obtained. Inserting into the function for total profits yields

$$\begin{aligned} \pi_1^{MM}(x_{1t_1}) &= (1 - x_{1t_1})x_{1t_1} + \rho\left(1 + \lambda x_{1t_1} - \frac{1 + \lambda x_{1t_1}}{2}\right)\frac{1 + \lambda x_{1t_1}}{2} \\ &= (1 - x_{1t_1})x_{1t_1} + \rho\,\frac{(1 + \lambda x_{1t_1})^2}{4}. \qquad (2) \end{aligned}$$

From the profit function it can be seen that there is a incentive for increasing output that is due network externalities or dynamic learning effects. This incentive is more pronounced

[8]Superscripts M, D and O denote monopoly, duopoly und oligopoly (i. e. all three firms are active in the market). Two capital letters are used to describe equilibrium quantities and profits in the correspondent situation — e. g. MO stands for “monopoly in t_1 and oligopoly in t_2”. MB and DB refer to blocked entry by the technological leader and the two–firm alliance, respectively.

for higher values of ρ, i. e. if the second period is relatively important. Optimal quantities in t_1 and t_2 and the resulting profits for monopoly in both periods are then given by[9]

$$x_{1t_1}^{MM} = \frac{2+\lambda\rho}{4-\lambda^2\rho}\,,\; x_{1t_2}^{MM} = \frac{2+\lambda}{4-\lambda^2\rho} \quad\Rightarrow\quad \pi_1^{MM} = \frac{1+\rho+\lambda\rho}{4-\lambda^2\rho} \tag{3}$$

In the case with market entry of the two potential competitors, profits in the second period have to be determined in an asymmetric oligopoly setting as only the technological leader is able to realize network externalities or learning curve effects. For a given quantity $\bar{x}_{1t_1}$ the profit functions in t_2 for the technological leader and each of the followers, respectively, are given by:

$$\pi_{1t_2}(x_{1t_2}, x_{2t_2}, x_{3t_2}) = (1+\lambda\bar{x}_{1t_1} - \sum_{i=1}^{3} x_{it_2})x_{1t_2} \tag{4}$$

$$\pi_{jt_2}(x_{1t_2}, x_{2t_2}, x_{3t_2}) = (1 - \sum_{i=1}^{3} x_{it_2})x_{jt_2} \quad \text{für} \quad j \in \{2,3\} \tag{5}$$

From the first order conditions the asymmetric oligopoly equilibrium quantities in the second period are obtained. $x_{1t_2}(x_{1t_1}) = (1+3\lambda x_{1t_1})/4$ bzw. $x_{2t_2}(x_{1t_1}) = x_{3t_2}(x_{1t_1}) = (1-\lambda x_{1t_1})/4$. This allows to write the total profit function of the technological leader as a function of x_{1t_1} and to determine the profit maximizing quantity $x_{1t_1}^{MO}$. The following values result for quantities and profits:

$$\begin{aligned} x_{1t_1}^{MO} &= \frac{8+3\lambda\rho}{16-9\lambda^2\rho}\,,\; x_{1t_2}^{MO} = \frac{4+6\lambda}{16-9\lambda^2\rho}\,,\; x_{2t_2}^{MO} = x_{3t_2}^{MO} = \frac{4-2\lambda-3\lambda^2\rho}{16-9\lambda^2\rho} \\ \Rightarrow \quad \pi_1^{MO} &= \frac{4+\rho+3\lambda\rho}{16-9\lambda^2\rho}\,,\; \pi_2^{MO} = \pi_3^{MO} = \frac{(4-2\lambda-3\lambda^2\rho)^2}{(16-9\lambda^2\rho)^2} \end{aligned} \tag{6}$$

The potential competitors earn positive profits and therefore will enter the market as long as $4-2\lambda-3\lambda^2\rho > 0$. However, the technological leader might be better off by producing a higher quantity in t_1 as would be optimal for monopoly in both periods in order to block entry. The appropriate quantity that renders market entry for the potential competitors unattractive, the resulting monopoly quantity in t_2, and total profit by blocking entry are given by

$$x_{1t_1}^{MB} = \frac{1}{\lambda}\,,\; x_{1t_2}^{MB} = 1 \quad\Rightarrow\quad \pi_1^{MB} = \frac{-1+\lambda+\lambda^2\rho}{\lambda^2}. \tag{7}$$

$x_{1t_1}^{MB}$ exceeds $x_{1t_1}^{MM}$ as long as $2-\lambda-\lambda^2\rho > 0$. When comparing profits with and without alliance in the correspondent parameter range, it has to be checked whether market entry is tolerated, blocked by $x_{1t_1}^{MB}$ or already impeded by $x_{1t_1}^{MM}$.

[9] Note that economically sensible results are only assured as long as $4-\lambda^2\rho > 0$. This will be considered in the following analysis.

3.2 Market outcome with alliances

In a second step it will now be analyzed under what circumstances market entry will be blocked by an alliance between a technological leader and a potential competitor. It is more likely that market entry will be impeded in this situation for two reasons:

- If there are two firms in the market in the first period, they will choose higher total output than a monopolist.
- As the third firm is now confronted with two competitors with high demand or low cost in in the second period, it will earn lower profits relative to a setting without an alliance.

