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# Does Cooperation in Manufacturing Foster Tacit Collusion?

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**Abstract**

This paper analyzes the effect of cooperation in manufacturing on firms' inclination to collude in the market. Compared to non-cooperation in manufacturing, coordination of the investments in production yields a higher competitive profit. If firms intensify cooperation and produce in a joint plant, this profit is still higher due to lower investment costs. Since firms return to competition after a defection from the collusive agreement, a high competitive profit implies a weak punishment. Collusion is thus more difficult, the closer firms cooperate in manufacturing. Moreover, given competition or collusion in the market, joint production yields the highest profit and welfare.

keywords: Manufacturing, Cooperative production, Dynamic competition, Collusion

JEL classification: C73, L13, L23, L41

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# 1 Introduction

The number of strategic alliances, among them production joint ventures and other collaborative projects in manufacturing, rose markedly in recent years. The trade-off between the potential efficiency gains from such cooperation and the possible losses from increased market power is an important issue for competition policy.

In order to promote the competitiveness of domestic industries by allowing for efficiency gains from cooperation, the *National Cooperative Research and Production Act* was enacted in the USA in 1993. In the European Union horizontal cooperation between competitors is regulated by the articles 81 and 82 of the Treaty of Rome and the new *Block Exemptions* and *Horizontal Guidelines* of 2001. This rather lenient regulation of cooperation in production, R&D, and marketing reflects that the implied intensification of dynamic competition, e.g. by development of new products or improvement of the production processes, is judged to be more important than the potential costs of collusion.

The more lenient legal treatment of horizontal inter-firm cooperation was accompanied by experts' warnings that such law changes could alleviate tacit anticompetitive behavior (collusion) of the participating firms (c.f., e.g. *Jorde*, *Teece* 1990, *Shapiro*, *Willig* 1990). Despite such worries, there are no econometric studies and only a small number of theoretical papers that analyze the effect of such cooperation and collusion in the market. This literature focuses entirely on cooperation in R&D.[1] There are also a few studies of horizontal cooperation in manufacturing by *Roy Chowdhury*, *Roy Chowdhury* (2001), as well as *Kwoka* (1992), *Bresnahan*, *Salop* (1986), and *Reynolds*, *Snapp* (1986). *Chen*, *Ross* (2003) study cooperation in the production of an input. However, none of these authors considers the possibility of an implicit agreement in the product market. These analyses do not take into account that firms usually compete in a market over a long time and thus can credibly threaten to punish a violator of an illegal (tacit or implicit) agreement by aggressive behavior in the future. Papers that assess the additional effect of long-run competition consider only cooperation in research, e.g. *Martin* (1995), *Petit*, *Tolwinski* (1999), and *Kesteloot*, *Veugelers* (1995). Research, however, is characterized by the involuntary leakage or conscious exchange of newly gained knowledge, whereas in manufacturing

[1] Recent examples are among others, *Anbarci et al.* (2002), *Battaggion*, *Garella* (2001), *Hinloopen* (2000), and *Brod*, *Shivakumar* (1997). Empirical papers as those by *Hernán et al.* (2003), *Kaiser* (2002), and *Bernstein*, *Nadiri* (1989) investigate the factors determining the formation of research joint ventures, but not their effect on competition in the product market.

the improvement of the production process in one plant has no effect on the efficiency of production in others. The motives for and the effects of cooperation are hence different in R&D and manufacturing.

The most cited motive for cooperation in manufacturing is the potential gain in efficiency (c.f., e.g. *Johnson*, *Houston* 2000). Another very important advantage is the internalization of the "negative externality" that arises from investments in the production process. A firm that invests in process improvement thereby reduces its rivals' profits since it lowers its own unit cost, produces more and competes more aggressively in the market. Thus, such cost reducing investments are a prime example of a strategy that makes a firm a "tough" competitor in the terminology introduced by *Fudenberg*, *Tirole* (1984). As this is true for all competitors, the possibility of process improvement results in a prisoners' dilemma. Each firm cuts own unit costs by high investments in order to keep up with its rivals. This more aggressive competition reduces the profits additionally to the expenditures on process improvement. If firms cooperate in manufacturing and coordinate investments, they are able to mitigate this negative externality and gain higher profits. A larger pool of financial funds and stronger bargaining power in negotiations with banks and financial investors are additional advantages of cooperation. Many examples of such alliances or joint ventures can be found in the automobile industry, where firms increasingly often produce the chassis, gearboxes, machines and some times even whole cars jointly in order to reduce production costs, but market the final products independently. For example, Fiat and General Motors cooperate in the production of engines and other parts and produce a light commercial van with Peugeot in a jointly owned factory (c.f. *The Economist*, April 4th 2002 and June 2nd 2000). The cooperation of several large producers of mobile phones in the production of specialized software is another example (c.f. *The Economist*, Feb 11th 1999).

The model proposed here describes such cases and derives their effect on firms' inclination to collude in the product market. As most firms regularly invest in order to optimize the production process, cooperation in manufacturing implies coordination of such investment decisions. In order to account for the fact that collective efforts take various organizational forms, we distinguish two types of cooperation, namely loose coordination of investment decisions in a production *joint venture* and close cooperation by *joint production* in a single plant. These are compared to noncooperative production termed *investment competition*. In contrast to the papers by *Kesteloot*, *Veugelers* (1995) and *Cabral* (2000) on collective research, we account for the fact that contracts on cooperation in manufacturing, R&D and other fields are allowed by antitrust regulation and therefore can be enforced in court. In fact, the level of investments can be verified easily by checking invoices and wage bills.

Our analysis shows that cooperation in manufacturing hampers collusion, whereas competition in the investment stage strengthens an anticompetitive agreement. Further, with *joint production* an implicit collusive agreement is less attractive than with coordination of investments in a production *joint venture*. The basic intuition for this seemingly counterintuitive result is the following. With cooperation in production, a firm accounts for the negative effect of a decrease in its own unit cost on the competitors' profits and invests less in the production process. Consequently, the competitive profit is higher than in the case of *investment competition*. This in turn implies a lower potential punishment which makes collusion more difficult. At the same time, due to the internalization of the negative externality and the additional cost savings achieved by production in a single plant, the individual competitive profits are even higher in the case of *joint production*, so that collusion is least likely in this case. Moreover, the resulting welfare level here is the highest within the three possible types of organizing the manufacturing process.

The rest of the paper is structured as follows: In the next section, we derive the profits and the incentive to participate in an implicit quota agreement in four different settings: the case without investments (the benchmark case), *investment competition*, production in a *joint venture*, and *joint production* in a single plant. In Section 3, we compare a firm's incentive to collude in these four cases and show that cooperation destabilizes an implicit anticompetitive agreement. The private profitability of cooperation is demonstrated in Section 4, whereas welfare effects are discussed in Section 5. The Conclusion summarizes our results.