First quantities and profits will be determined for the situation with entry. This allows to find out the threshold values for blockaded entry, i. e. negative profits for the third firm even if alliance members do not adjust quantities in order to block entry of the third firm. While the second period profit function for the "outsider" does not change relative to (5), demand of the alliance member is higher under network externalities or their cost is lower with learning effects as they also gain from the output of the other alliance member in t_1. The profit function for alliance members — for both a two–firm alliance and an alliance of all firms — is given by

$$\pi_{jt_2}(x_{1t_2}, x_{2t_2}, x_{3t_2}) = (1 + \lambda \sum_{j \in A} x_{jt_1} - \sum_{i=1}^{3} x_{it_2}) x_{jt_2}. \tag{8}$$

Based on (5) and (8) it is possible to determine equilibrium quantities for the subgame in the second period as a function of the equilibrium quantities in the first period duopoly: $x_{1t_2}(x_{1t_1}, x_{2t_1}) = x_{2t_2}(x_{1t_1}, x_{2t_1}) = [1 + 2\lambda(x_{1t_1} + x_{2t_1})]/4$ bzw. $x_{3t_2}(x_{1t_1}, x_{2t_1}) = [1 - 2\lambda(x_{1t_1}, x_{2t_1})]/4$. Inserting this result into the functions for total profit of the two alliance members, it is now possible to calculate first period output levels and total profits. This yields the following equilibrium quantities and profit levels (with $j \in \{1, 2\}$):

$$\begin{aligned} x_{jt_1}^{DO} &= \frac{4 + \lambda\rho}{12 - 4\lambda^2\rho}, \; x_{jt_2}^{DO} = \frac{3 + 4\lambda}{12 - 4\lambda^2\rho}, \; x_{3t_2}^{DO} = \frac{3 - 4\lambda - 2\lambda^2\rho}{12 - 4\lambda^2\rho} \\ \Rightarrow \quad \pi_j^{DO} &= \frac{16 + 9\rho + \lambda\rho - 2\lambda^2\rho^2 - 4\lambda^2\rho^3}{(12 - 4\lambda^2\rho)^2}, \; \pi_3^{DO} = \frac{(3 - 4\lambda - 2\lambda^2\rho)^2}{(12 - 4\lambda^2\rho)^2} \end{aligned} \tag{9}$$

The subgame–perfect equilibrium yields results with a positive quantity for the third firm as long as $3 - 4\lambda - 2\lambda^2\rho > 0$. Outside this parameter range the situation with blockaded entry must be considered. Two possibilities must be distinguished:

- Entry is already blocked by the quantities that result under duopoly competition in both periods ("blockaded entry").

- Alliance members decide to produce together an entry blocking first period quantity if the duopoly quantity would be too low and the advantage of a duopoly in the second period exceeds the profit reduction due to the suboptimally high quantity in the first period ("active entry blocking").

Quantities in the second period as function of first period output can again be determined based on (8): $x_{jt_2}(x_{1t_1}, x_{2t_1}) = [1 + \lambda(x_{1t_1} + x_{2t_1})]/3$ If the resulting first period duopoly quantities already block entry, the following quantities and profits result (as before with $j \in \{1, 2\}$):

$$\begin{aligned} x_{jt_1}^{DD} &= \frac{9 + 2\lambda\rho}{27 - 4\lambda^2\rho}, \; x_{jt_2}^{DD} = \frac{9 + 6\lambda}{27 - 4\lambda^2\rho} \\ \Rightarrow \quad \pi_j^{DD} &= \frac{81 + 81\rho + 90\lambda\rho - 8\lambda^2\rho^2 - 8\lambda^2\rho^3}{(27 - 4\lambda^2\rho)^2} \end{aligned} \tag{10}$$

Inserting $x_{jt_1}^{DD}$ in $x_{3t_2}(x_{1t_1}, x_{2t_1})$ shows that market entry is not blocked by these quantities if $9 - 12\lambda - 4\lambda^2\rho > 0$. In this case alliance partners must jointly produce the blocking output. Because firms are symmetric (after the technology transfer) it assumed that each firm produces half of this quantity. Note that this solution is a Nash equilibrium as long as entry blocking maximizes total profits over both periods: Rising the own output is not beneficial as the output already exceeds the optimal quantity under duopoly. While reducing the quantity raises first period profits, it would yield market entry of the third firm which reduces joint total profits of the alliance members. As first period profits of the firm that is still producing the Nash quantity will raise more than the profits of the deviating firm, a deviation cannot raise total profits of this firm. [10] With active entry blocking the following quantities and profits result in equilibrium:

$$x_{jt_1}^{DB} = \frac{1}{4\lambda}, \; x_{jt_2}^{DB} = \frac{1}{2} \;\Rightarrow\; \pi_j^{DB} = \frac{-1 + 2\lambda + 2\lambda^2\rho}{8\lambda^2} \tag{11}$$

A comparison with (7) shows that the blocking quantity is much lower as in the situation without an alliance: the joint output necessary to impede entry of the third firm is only 50 % of the respective quantity of the monopoly producer.

Blocking market entry is not relevant if an alliance of all three potential competitors is considered. Similar to the duopoly case without entry blocking it is necessary to first

[10] In the parameter range with entry blocking the resulting first period profits are always positive which can be seen from (11)

determine the oligopoly equilibrium in the subgame in period two. However, it must now be taken into account that all three firms are active in the first period. Based on the profit function (8) the equilibrium quantities in the second period are given by $x_{it_2}(x_{1t1}, x_{2t_1}, x_{3t_1}) = (1 + \lambda \sum_{i=1}^{3} x_{it1})/4$. By inserting into the profit functions and determining the first period equilibrium, quantities und profits for an alliance of all three firms can be calculated (for $j \in \{1,2,3\}$):

$$
\begin{aligned}
x_{jt_1}^{OO} &= \frac{8+\lambda\rho}{32-3\lambda^2\rho},\ x_{jt_2}^{OO} = \frac{8+6\lambda}{32-3\lambda^2\rho} \\
\Rightarrow \quad \pi_j^{OO} &= \frac{64+64\rho+80\lambda\rho+12\lambda^2\rho-3\lambda^2\rho^2-3\lambda^3\rho^2}{(32-3\lambda^2\rho)^2}
\end{aligned}
\tag{12}
$$

3.3 Entry blocking with and without an alliance

Alliance formation will be discussed in the next section. As entry blocking is an important incentive to form an alliance, entry blocking with and without alliances is now visualized graphically. This should help to get a better understanding for what parameter range this incentive is likely to be relevant. In figure 1 the threshold values for entry blocking are shown in the parameter range of $\rho \in [0,5]$ and $\lambda \in [0,2]$ The border of the economically relevant parameter range is given by $4-\lambda^2\rho > 0$ — as can be seen by looking at (3) there would be infinite or negative quantities in monopoly setting.[11]

As can be seen in the figure, entry will not be impeded for relatively small network externalities or learning curve effects. This is due to the fact that the necessary demand enhancement or cost reductions for the second period could only be achieved by very high quantities (and accordingly low profits) in the first period. For medium values a two–firm alliance will block entry of the third competitor. Without alliances the technological leader will only block entry of the potential competitors for relatively high values — in particular for small ρ, i. e. if the advantage of the technological leader is pronounced.

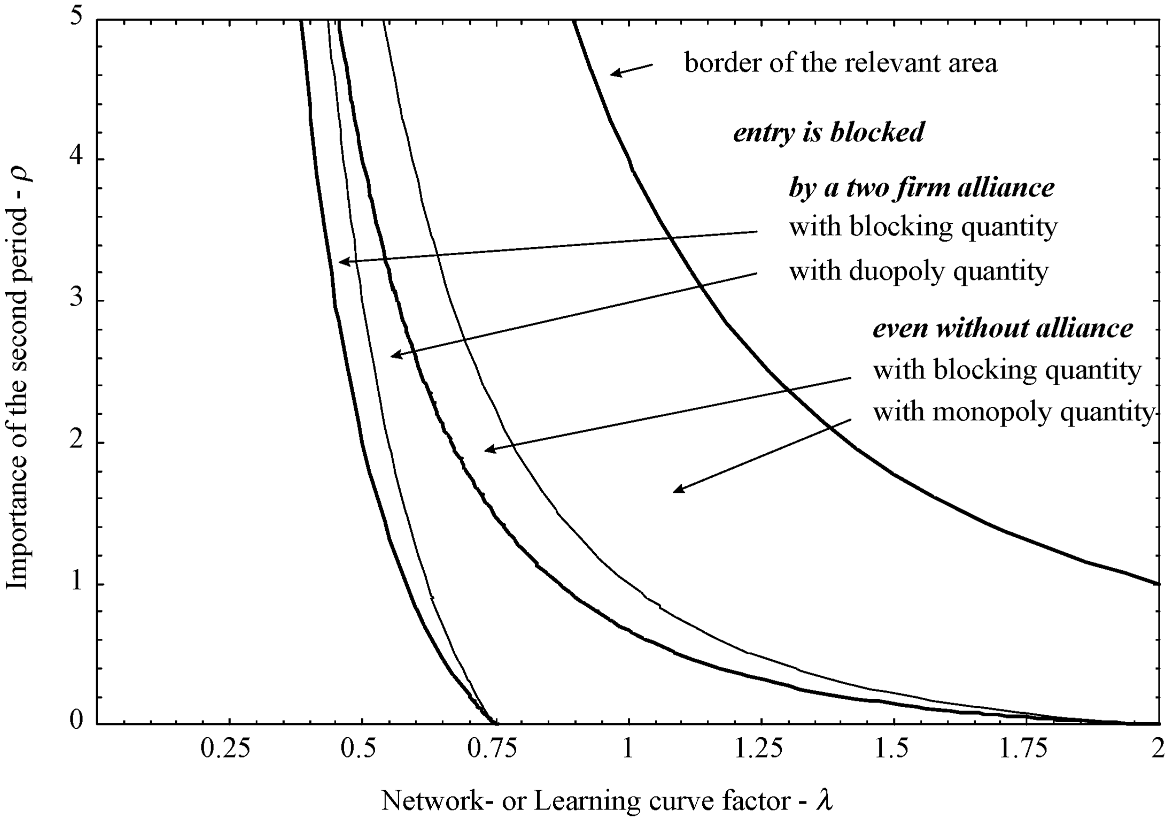
As already discussed in 3.2 entry blocking is more likely with alliances:

- Duopoly competition in the first period yields higher industry output.