# 2 Collusion and Cooperative Production

In most oligopolistic markets firms compete over a long time span and have neither a plan to exit the market at a certain point in time nor do they know when the market will disappear due to lack of demand. Firms repeatedly compete with the same rivals because oligopolies are as a rule protected by high entry barriers. We model such a market by assuming that competition takes place over an infinite number of periods. Such an infinitely repeated game can also be interpreted as a model of finitely repeated competition with uncertain end (c.f. *Tirole*, 1988, 253). In this case, firms valuation of future profits accounts for the uncertainty of continuation of the competition. The assumption of an infinite time horizon is hence a convenient simplification that is not as restrictive as it might seem at first glance. With such long-term interaction, firms have an incentive to restrain competition by implicitly agreeing to produce quantities below the competitive level. In order to maximize their joint profits, firms will set the lowest quantity that just not destabilizes collusion. Such an implicit quota agreement can be enforced because firms can credibly threaten to punish a deviator by producing the competitive quantity for ever.[2]

In order to highlight the effect of investments in the production process on an implicit agreement in the product market, we will first derive firms' inclination to collude in a situation without such expenditures.

## 2.1 No Investments in Production

*Friedman* (1971) analyzes the basic case of tacit collusion between symmetric firms that do not invest in the production process. We briefly review a part of his results that will serve as a benchmark for comparison with the three cases where firms invest in the improvement of the production process. In this simple model of competition over an infinite horizon, a firm takes part in an implicit agreement if the resulting discounted stream of current and future collusive profits is at least as large as the one-time gain from cheating and the profit stream in the ensuing infinite punishment phase. Hence, the implicit agreement is advantageous if

$$\frac{1}{1-\delta}\,\pi_A \geq \pi_D + \frac{\delta}{1-\delta}\,\pi_N$$

holds, where $\delta$ is the market discount factor.[3] Index $A$ stands for a collusive "agreement", $D$ for "defection", and $N$ for "Nash"-Cournot competition. By solving for the critical threshold of the discount factor, fulfilling this condition with equality, we obtain

$$\delta \geq \underline{\delta} \equiv \frac{\pi_D - \pi_A}{\pi_D - \pi_N} \tag{1}$$

as the condition for joint monopolization of the market. Obviously, collusion is possible as long as firms value future profits higher than indicated by the critical value

[2] Shorter periods of more severe punishments could be used to implement an optimal punishment as introduced by *Abreu* (1986). Here, we consider an unrelenting trigger strategy in order to keep the analysis as simple as possible.

[3] In the following, a firm index is omitted where no information is lost.

$\underline{\delta}$. Standard calculations reveal that the profits from Nash-Cournot competition, collusion, and defection are $\pi_N = (a-c)^2/9,\ \pi_A = (a-c)^2/8$, and $\pi_D = 9(a-c)^2/64$, respectively. Hence, without investments, the critical lower bound of the discount factors consistent with collusion is $\underline{\delta} = 9/17$. If firms are at least as patient, and thus, $\delta \geq \underline{\delta}$ holds, they can tacitly agree to set any quota between the competitive and the joint-profit-maximizing level. However, choosing the smallest quantity that does not destabilize collusion yields the highest profit and is thus optimal for every firm.

## 2.2 The Basic Model of the Production Process

The manufacturing of medium- and high-tech products requires sophisticated technical equipment and constant adoption of new production processes. Production costs differ greatly depending on the quality of the machinery and the technology embodied in this equipment. Therefore, by investing in the latest equipment and reorganizing production to make the best use of novelties allows for a considerable reduction of production costs. However, such capital goods depreciate fast: Firstly, very sensitive measurement and production machinery is usually fragile and wears off quickly. Secondly, such equipment is itself a high-tech product that is subject to rapid technological progress. This fact is mirrored by the assumption that the knowledge embodied in high-tech production equipment is outdated and worthless after one period. Recurring investments are therefore necessary in order to keep the manufacturing process efficient. If these are not made, costs remain at the high level corresponding to production with “traditional” technology.

In order to keep our model simple, we consider a duopoly ($n = 2$) and model this investment-quantity competition as infinite repetition of a two-stage basic game. In the first stage of each period, firm $i$ invests in order to reduce the initial unit cost $c$ by $e_B\, x_i,\ i = 1,\, 2,\ B = C,\ J,\ P$. This requires expenditures $\gamma\, x_i^2/2$ on the improvement of the production process. The efficiency parameter $e_B$ describes the effectiveness of cost reduction achieved by the different possibilities to organize production where the index $C$ indicates *investment “competition”*, index $J$ a *“joint” venture*, and index $P$ *joint “production”*. If firms realize synergies by cooperation, as is often claimed, the efficiency parameter $e_B$ is higher the closer firms coordinate their investment decisions. The investments of all firms are observable by the rivals. This mirrors the fact that usually firms monitor each others activities, and workers of rival firms meet each other and talk about their work. The function

$$C(x_i) = c - e_B\, x_i,\ i = 1, 2$$

thus describes the unit costs of firm $i$ achieved by investments in the production process if there are no fixed costs of production.

In stage two, firms produce and market the good. In order to keep the number of parameters small we use a normed demand function. The inverse demand for the homogeneous good is given by

$$p_i = (a - q_i - q_j),\ i \neq j.$$

Therefore, a firm realizes the individual profit net investment costs

$$\pi_i = \{a - q_i - q_j - [c - e_B\, x_i)]\}\ q_i - \gamma \frac{{x_i}^2}{2},\ \ c < a.$$

If a firm competes in the product market, it maximizes its individual profit, but if it participates in collusion, it maximizes the sum of both firms' profits, considering in both cases the decision on cooperation or non-cooperation in manufacturing in the first stage which is discussed in the following subsections.[4]

## 2.3 Investment Competition

In this case, firms set their investments non-cooperatively in order to maximize their individual profits. We call this *investment competition* and indicate it by index $C$. Table 1 gives the individual quantities, investments, and per-period profits from competition, collusion, and defection in the market stage that result if firms set investments non-cooperatively in the first stage of each period. They are derived by solving the respective stage games by backward induction.

When cheating a firm always sets the collusive investment in the production stage and defects in the market stage. This is true because the alternative deviation profit

[4] Note, that extended to differentiated products this model can also be applied to demand increasing investments. Then, $a + e_B\, x_i$ is the market size achieved by expenditures $\gamma\ x_i^2/2$. The assumption that the effect of investment wears off after one period then describes the fact that consumers get used to the change in the design, packaging, or recipe and demand declines again after a while. Hence, regular changes amounting to "rebranding" are needed in order to keep demand high over time.

Table 1: Quantities, Investments, and Profits with *Investment Competition*

| | Quantities | Investments | Profits |
|---|---|---|---|
| Punishment | $q_{NC} = \frac{3\,\gamma\,(a-c)}{9\,\gamma-4\,e_C^2}$ | $x_{NC} = \frac{4\,e_C\,(a-c)}{9\,\gamma-4\,e_C{}^2}$ | $\pi_{NC} = \frac{\gamma\,(a-c)^2\,\left(9\,\gamma-8\,e_C^2\right)}{\left(9\,\gamma-4\,e_C^2\right)^2}$ |
| Collusion | $q_{AC} = \frac{4\,\gamma\,(a-c)}{16\,\gamma-5\,e_C^2}$ | $x_{AC} = \frac{5\,e_C\,(a-c)}{16\,\gamma-5\,e_C^2}$ | $\pi_{AC} = \frac{\gamma\,(a-c)^2\,(64\,\gamma-25\,e_C)}{2\left(16\,\gamma-5\,e_C^2\right)^2}$ |
| Deviation | $q_{DC} = \frac{6\,\gamma\,(a-c)}{16\,\gamma-5\,e_C^2}$ | $x_{DC} = x_{AC}$ | $\pi_{DC} = \frac{\gamma\,(a-c)^2\,\left(72\,\gamma-25\,e_C^2\right)}{2\left(16\,\gamma-5\,e_C^2\right)^2}$ |

that it gains by investing non-cooperatively,

$$\pi_{DC,alt.} = \frac{4\,\gamma\,(a-c)^2\,\left(8\,\gamma-5\,e_C^2\right)^2}{\left(9\,\gamma-8\,e_C^2\right)\,\left(16\,\gamma-5\,e_C^2\right)^2},$$

is lower than $\pi_{DC}$ for $\gamma > 161\,e_C^2/136$ which is true for stable equilibria.[5] By inserting the profits from Table 1 in (1) we obtain

$$\delta \geq \underline{\delta}_C \equiv \frac{8\,\left(9\,\gamma-4\,e_C^2\right)^2}{\gamma\,\left(1224\,\gamma-233\,e_C^2\right)-58\,e_C^4} \tag{2}$$

as condition for collusion if firms compete in investments. If firms value future profits highly, corresponding to a discount factor at least as large as $\underline{\delta}_C$, the above condition is fulfilled. With these findings we are able to state our first result.

***Proposition 1:*** *In the case of non-cooperative investments in the production process, a firm takes part in a collusive agreement if it values future profits as least as much as indicated by the critical discount factor $\underline{\delta}_C$ defined in (2).*

With help of the critical threshold $\underline{\delta}_C$, we are also able to derive the effect of increased efficiency in process improvement on the inclination to collude. The partial derivative of the critical value of the discount factor with respect to $e_C$

$$\frac{\partial\,\underline{\delta}_C}{\partial\,e_C} = -\frac{304\,\gamma\,e_C\,\left(9\,\gamma-4\,e_C^2\right)\,\left(405\,\gamma-104\,e_C^2\right)}{\left(58\,e_C^4+233\,\gamma\,e_C^2-1224\,\gamma^2\right)^2}$$

is negative by the second order condition for competition. Therefore, collusion in the product market is facilitated if firms efforts to reduce costs are more effective. The

[5] The second order condition for Nash-Cournot competition (punishment), is fulfilled if $\gamma > 8\,e_C^2/9$, and for collusion if $\gamma > 3\,e_C^2/8$ holds. Moreover, local stability of the equilibria in the investment stage requires $\left|\frac{\partial^2\pi_i/\partial x_i\,\partial x_j}{\partial^2\pi_i/\partial x_i^2}\right| < 1$ (e.g. *Martin*, 2002, 30/1). In the present case, this is fulfilled as long as $-1 < \frac{4\,e_C^2}{9\,\gamma-8\,e_C^2} < 1$ holds in the punishment phase, and $-1 < \frac{e_C^2}{16\,\gamma-6\,e_C^2} < 1$ is true for tacit collusion. A value of the investment cost parameter $\gamma$, $\gamma > 4\,e_C^2/3$ fulfills the strictest of these conditions. Hence, we restrict attention to such cases.

reason for this effect is the negative externality of own cost reduction on the rival's profits. Since, the profit from defection appears in the denominator and numerator of the critical discount factor (2), the effect is driven by the changes of the profits from punishment and collusion. By the second order conditions the sign of the partial derivatives

$$\frac{\partial \pi_{NC}}{\partial e_C} = \frac{64\gamma\,(a-c)^2}{(4-9\gamma)^3} < 0 \quad \text{and}$$

$$\frac{\partial \pi_{AC}}{\partial e_C} = \frac{5\gamma\,(a-c)^2\,(25-48\gamma)}{(5-16\gamma)^3} > 0,$$

can be determined. The competitive profit $\pi_{NC}$ falls with increasing efficiency because greater effectiveness of the rival's cost reduction lowers a firm's own profit strongly and requires high expenditures on the improvement of its own production process. The lower competitive profit implies a higher potential punishment of a defector. Moreover, the collusive profit $\pi_{AC}$ rises with greater efficiency $e_C$ due to the internalization of the negative strategic effect that requires a smaller effective cost reduction $e_C\,x_i$, which is achieved by a lower investment. Both effects of a rise in efficiency of the process improvement increase a firm's inclination to participate in an implicit quota agreement.

## 2.4 Joint Venture

If firms cooperate in improving the production process, they specify their obligations in a formal contract. Such a *joint venture* is covered by a block exemption or can be registered at the competition authorities and is then legal. We model such cooperation in a *joint venture* by assuming that the participating firms choose the level of investment that maximizes joint profits. The corresponding values of investments, quantities and profits are indicated by index $J$. As process improvements are firm-specific, the rival's efforts do not directly lower a firm's production costs despite coordination of investments. However, as argued in the introduction increased efficiency is often cited as the main motive to participate in joint ventures and is most likely obtained by organizational and technological learning from each other. In our model, such efficiency gains can be captured by assuming that the effectiveness of cost reducing activities is higher if firms participate in a *joint venture* than in the case of non-cooperative investment, $e_J > e_C$.

In order to maximize their profits, firms that participate in collusion specify the corresponding joint-profit maximizing investment level in the *joint venture* contract.

Since a violator of the contract on cooperation in production is liable to pay damages and a contractual penalty, a firm that deviates from an illegal quota agreement in the market continues to set this joint-profit-maximizing investment.[6] The equilibria in the cases of deviation, collusion, and punishment given in Table 2 below are again derived by solving the corresponding basic games by backward induction.[7]

Table 2: Quantities, Investments, and Profits with a *Joint Venture*

| | Quantities | Investments | Profits |
|---|---|---|---|
| Punishment | $q_{NJ} = \frac{3\,\gamma\,(a-c)}{9\,\gamma - 2\,e_J^2}$ | $x_{NJ} = \frac{2\,e_J (a-c)}{9\,\gamma - 2\,e_J^2}$ | $\pi_{NJ} = \frac{\gamma\,(a-c)^2}{9\,\gamma - 2\,e_J^2}$ |
| Collusion | $q_{AJ} = \frac{\gamma (a-c)}{4\,\gamma - e_J^2}$ | $x_{AJ} = \frac{e_J\,(a-c)}{4\,\gamma - e_J^2}$ | $\pi_{AJ} = \frac{\gamma\,(a-c)^2}{2(4\,\gamma - e_J^2)}$ |
| Deviation | $q_{DJ} = \frac{3\,\gamma\,(a-c)}{2(4\,\gamma - e_J^2)}$ | $x_{DJ} = x_{AJ}$ | $\pi_{DJ} = \frac{\gamma\,(a-c)^2\left(9\,\gamma - 2\,e_J^2\right)}{4\left(4\,\gamma - e_J^2\right)^2}$ |

The per-period profits given in Table 2 determine a firm's incentive to participate in an implicit agreement. In order to determine the lowest value of the discount factor that is consistent with perfect collusion we insert these profits in the condition for collusion (1) and obtain

$$\delta \geq \underline{\delta}_J \equiv \frac{9\,\gamma - 2\,e_J^2}{17\,\gamma - 4\,e_J^2}. \tag{3}$$

This proves our next Proposition.