- The competitive pressure for the third firm is more pronounced in the case of a two–firm alliance as there are two competitors with higher demand or lower costs.

[11]If the condition is fulfilled, finite and positive quantities are also assured for the other cases as the numerator in (6), (9), (10) and (12) will then be greater than zero.

Figure 1: Entry blocking with and without alliances



The analysis in section 4 shows that the potential for entry blocking is an important incentive for alliance formation.

4 Incentives for alliance formation

Equilibrium quantities, profits, and implications for entry have now been analyzed for all scenarios. Based on this, incentives for alliance formation can be discussed and the alliance structure can be determined as a function of the parameter values. Firms decide about alliance formation before they start producing. Formally we have to analyze a three–stage game:

- In t_0 firms decide about forming an alliance.
- In t_1 the technological leader decides about his first period quantity if no alliance has be formed; otherwise alliance members simultaneously determine their quantities.

- In t_2 non–members decide about market entry and all active firms simultaneously determine second period quantities.

For the first stage of the game it is now assumed that firms choose the cooperation structure (no alliance, two–firm alliance or alliance of all firms) that maximizes industry profit. This assumption is made as firms can make side payments to one another (otherwise a technological leader would never accept the formation of an alliance. If firms form a three–firm alliance joint profit of alliance members and industry profit coincide. Such an alliance might only be formed if joint profits are higher than in the situation without an alliance because otherwise the two lagging firms would not be able to make side payments to the technological leader that are high enough to let him accept the alliance. In the case of two–firm alliance profits of the non–member will be reduced. If industry profits are higher without an alliance, this firm could bribe the technological leader to not form the alliance by making a sufficiently high side payment. And if industry profits are higher with a three–firm alliance, the third firm can make side payments to both other firms that are high enough to accept the third firm as an alliance member. However, if a two–firm alliance maximizes industry profits, the willingness to pay of the outsider is too low to let the alliance partners change their decision.

To determine the alliance structure in equilibrium, industry profits without an alliance, $\Pi^{\{\}}$, with a two–firm alliance, $\Pi^{\{12\}}$, and with an alliance of all firms, $\Pi^{\{123\}}$, have to be compared.

$$\Pi^{\{\}} = \begin{cases} \sum_{i=1}^{3} \pi_i^{MO} & \text{für} \quad (4-2\lambda-3\lambda^2\rho) > 0 \\ \pi_1^{MB} & \text{für} \quad (4-2\lambda-3\lambda^2\rho) \leq 0 \wedge (2-\lambda-\lambda^2\rho) > 0 \\ \pi_1^{MM} & \text{für} \quad (2-\lambda-\lambda^2\rho) \leq 0 \wedge (4-\lambda^2\rho) > 0 \end{cases} \tag{13}$$

$$\Pi^{\{12\}} = \begin{cases} \sum_{i=1}^{3} \pi_i^{DO} & \text{für} \quad (3-4\lambda-2\lambda^2\rho) > 0 \\ \sum_{i=1}^{2} \pi_i^{DB} & \text{für} \quad (3-4\lambda-2\lambda^2\rho) \leq 0 \wedge (9-12\lambda-4\lambda^2\rho) > 0 \\ \sum_{i=1}^{2} \pi_i^{DD} & \text{für} \quad (9-12\lambda-4\lambda^2\rho) \leq 0 \wedge (4-\lambda^2\rho) > 0 \end{cases} \tag{14}$$

$$\Pi^{\{123\}} = \sum_{i=1}^{3} \pi_i^{MO} \tag{15}$$

Doing the comparison, one has to distinguish between the five areas in figure 1: Without entry blocking, active entry blocking with a two–firm alliance, blockaded entry with a two–firm alliance that chooses duopoly quantities, active entry blocking by the technological leader, and blockaded entry by technological leader that chooses monopoly output.

Assuming that another firm may only join an alliance if this increases industry profits, the following three conditions for the three possible alliance structures are obtained:

$$\{\} \quad \text{falls} \quad \Pi^{\{\}} \geq \Pi^{\{12\}} \wedge \Pi^{\{\}} \geq \Pi^{\{123\}} \tag{16}$$

$$\{12\} \quad \text{falls} \quad \Pi^{\{12\}} > \Pi^{\{\}} \wedge \Pi^{\{12\}} \geq \Pi^{\{123\}} \tag{17}$$

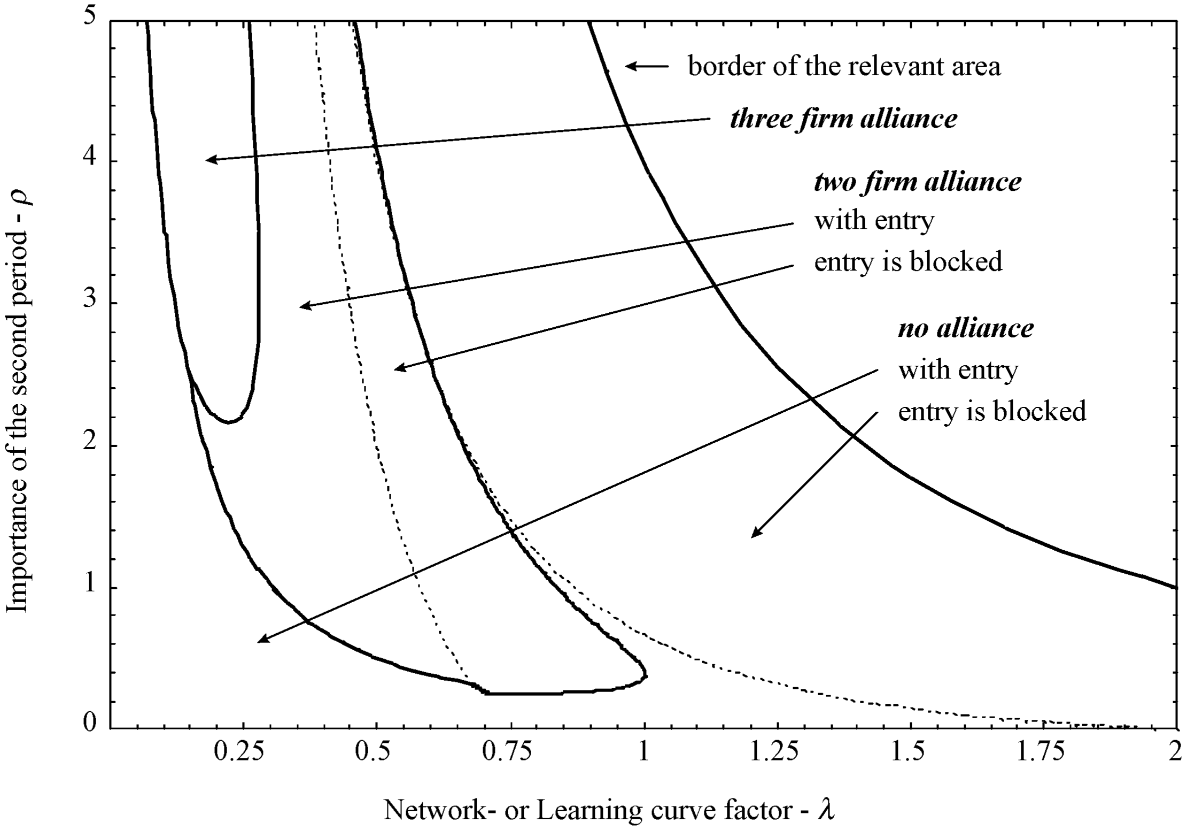
$$\{123\} \quad \text{falls} \quad \Pi^{\{123\}} > \Pi^{\{\}} \wedge \Pi^{\{123\}} > \Pi^{\{12\}} \tag{18}$$

By determining the resulting threshold values as a function of λ und ρ, it is possible to obtain the parameter combinations that lead to a specific alliance structure in equilibrium. Doing these calculations one has to make sure to use the appropriate formulas for $\Pi^{\{\}}$ and $\Pi^{\{12\}}$ according to (13) and (14), respectively. The equations for the threshold values are very complicated and it is neither possible to give an economic interpretation from the equation nor can they be solved explicitly with respect to λ or ρ. The formulas will therefore not be presented in the text (but can be obtained from the author on request). Instead the economic intuition is given by interpreting a graphical representation of the results. Figure 2 shows the threshold values for $\rho \in [0, 5]$ and $\lambda \in [0, 2]$ in the same way as has been done with the results concerning entry blocking in figure 1. In addition the threshold values for active entry blocking are marked by dotted lines.

A three–firm alliance will only result in the area without entry blocking if the second period is relatively important. The economic intuition is as follows. First period profits will be low with three active firms. The potential advantages of the three–firm alliance are enhanced demand or lower cost for *all* firms in the second period — industry profits may rise because the relatively low valued or inefficient production of a late entrant is avoided. The positive impact can only dominate lower profits in the first period if ρ is high, i. e. if the technological leader has only a small head start. If the technological leader alone or a two–firm alliance could impede entry, all active firms have the same demand or cost in t_2 and in addition competition is less intense with two firms — a three–firm alliance could therefore never be appealing in this parameter range.

An alliance between the technological leader and one of the followers ("two–firm alliance") is chosen for medium values of λ if the second period not to unimportant (depending on the exact value of λ approximately for $\rho > 1/2$). Relative to the three–firm alliance the reduction of first period profits is here less pronounced. In addition competition is not as intense in the second period — either the third firm has lower demand or higher costs, respectively, or entry of this firm is blocked. Relative to the situation without an alliance the low second period market share of the third firm or the prevention of market entry

Figure 2: Alliance structures in equilibrium



is an advantage. On the other hand the lower industry profit in the first period due to duopoly instead of monopoly is unfavorable — this is the reason why a two–firm alliance will not result for a pronounced head start of the technological leader (low ρ).