***Proposition 2:*** *Firms that cooperate in a joint venture participate in collusion if they value future profits highly implying a discount factor that is at least as high as the threshold* $\underline{\delta}_J$ *given by (3).*

[6] $\pi_{DJ,alt.} = \frac{4\,\gamma\,(a-c)^2\left(2\,\gamma - e_J^2\right)^2}{\left(4\,\gamma - e_J^2\right)^2\left(9\,\gamma - 8\,e_J^2\right)}$ is the profit a defecting firm obtains if it deviates already in the investment stage. Comparison of this alternative profit with the deviation profit gained from an investment at the collusive level $\pi_{DJ}$ given in Table 2 shows that the latter is higher for $\gamma > 26\,e_J^2/17$ and hence for all stable equilibria. As in the case of *investment competition*, a defection in the investment stage does not occur even if the investment level are not contractible.

[7] $\gamma > 10\,e_J^2/9$ and $\gamma > 3\,e_J^2/8$ are the second order conditions and $-1 < \frac{8\,e_J^2}{9\,\gamma - 10\,e_J^2} < 1$ and $-1 < \frac{e_J^2}{8\,\gamma - 3\,e_J^2} < 1$ the conditions for local stability of the equilibria in the case of non-cooperative and collusive quantity setting, respectively. In order to ensure stability, we assume $\gamma > 2\,e_J^2$ to hold. *Salant*, *Shaffer* (1998) analyze R&D investments in a model that is technically very similar to the one presented here. They show that in the case of cooperative investments profits are maximized by asymmetric R&D expenditures for certain parameter configurations. However, for our linear, normed demand function and perfect appropriability, this is true only for values $\gamma < 2$ ($e_J = 1$ in their setting) that are not consistent with stable equilibria.

According to business representatives, an increase in efficiency is the most important reason for cooperation in manufacturing. Thus, it is interesting to determine how efficiency gains, described by a rise in the parameter $e_J$, influence a firm's inclination to collude. The partial derivative of the critical discount factor with respect to the efficiency parameter $e_J$

$$\frac{\partial \underline{\delta}_J}{\partial e_J} = \frac{4\,\gamma\, e_J}{(17\,\gamma - 4\,e_J^2)^2}$$

is positive. Therefore, collusion is less likely the higher the effectiveness of cost reductions $e_J$. The partial derivatives

$$\frac{\partial \pi_{NJ}}{\partial e_J} = \frac{4\,\gamma\, e_J\,(a-c)^2}{(2\,e_J^2 - 9\,\gamma)^2} > 0 \quad \text{and}$$

$$\frac{\partial \pi_{KJ}}{\partial e_J} = \frac{\gamma\, e_J\,(a-c)^2}{(e_J^2 - 4\,\gamma)^2} > 0$$

show that both the profit from competition and collusion increase with rising efficiency $e_J$. Here, firms internalize the negative externality either only by cooperation in production or additionally by implicit coordination in the market. However, the increases of competitive and collusive profits have counteracting effects on the feasibility of collusion. The negative sign of the difference between these partial derivatives

$$\frac{\partial \pi_{NJ}}{\partial e_J} - \frac{\partial \pi_{KJ}}{\partial e_J} = \frac{\gamma^2\, e_J\,(a-c)^2\,(4\,e_J^2 - 17\,\gamma)}{(2\,e_J^2 - 9\,\gamma)^2\,(e_J^2 - 4\,\gamma)^2} < 0.$$

demonstrates that the competitive profit increases less than the collusive profit. Hence, cooperation in a *joint venture* makes illegal anti-competitive agreements less likely if it raises firms' effectiveness in improving the production process.

## 2.5 Joint Production

In other cases, cooperation includes production in a single plant. We term this type of cooperation *joint production* and denote it by index $P$. Such close cooperation implies that firms jointly choose the level of cost reduction $e_P\,X = e_P\,(x_i + x_j)$ and share the total investment costs $\gamma/2\,X^2$ equally.

As firms produce in a jointly owned plant, they cannot reduce the investment in process improvement without the partner noticing this and taking the case to court. Therefore, in the case of defection or punishment, the firms continue to invest the previously agreed collusive investment levels if they participate in an implicit agreement. Defection and punishment is hence restricted to the market stage. All equilibrium values for this type of close cooperation in manufacturing are summarized in Table 3 below. The equilibria are again obtained by solving the corresponding stage games by backward induction.[8]

Table 3: Quantities, Investments, and Profits with *Joint Production*

| | Quantities | Investments | Profits |
|---|---|---|---|
| Punishment | $q_{NP} = \frac{3\gamma(a-c)}{9\gamma-4e_P^2}$ | $x_{NP} = \frac{2e_P(a-c)}{9\gamma-4e_P^2}$ | $\pi_{NP} = \frac{\gamma(a-c)^2}{9\gamma-4e_P^2}$ |
| Collusion | $q_{AP} = \frac{\gamma(a-c)}{2\left(2\gamma-e_P^2\right)}$ | $x_{AP} = \frac{e_P(a-c)}{2\left(2\gamma-e_P^2\right)}$ | $\pi_{AP} = \frac{\gamma(a-c)^2}{4\left(2\gamma-e_P^2\right)}$ |
| Deviation | $q_{DP} = \frac{3\gamma(a-c)}{4\left(2\gamma-e_P^2\right)}$ | $x_{DP} = x_{AF} = \frac{e_P(a-c)}{2\left(2\gamma-e_P^2\right)}$ | $\pi_{DP} = \frac{\gamma(a-c)^2\left(9\gamma-4e_P^2\right)}{16\left(2\gamma-e_P^2\right)^2}$ |

A firm's inclination to participate in an implicit agreement depends on the relative sizes of the per-period profits given in Table 3. By inserting these profits in condition (1), we obtain

$$\delta \geq \underline{\delta}_P \equiv \frac{9\gamma - 4e_P^2}{17\gamma - 8e_P^2}. \tag{4}$$

as the condition for collusion. Therefore, the following Proposition is true.