Irrespective of the degree of network externalities or learning curve effects no alliance will be formed if the second period is sufficiently unimportant. This is straightforward as an alliance always yields lower industry profits in t_1 while a positive impact can only result in t_2. If network externalities or learning curve effects are low, there is also no incentive to form an alliance as the positive impact of higher demand or lower cost in the second period will not be sufficiently pronounced to compensate for the more intense competition in the first period. This is most apparent for $\lambda = 0$ as in this case the only impact of an alliance is lower industry profit in the first period.

It is now possible to sum up the results obtained. While there is no incentive to form an alliance in a market with small network externalities or learning curve effects, a two–firm alliance between the technological leader and one follower results in equilibrium for medium values of λ as long as the second period is sufficiently important. If there is only a relatively small head start of the technological leader and thus the second period is much more important than the first one (approximately for $\rho > 2$), an alliance of all firms forms if λ is not too high. However, if network externalities or learning curve effects are very pronounced, no alliance will be formed as the technological leader is able to block entry of potential competitors by himself.

5 Welfare impact of alliance formation

When deciding about alliance formation, the firms behave in a way that yields the highest possible industry profit. However, it is not assured that this kind of decision is also preferable from a social perspective. In order to analyze this aspect the impact on consumer surplus must be considered as well.

In the linear Cournot model with $p'(X) = -1$ consumer surplus is given by $X_{t_1}^2/2 + \rho X_{t_2}^2/2$ gegeben. Total surplus as a partial equilibrium welfare measure is then given by summing up industry profits from (13) – (15) with the corresponding consumer surplus. Based on the resulting values $W^{\{\}}$, $W^{\{12\}}$, and $W^{\{123\}}$ it is possible to determine the parameter area where a specific alliance structure maximizes welfare:

$$\{\} \quad \text{maximizes welfare if} \quad W^{\{\}} \geq W^{\{12\}} \wedge W^{\{\}} \geq W^{\{123\}} \tag{19}$$

$$\{12\} \quad \text{maximizes welfare if} \quad W^{\{12\}} > W^{\{\}} \wedge W^{\{12\}} \geq W^{\{123\}} \tag{20}$$

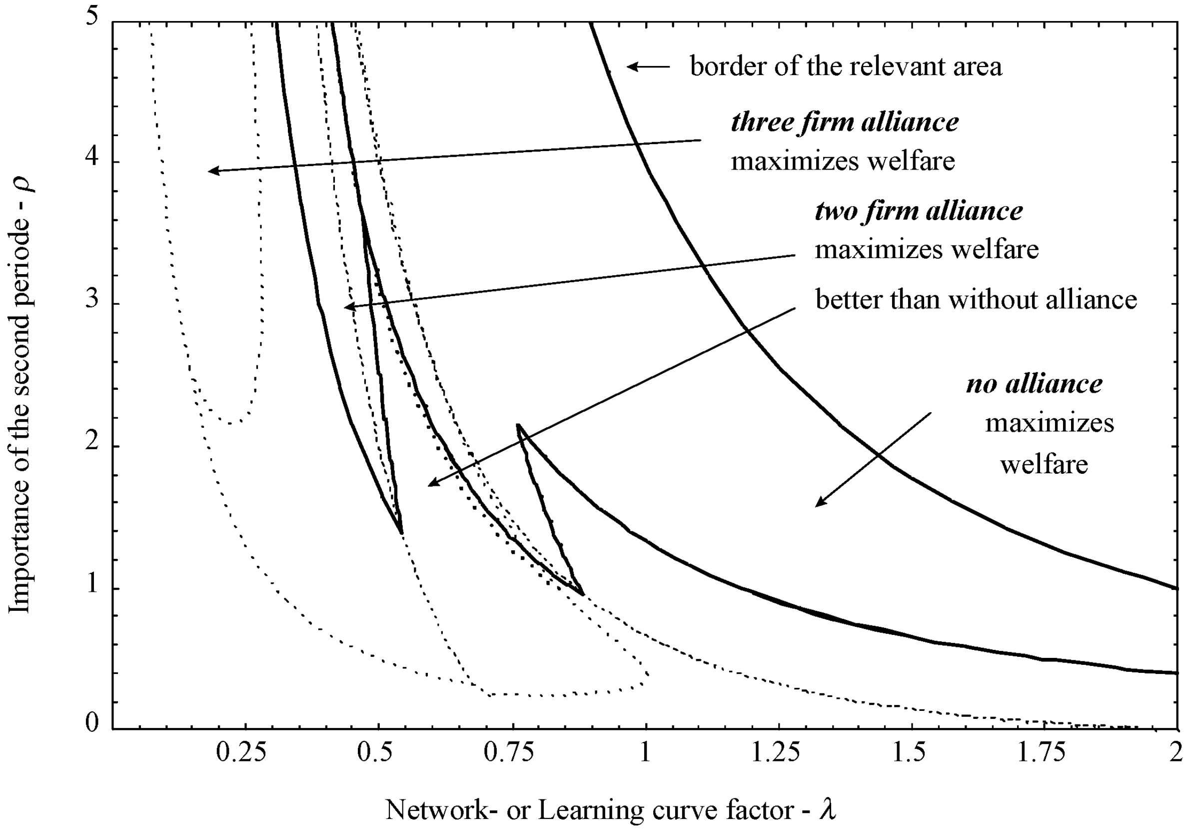
$$\{123\} \quad \text{maximizes welfare if} \quad W^{\{123\}} > W^{\{\}} \wedge W^{\{123\}} > W^{\{12\}} \tag{21}$$