***Proposition 3:*** *If firms that cooperate by joint production value future profits highly, i.e. if the discount factor is at least as high as the critical value $\underline{\delta}_P$ defined by (4), they participate in collusion.*

The sign of the partial derivative with respect to the efficiency parameter

$$\frac{\partial\,\underline{\delta}_P}{\partial\,e_P} = \frac{8\gamma\,e_P}{(17\gamma - 8e_P^2)^2}$$

is positive. If firms are more effective in cost reductions, they have to place a higher value on future profits to be able to collude. The difference between the partial derivatives

$$\frac{\partial\,\pi_{NP}}{\partial\,e_P} - \frac{\partial\,\pi_{AP}}{\partial\,e_P} = \frac{\gamma^2\,e_P\,(a-c)^2\,(8e_P^2 - 17\gamma)}{2\,(4e_P^2 - 9\gamma)^2\,(e_P^2 - 2\gamma)^2} > 0$$

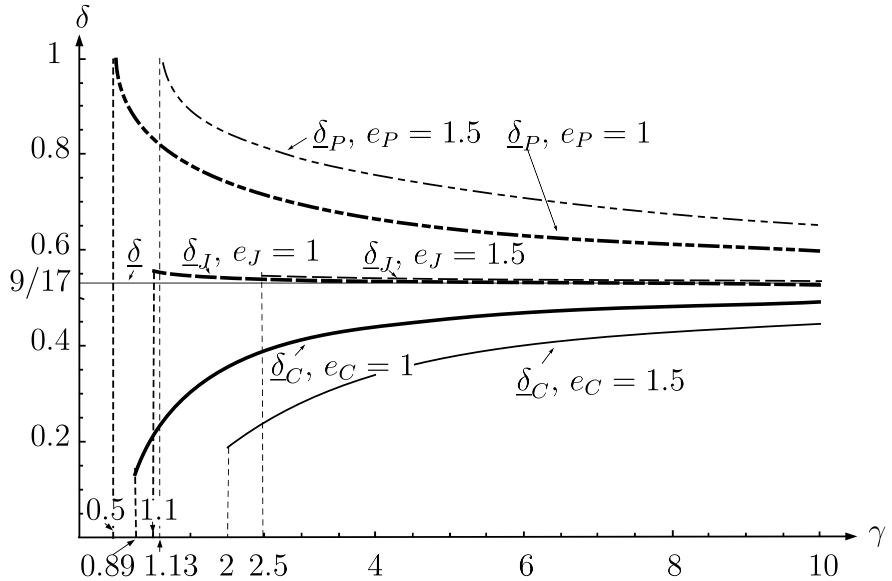
[8] The second order condition for the punishment is given by $\gamma > 4e_P^2/9$, and for the collusive equilibrium by $\gamma > e_P^2/2$. As firms choose the investment $X_P$ jointly, local stability of the equilibria is not an issue here.

is positive by the second order condition for collusion. If firms' effectiveness in cost reductions rises, the increase in the collusive profit does not outweigh the greater reduction of the potential punishment. Thus, the reason for the lower inclination to collude is the same as in the case of a *joint venture*.

# 3 Feasibility of Collusion

As in the case without investment in an improvement of the production process, the feasibility of collusion depends on the value that firms place on future profits. The lowest values, i.e. discount factors, that are consistent with collusion are drawn in Figure 1. Note, that the second order conditions require $\gamma > 8\,e_C^2/9 \simeq 0.89\,e_C^2$ in the case of *investment competition*, $\gamma > 10\,e_J^2/9 \simeq 1.1\,e_J^2$ in the case of *joint venture*, and $\gamma > e_P^2/2$ in the case of *joint production*. These conditions are represented by the dashed vertical lines in Figure 1.

Figure 1: Feasibility of Collusion with Different Organization of Manufacturing



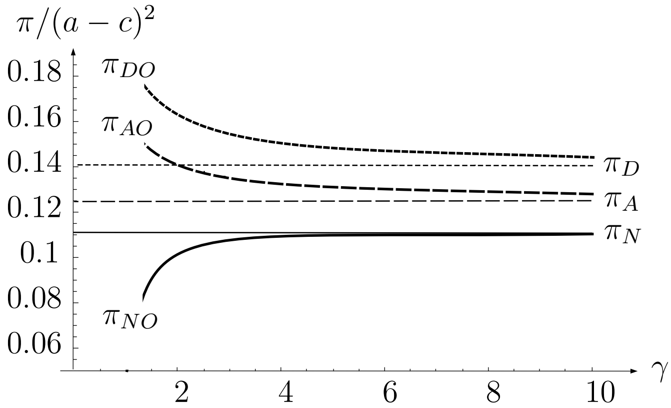

The lower the threshold of the discount factor the larger is the scope for collusion. Thus, a comparison of the critical values of the discount factor for *joint production* $\underline{\delta}_P$, for production in a *joint venture* $\underline{\delta}_J$, and for *investment competition* $\underline{\delta}_C$ determines the ranking of the three types of production organization with respect to the feasibility of collusion. It demonstrates that firms gain the widest room for collusion if they do not cooperate in the investment stage. This finding stands in sharp contrast to experts' warnings in the discussions on the legal treatment of cooperation in manufacturing.

Technically, straightforward comparisons of analytical expressions for the thresholds $\underline{\delta}_P$ in (4), $\underline{\delta}_J$ in (3), and $\underline{\delta}_C$ in (2) lead to the following conclusions. The inequality $\underline{\delta}_P > \underline{\delta}_J$ holds for all values of the investment cost parameter $\gamma$ that fulfill the respective second order conditions if the effectiveness of cost reductions is the same in a *joint venture* and with *joint production*, $e_P = e_J$. Comparison of the derivatives from Propositions 2 and 3 shows that the critical threshold $\underline{\delta}_P$ rises stronger in the efficiency parameter $e_P$ than $\underline{\delta}_J$ in $e_J$. Therefore, the inequality $\underline{\delta}_P > \underline{\delta}_J$ is all the more true, if firms gain effectiveness in process improvement by closer cooperation in the production stage, $e_P > e_J$. Furthermore, $\underline{\delta}_J > \underline{\delta}_C$ holds for $\gamma < 2\,e^2\left(378 - 19\sqrt{17}\right)/2613$ and $\gamma > 2\,e^2\left(378 + 19\sqrt{17}\right)/2613]$, if investments are equally effective in both cases, $e_C = e_J = e$. The first range of $\gamma$ is excluded, but the last inequality holds by the the second order condition $\gamma > 3\,e_C^2/8$ or $\gamma > 3\,e_J^2/8$. Propositions 1 and 2 demonstrate that the critical value of the discount factor $\underline{\delta}_C$ falls, but $\underline{\delta}_J$ rises in the efficiency of cost reductions. Again, the conclusion $\underline{\delta}_J > \underline{\delta}_C$ is strengthened if cooperation in a *joint venture* implies an efficiency gain, $e_J > e_C$. Figure 1 illustrates this results that are summarized in the following Proposition.

***Proposition 4:*** *Collusion is most difficult in the case of joint production, less difficult in the case of a joint venture, and least difficult if firms compete in the investments, i.e.* $\underline{\delta}_P > \underline{\delta}_J > \underline{\delta}_C$ *holds.*

The critical threshold of the discount factor for collusion is lowest in the case of *investment competition*. Figure 2 illustrates the development of the corresponding per-period profits, adjusted by division by $(a-c)^2$, in dependence of the investment cost parameter $\gamma$. The thin lines show the profits obtained without investments, the thick lines those gained from *investment competition* when $e_C = 1$. Without cooperation, the profit from non-cooperative investments in the production stage is lower than without such cost-reducing process improvement. This illustrates that cost reduction is a "tough" strategy in the terminology introduced by *Fudenberg, Tirole* (1984) if firms compete in strategic substitutes (as is the case with quantity competition when the good is homogeneous, c.f. *Bulow et al.* 1985). In this prisoners' dilemma firms compete more aggressively and gain lower profits than in a market without investments in cost reduction. Profits from collusion and defection in the market stage, however, are increased by efforts to reduce unit costs compared to profits gained without investments. When colluding, firms indirectly internalize the

Figure 2: Per-Period Profits with *Investment Competition* and without Investments




negative effect of own cost reduction on the rival's profit by joint profit maximization in the market stage. This effect together with the lower competitive profit, i.e. higher punishment, overcompensates the increased one-shot gain from defection so that collusion is more stable than without investments in cost reduction. As argued in the discussion of Proposition 1, this "tough" strategic effect also determines the changes of per-period profits caused by efficiency gains. Therefore, the effects of investments are even more pronounced the higher the efficiency in process improvement.

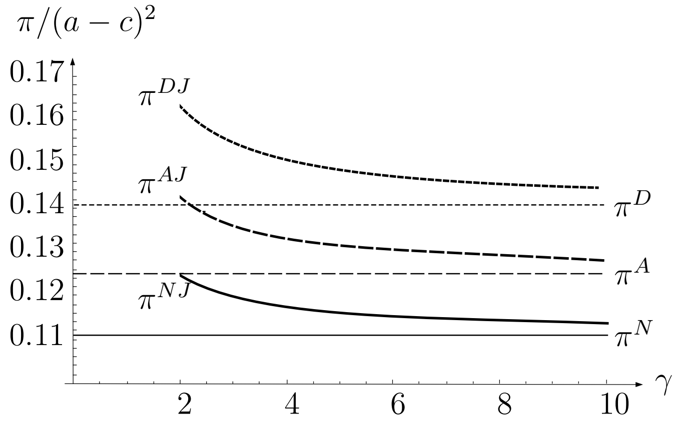
Perhaps surprisingly, firms' inclination to collude is lower than without investments in production if they cooperate in a *joint venture*. Figure 3 demonstrates that such cooperative investments in unit-cost reduction increase the profit from defection more than the collusive profit which in turn rises stronger than the profit from punishment compared to the respective profits gained without process improvement. Analytically,

$$(\pi_{DJ} - \pi_D) - (\pi_{AJ} - \pi_A) = \frac{(a-c)^2\, e_J^2\, (8\gamma - e_J^2)}{64\, (4\gamma - e_J^2)^2} > 0 \quad \text{for} \quad \gamma > e_J^2/8 \quad \text{and}$$

$$(\pi_{AJ} - \pi_A) - (\pi_{NJ} - \pi_N) = \frac{e_J^2\, (a-c)^2\, (17\gamma - 2\, e_J^2)}{72\, (4\gamma - e_J^2)\, (9\gamma - 2\, e_J^2)} > 0 \quad \text{for} \quad \gamma > 2\, e_J^2/17.$$

Thus, both differences of profits are positive by the second order condition for collusion. This holds for all degrees of efficiency of cost reducing activities $e_J$. For the sake of concreteness, Figure 3 shows the per-period profits for an effectiveness in cost reduction of $e_J = 1$. As participants in a *joint venture* internalize the negative effect of unit-cost reductions, cheating on a competitor that trustfully sets the collusive output quota is all the more profitable. Moreover, the profit from competition in the market stage is also higher implying a lower punishment. The collusive profit does not offset this incentive to defect from the agreement. Therefore, collusion is

Figure 3: Per-Period Profits with a *Joint Venture* and without Investments



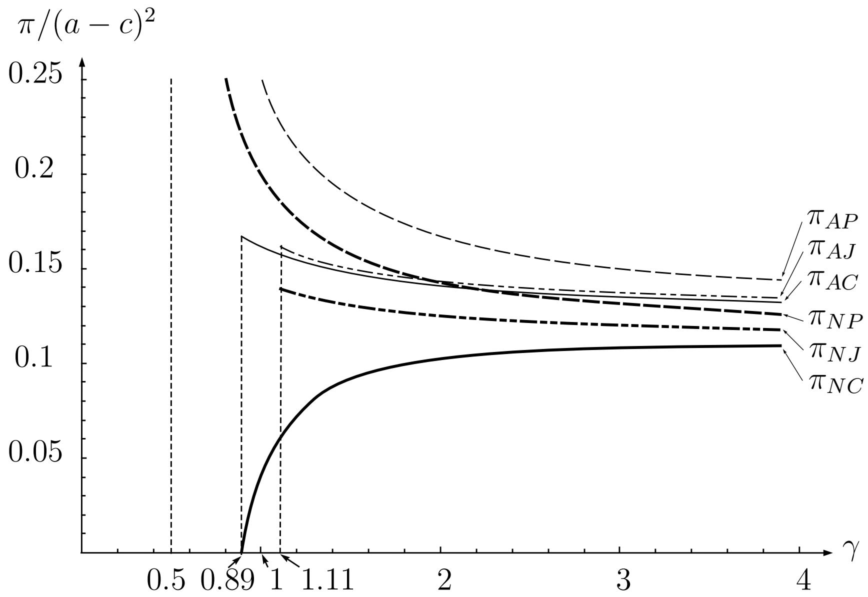

less stable than in a market where firms cannot reduce production costs. In the case of *joint production* the incentive to collude is even lower than in a *joint venture* due to the additional increase of profits that results from the saving of investment costs implied by production in a single plant. As in the case of a *joint venture*, the competitive profit and the defection profit rise stronger than the collusive profit. The graphic of these profits and the corresponding profits without investments in cost reduction is qualitatively identical to Figure 3 and is thus omitted.

Note also, that the above effects of cost-reducing investments with different types of organizing production are most pronounced for low costs of process improvement, corresponding to a low value of the parameter $\gamma$. If conditions for investment in production are unfavorable, however, these are small and the critical thresholds of the discount factors converge against the critical value $\underline{\delta} = 9/17$ relevant in a market where unit costs cannot be reduced by investing.

# 4 Profitability of Cooperation in Manufacturing

The ranking of profits gained by *investment competition*, cooperation in a *joint venture*, and *joint production* is also a result of different extents of the strategic effect of cost-reducing investments in the production process. If firms compete in the production stage, these investments impose a negative externality on the rival's profit. If firms cooperate in a *joint venture* or by *joint production* they internalize this negative effect. Moreover, the individual profit gained by *joint production* is higher than in a *joint venture* because investments have to be made in only one plant. If a firm takes part in an implicit agreement in the market stage it also accounts for the negative effect of a larger production on rival's profit. Therefore, collusive profits are higher than competitive profits given the organization of production. In short, the per-period profit is larger, the more intense cooperation in the investment decision. Furthermore, it is higher if firms also implicitly coordinate their output decisions in the market stage.[9] Figure 4 shows the per-period profits for a situation where the organization of manufacturing does not influence firms' effectiveness in cost reduction and $e_C = e_J = e_P = 1$.