In conjunction with the results from section 4 it is now possible to answer the question under what circumstances the equilibrium alliance structure results in a socially desirable result. If this is true for the whole parameter area, there would be no need to intervene by anti trust or industrial policy. Otherwise it might be preferable to forbid some alliances by anti trust measures or to stimulate alliance formation by industrial policy. As in section 4 the resulting equations for the threshold values are quite complicated. Therefore the results will again be discussed based on a graphical representation. To allow the necessary comparisons the outcomes from figure 2 displayed by dotted lines.

Two forces determine whether one alliance structure is preferable from a social point of view relative to another one:

- A larger number of competitors in both periods increases allocative efficiency.

Figure 3: Welfare maximizing alliance structures



- Higher industry profits in monopoly or duopoly in t_2 give an incentive to produce more in t_1 which in addition has a positive influence on welfare as it enhances the valuation or reduces cost in the second period.

Based on this the outcome displayed in figure 3 can be explained as follows:

- A three–firm alliance would be socially optimal for relatively low values of λ and also for a low relevance of the second period. This is due to the fact that the relative importance of allocative efficiency gains weight for low λ and that production incentives due to profits in the second period do not loom large for low ρ .

- If the head start of the technological leader is smaller and network externalities or learning curve effects are sufficiently pronounced, dynamic incentives dominate. Under these circumstances the first period output of a monopolist is higher than joint production by the alliance members and the resulting demand enhancement or cost reduction in the second period dominate the negative impact of monopoly pricing in the second period.

- A two–firm alliance is in an intermediate position. It is only socially optimal in a relatively small parameter range for medium values of λ and high ρ. However, beyond that the two–firm alliance is better than the solution without an alliance whenever a three–firm alliance would be socially optimal.

Comparing these results with the equilibrium alliance structures that are indicated by dotted lines, it is possible to state whether letting firms form alliances is preferable from a social point of view. In the parameter range with entry blocking by the technological leader this result is in most cases also socially optimal — only for small values of ρ a three–firm alliance may be preferable. In the small area where a two–firm alliance maximizes welfare, this solution will also result in equilibrium. In the rest of the parameter space a three–firm alliance would be optimal. While this alliance structure actually will only be an equilibrium for a small part of this area, a two–firm alliance at least assures higher welfare than the situation without alliances. Based on the results of the model the following policy recommendation is obtained: A general prohibition of alliance formation is not in the interest of society in markets with network externalities or dynamic learning effects. It might even be advisable to stimulate alliance formation by appropriate industrial policy measures.

6 Conclusion

In this paper incentives for alliance formation have been analyzed in two–period asymmetric three–firm Cournot model with network externalities or dynamic learning effects. In particular it has been dealt with the question whether a technological leader has an incentive to share its technology with potential competitors in this setting. As the potentially positive impact of joint profits is comprised by a profit reduction for the technological leader and higher profits for the other alliance partners, cooperation can only result if side payments between alliance members are feasible. Under these circumstances an alliance is only stable if not only joint profits of the alliance members but also industry profits are highest under the given alliance structure — otherwise the outsider could render the alliance unattractive for at least one member by an appropriate side payment.

In this setting there are two incentives for alliance formation:

- As all alliance members jointly realize network externalities or learning curve effects industry profits tin the second period are higher than in an asymmetric oligopoly without cooperation — the inefficient entry of an follower selling an incompatible product with lower demand or producing with higher costs is avoided.

- A two–firm alliance between the technological leader and one of the followers facilitate entry blocking in situations where the technological leader cannot profitably block entry by himself. With an alliance two firms have higher demand or lower cost in the second period and therefore it is possible to render entry of the third firm unattractive with a first period industry output that is lower than the quantity the technological leader must produce to block entry of both potential competitors.

On the other hand an alliance yields lower first period industry profits due to more intense competition for cases where entry is neither blocked by the alliance nor by a technological leader alone. If market entry would be blocked without an alliance or by a two–firm alliance, respectively, the alliance formation or the enlargement to a three–firm alliance, respectively, also yields more intense competition in the second period.