Figure 4: Per-Period Profits from Collusion and Quantity Competition




Analytically, these conclusions are confirmed by comparisons of the per-period profits given in Tables 1, 2, and 3. They lead to the following inequalities:

$\pi_{AP} > \pi_{AJ}$, for $e_P > e_J/\sqrt{2}$ (if $e_P = e_J$, $\forall\,\gamma$),

$\pi_{AJ} > \pi_{AC}$ for $\gamma > \left[25\,e_C^2\,\left(e_J^2 - e_C^2\right)\right] / \left[64\,e_J^2 - 60\,e_C^2\right]$ for(if $e_J = e_C$, for $\gamma > e^2/4$,

$\pi_{NP} > \pi_{NJ}$ for $e_P > e_J/\sqrt{2}$ if $e_P = e_J$, $\forall\,\gamma$) and

$\pi_{NJ} > \pi_{NC}$ for $\gamma > \left[8\,e_C^2\,\left(e_J^2 - e_C^2\right)\right] / \left[9\,e_J^2\right]$ (if $e_J = e_C$, for $\gamma > 2/9e^2$).

These inequalities hold by the respective second order conditions.

$\pi_{NP} < \pi_{AC}$ if $e_P > \left\{9\,\gamma - \left[2\,\left(16\,\gamma - 5\,e_C^2\right)^2\right] / \left[64\,\gamma - 25\,e_C\right]\right\} / 4$ and

$\pi_{NP} < \pi_{AJ}$ if $\gamma > 2\,\left(e_P^2 - e_J^2\right)$

[9] Firms anticipate whether the value of future profits is sufficiently high to allow for collusion and compete in the market otherwise. Therefore, defection does not occur in equilibrium. Hence, the profits from defection are not discussed here and are also omitted in the Figure 4.

complete the comparison. Proposition 5 summarizes these findings.

**Proposition 5:** $\pi_{AP} > \pi_{AJ} > \pi_{AO} > \pi_{NP} > \pi_{NJ} > \pi_{NC}$, *holds for values of* $\gamma$ *that fulfill the inequality* $e_P > \left\{9\,\gamma - \left[2\,(16\,\gamma - 5\,e_C^2)^2\right] / [64\,\gamma - 25\,e_C]\right\} / 4$. *In other words, this profit ranking results except if the conditions for investments in process improvement are extremely favorable.*

Thus, even the lowest collusive profit $\pi_{AC}$ is higher than the highest competitive profit $\pi_{NP}$ except if the investment costs are low due to a value of $\gamma$. Since in the case of *joint production* firms need only invest in a single plant, investment costs implied by a certain level of unit costs are lower than in all other cases. If the costs of process improvement are low, due to a small value of the parameter $\gamma$, this cost saving outweighs the the profit increase associated with collusion. As a result, the profit from *joint production* is higher than from *investment competition* even if firms compete in the first and collude in the second case. In all other situations, the ranking of profits is independent of technological conditions mirrored by the parameter $\gamma$.

# 5 Welfare

From the perspective of policy agencies, the social welfare is the most appropriate benchmark for a comparison of the results with different degrees of cooperation in the investment decision and different product market strategies, i.e. collusion or competition.

Welfare is defined as the sum of consumer surplus and the sum of the firms' profits. If both firms produce in separate plants this amounts to

$$W(Q) = (a - Q/2)\;Q - [c - e_B\,x]\;Q - \gamma\,x^2,\;B = C,\,J \tag{5}$$

where $Q$ is the total quantity produced in the market. If production takes place in a jointly owned plant welfare is given by

$$W(Q) = (a - Q/2)\;Q - [c - e_P\,X]\;Q - \frac{\gamma}{2}X^2, \tag{6}$$

Inserting the equilibrium quantities and investments in these equations yields the social welfare achieved by the three types of organizing production given in Table 4.

If production takes place in two plants, investment is required in both of them in order to reduce unit costs, but if the total quantity is produced in one plant there is also only one production process that has to be optimized. Investment costs are lower and welfare is higher in this case. Thus, a social planner maximizes the welfare level (6) and sets $X^* = [(a-c)\ e_P] / [\gamma - e_P^2]$ and $Q^* = [\gamma\ (a-c)] / [\gamma\ - e_P^2]$ as the optimal investment and quantity. In the first best case, the social welfare level is

$$W^* = \frac{\gamma\ (a-c)^2}{2\ (\gamma - e_P^2)}. \tag{7}$$

In the benchmark case without investment, social welfare amounts to

Table 4: Welfare with Different Organization of Manufacturing

| | Punishment | Collusion |
|---|---|---|
| *Investment Competition* | $W_{NC} = \frac{4\gamma\,(a-c)^2}{\left(9\gamma-4\,e_C^2\right)^2}$ | $W_{AC} = \frac{\gamma\,(a-c)^2\left(96\,\gamma-25\,e_C^2\right)}{\left(16\,\gamma-5\,e_C^2\right)^2}$ |
| *Joint Venture* | $W_{NJ} = \frac{4\gamma\,(a-c)^2\left(9\,\gamma-e_J^2\right)}{\left(9\gamma-2\,e_J^2\right)^2}$ | $W_{AJ} = \frac{\gamma\,(a-c)^2\left(6\,\gamma-e_J^2\right)}{\left(4\,\gamma-e_J^2\right)^2}$ |
| *Joint Production* | $W_{NP} = \frac{4\gamma\,(a-c)^2\left(9\,\gamma-2\,e_P^2\right)}{\left(9\gamma-4\,e_P^2\right)^2}$ | $W_{AP} = \frac{\gamma\,(a-c)^2\left(3\,\gamma-e_P^2\right)}{2\left(2\,\gamma-e_P^2\right)^2}$ |

$$W_N = 4/9\ (a-c)^2\,, \tag{8}$$

$$W_A = 3/8\ (a-c)^2\,, \tag{9}$$

in the case of competition and collusion between the firms, respectively.[10] If unit-cost-reducing investments are prohibitively expensive, firms' investment levels converge to zero and the above levels of welfare result, irrespective of whether firms are patient enough to collude or not.

[10] As one would expect, the welfare levels are higher the higher firms' efficiency in cost reduction. In order to see this, consider the partial derivatives

$(\partial\, W_{NC}) / (\partial\, e_C) = 32\,\gamma\, e_C\ (a-c)^2 / \left(9\,\gamma - 4\, e_C^2\right)^2 > 0.$

The sign of the following derivatives follows from the respective second order conditions.

$(\partial W_{AC}) / (\partial e_C) = 10\,\gamma\, e_C\ (a-c)^2\ \left(112\,\gamma - 25\, {e_C}^2\right) / \left(16\,\gamma - 5\, {e_C}^2\right)^3 > 0$

$(\partial W_{NJ}) / (\partial e_J) = 8\,\gamma\, e_J\ (a-c)^2\ \left(27\,\gamma - 2\, {e_J}^2\right) / \left(9\,\gamma - 2\, {e_J}^2\right)^3 > 0$

$(\partial W_{AJ}) / (\partial e_J) = 2\,\gamma\, e_J\ (a-c)^2\ \left(8\,\gamma - e_J^2\right) / \left(4\,\gamma - e_J^2\right)^3 > 0$

$(\partial W_{NP}) / (\partial e_P) = 16\,\gamma\, e_P\ (a-c)^2\ \left(27\,\gamma - 4\, e_P^2\right) / \left(9\,\gamma - 4\, e_P^2\right)^3 > 0$

$(\partial W_{AP}) / (\partial e_P) = \gamma\, e_P\ (a-c)^2\ \left(4\,\gamma - e_P^2\right) / \left(2\,\gamma - e_P^2\right)^3 > 0.$

Figure 5: Welfare with Different Organization of Manufacturing

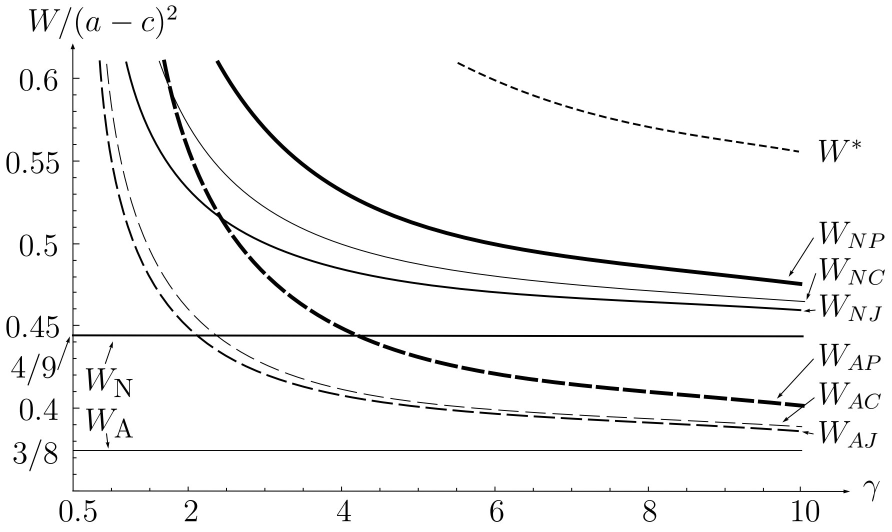



Figure 5 shows the different welfare levels for the case without additional efficiency gains from collaboration, $e_C = e_J = e_P = e = 1$. Comparison of the welfare achieved with investment in the reduction of unit costs shows that no extent of coordination in production leads to the maximal welfare that would result from investments and quantities chosen by a social planner. The second best in terms of welfare is *joint production* with competition in the market. This follows from the avoidance of "duplicative" investments. Whereas with both a *joint venture* and *investment competition* both firms have to spend the same amount in order to achieve a certain level of unit cost, in the case of *joint production* they invest in a single plant and share the resulting expenses. Thus, they reach the same level of production costs by much lower investments. This saving makes *joint production* superior to the other two types of organizing manufacturing given competition or collusion in the product market. In the other two cases, the firms produce in separate plants. Hence, both competitors have to optimize their production process. Out of the two cases with separate production, *investment competition* should be chosen by a policy maker, since here, firms do not internalize the negative effect of own cost reduction on rivals' profits. Hence, investments and quantities are higher, the market price is lower, and a higher welfare than in the case of *joint venture* formation results. Moreover, given the organization of production, collusion implies a lower welfare than competition. As a firm that takes part in an implicit agreement accounts for the fact that a reduction of own production increases the rival's profit, it invests less and additionally reduces output in order to achieve a higher market price. This in turn hurts consumers and reduces welfare. Only in the case of low investment costs (a low value of $\gamma$) is *joint production* superior to all other cases (except of course *joint production* with competition in the market) even if the firms collude. Proposition 6 summarizes these findings.

***Proposition 6:*** *The welfare ranking of joint production, investment competition, and joint venture formation results given either unrestrained quantity competition or an implicit quota agreement. Given the organization of production, welfare is lower in the case of collusion than in the case of competition in the product market, except if the investment costs are low, i.e. $\gamma$ is very small.*

The results for equal efficiency are obtained by straightforward comparison of the welfare levels given in Table 4. The ranking for differences in the efficiency parameters are obtained analogously. The proof is hence omitted.

# 6 Conclusion

Experts warned that collaboration in manufacturing might facilitate anticompetitive agreements in the product market. Our analysis disproves these conjectures. Compared to non-cooperation in production, collusive agreements are less likely in the case of cooperation in a *joint venture* or by *joint production*.

If firms do not cooperate in production, they reduce their unit costs by investing in the production process and compete more aggressively in the product market. If firms form a *joint venture* and coordinate their cost-reducing investments, they internalize this negative effect on rivals' profits and invest less. In consequence, the competitive profit rises strongly relative to the profit gained from participation in collusion. The potential punishment for defection from an implicit agreement and hence firms incentive to participate in collusion is thus lower in the case of coordination of the investment decisions in a *joint venture* compared to non-cooperation in production. Moreover, collusion is even less likely if firms produce in a single jointly owned plant. In this case, they share the investment in cost reduction. The competitive profit is therefore even higher and consequently the potential punishment lower than in the case of a *joint venture*. These results are strengthened if cooperation gives rise to efficiency gains in the cost-reducing activities.

Moreover, our model demonstrates that cooperation by *joint production* also yields the highest welfare level if firms compete in the product market and is second best only compared to the social-planner solution. Comparison of non-cooperation in production and *joint venture* formation shows that in the latter case firms reduce unit costs less and produce less in order to mitigate the negative effect of cost reduction and high production on the rival's profit. Therefore, welfare is lower in the case of a *joint venture* than in the case of non-cooperation in manufacturing. The welfare ranking of *joint production*, *investment competition*, and *joint venture* formation applies given collusion or competition in the product market. The exploitation of market power by colluding firms implies that the welfare is lower if firms participate in an implicit agreement than if they compete in quantities given the decision on the organization of production. An exception to this is the case of *joint production* that is superior to the other market outcomes even in the case of collusion if investment costs are very low.

Hence, contrary to the intuition, *joint production* is a very attractive form of cooperation in manufacturing as it yields the highest welfare level given either competition or collusion in the product market. Above all, in this case it is most difficult for the firms to collude in the market. If competitors are not willing to cooperate closely in *joint production*, for example for fear of leakage of proprietary knowledge concerning research, marketing and other business areas, policy makers have to weigh the increased probability of collusion in the product market against the higher welfare level that results from *investment competition* in comparison to a *joint venture*. As *investment competition* yields a higher welfare level than a *joint venture* if firms compete in the market, encouraging the formation of a *joint venture* is only advisable if implicit collusion is a severe threat. In short, contrary to conventional wisdom, relatively lenient antitrust regulation of cooperation in manufacturing is appropriate especially if firms have a high inclination to collude in the product market.

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