An alliance will be formed for medium values of network externalities or learning curve effects as long as the head start of the technological leader is not too pronounced. However, if network externalities or learning curve effects are low or the second period is not sufficiently important, the loss in industry profits in the first period cannot be compensated by advantages in the second period. For very pronounced network externalities or learning curve effects the technological leader can block entry by himself and has therefore no incentive to join in an alliance. Concerning the cases with alliance formation, a three–firm alliance will only result for a small head start of the technological leader and relatively small network externalities or learning curve effects; otherwise a two–firm alliance is preferable as the pro–competitive impact is less pronounced and entry of the third firm is actively blocked for higher levels of network externalities or learning curve effects.

From a public policy perspective the no–alliance equilibrium with entry blocking by the technological leader is almost always advantageous: the positive impact on demand or cost dominates the reduction in allocative efficiency due to monopoly pricing. For lower values of network externalities or learning curve effects an alliance of all firms is in most cases the most attractive result from a social point of view. While such a three–firm alliance only results in equilibrium if the second period is very important and at the same time network externalities or learning curve effects are quite low, welfare in the case of a two–firm alliance is always higher than without alliance formation in almost all cases when this the equilibrium alliance structure. Therefore restricting alliance formation in markets with network externalities or learning curve effects by anti trust policy cannot be recommended based on the analysis in the present model. Rather some mild form of industrial policy that stimulates an alliance formation between all potential competitors might enhance welfare as long as network externalities or learning curve effects are not very pronounced.

The results discussed above have been obtained in a model with some quite specific assumptions. By comparing the outcomes with these from other papers in the literature, it is possible to point out these aspects that are of general importance for alliance formation in markets with network externalities and learning curve effects and it can be shown which problems have not been dealt with yet in the literature, but could be highlighted just by these specific assumptions.

- Cooperation incentives in a learning curve setting are to my knowledge only discussed in a paper by *Petit/Tolwinski (1997)* who consider technology transfer in a explicitly dynamic duopoly model. As in the present setting cooperation might have a positive impact on welfare that is due to the joint realization of cost reductions from learning by doing. The technological leader is not very eager to cooperate as he would prefer monopolization of the industry. This is in line with our results with respect to the welfare impact of three–firm alliances and the incentive for entry blocking by the technological leader. As the analysis is performed in a duopoly setting, cooperation by a part of the industry is not considered.

- *Axelrod et. al. (1995)* consider standard setting alliances in a setting with network externalities. There are similar incentives for alliance formation like in the present analysis: compatibility allows to jointly realizing network externalities but intensifies competition between the cooperating firms. However, the authors assume a different kind of asymmetry: potential alliance partners differ with respect to the intensity of competition between each other. In this setting it is possible to determine under what circumstances a common industry standard is likely to result (high network externalities and relatively symmetric intensity of competition) and which firms are likely to cooperate in the case of competing standards (cooperation with direct competitors is avoided).

- As already mentioned in the introduction, *Economides (1996)* analyzes the incentive for a technology transfer in a network externalities industry with a "fulfilled expectations equilibrium" approach: consumers have rational expectations with respect to the network size and in equilibrium expect size and actual size coincide. In this setting the technology transfer itself has commitment value: if there are more firms that produce a compatible product, consumers expect higher output and thus value the product more. In contrast to the present paper a technology transfer may then be profitable for the technological leader even without side payments. Apart from this difference results are similar insofar as side payments in the form of royalties increase incentives for cooperation and make it possible to achieve a socially preferable outcome.

- *Economides/Flyer (1995)* consider incentives for cooperation between symmetric firms in "fulfilled–expectations"–setting. They show that a single standard results only for relatively low network externalities (this is similar to our result with respect to the formation of a three–firm alliance). The reason is that for an already relatively large alliance an additional member has only a small impact on realized network externalities but intensifies competition substantially. In *Bloch (1995)* the same mechanism yields the result that entry of further alliance partners is blocked by relatively large alliances and therefore two competing alliances result in equilibrium.

What are the main similarities and the central differences between markets with network externalities and learning curve effects, respectively? Both phenomena are similar with respect to the basic dynamic structure — this made it possible to use the same model as long as adaptive expectations are assumed under network externalities. The main difference lays in the fact that with a learning curve the dynamic scale economies result from the cumulated production of the good, while expectations of consumers and the resulting willingness to pay determine the demand side scale economies in the case of network externalities. Therefore an alliance between firms in a market with learning curve effects implies joint production. With network externalities it suffices to transfer the technology as the higher willingness to pay is the same for all compatible products. Furthermore it is possible in principle to influence the expectation of consumers directly by the alliance formation: in the "fulfilled expectations equilibrium" approach consumers expect higher output if more firms supply a compatible product which in turn yields a higher willingness to pay for this product. In the learning curve setting expectations are irrelevant. Therefore a strategic impact cannot be derived by just joining an alliance: only a "strategic investment" by joint production in the first period can achieve this.

It is now possible to draw the following main conclusions from the present analysis:

- The basic incentives for alliance formation and the predicted alliance structures are similar in markets with network externalities and learning curve effects. As long as adaptive expectations are assumed in the network externalities setting the results are actually identical — the only difference is the necessity of joint production in the case with learning curve effects.

- Entry blocking can be an important incentive to form an alliance for intermediate values of network externalities or learning curve effects where this kind of strategy is not profitable for the technological leader alone.

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