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THE IMPACT OF COMPETITION ON UNILATERAL INCENTIVES TO INNOVATE

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The impact of competition on unilateral incentives to innovate

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Abstract:
We investigate the impact of the degree of competition in a Cournot market on one firm's unilateral incentives to invest in R&D. Applying comparative static analyses we get different predictions depending on the magnitude of the innovation efficiency parameter α. Even inner solutions arose. For $\alpha \to 1$ the comparative statics predicate that incentives to invest in R&D are strongest in a monopoly whereas for smaller α the optimal market structure for unilateral innovation varies depending on the cost level.

Keywords: innovation incentives; market structure; Cournot competition

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1. Introduction

A bulk of evidence indicates that there is a positive effect of innovative activity on firm profits, productivity, economic growth and total welfare. Among others Kamien and Schwartz (1975) already stressed the general importance of research and development (R&D). On account of all the positive effects innovation has in general on an economy, it is important to understand which conditions promote R&D activity of the firms. Therefore in this paper we consider the question which degree of competition in the product market provides the strongest unilateral incentives for a single firm to innovate. Is it more worthwhile for a firm to invest in R&D if this firm faces more competition? Is the increase in its profits caused by a cost reducing innovation highest in a monopoly setting? Or is it rather more profitable to innovate under moderate competition?

The question which market structure provides strongest incentives to invest in R&D is not new.[1] Schumpeter (1954) advocates that a monopoly setting guarantees a strong interest for a firm to invest in innovation[2]. Schumpeter thinks of an economy as a process of "creative destruction", meaning that in an economy products and processes are constantly renewed or replaced by improved ones. This implies that a monopoly position which can be achieved by innovation will be temporarily limited. A firm will invest in innovation only if it gets the chance of obtaining monopoly power by innovation at least for a time and it will continue investing in innovation due to the threat of losing its monopoly position.[3] Therefore, perfect competition which implies immediate imitation would destroy incentives to innovate.[4]

Arrow (1962) supports a different view. He states that "the incentive to invent is less under monopolistic than under competitive conditions, but even in the latter case it will be less than is socially desirable" (Arrow (1962), p. 619). So according to Arrow there is less innovative activity in a monopoly than in a competitive market.[5]

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[1] Nevertheless, the discussion of this problem has not lead to generally accepted results. Cohen and Levin (1989, p. 1075) already stated that "[e]conomists have offered an array of theoretical arguments yielding ambiguous predictions about the effects of market structure on innovation."

[2] Similarly Aghion et al (2005, p. 1) state that also IO theory "typically predicts [that] innovation should decline with competition while empirical work finds that it increases".

[3] Note that Schumpeter emphasizes the impact of the *threat* of potential entrant and rivalry, a situation which is not framed in this paper.

[4] For a discussion of the Schumpeterian hypotheses see Kamien and Schwartz (1982).

[5] This is a more common view. For instance, Dasgupta and Stiglitz (1980, p. 289) also emphasize that "a pure monopolist […] appears to have insufficient incentive […] to undertake R&D expenditure". Furthermore, Geroski (1990) found strong evidence that monopoly power has a dampening effect on innovative activity and that competition is desirable to improve R&D incentives. In his study he used data on major innovations introduced in the UK during the 1970s. Nickell (1996) and Blundell et al (1995) came to similar results.

Intuitively, one might think that the incentive to innovate is strongest if there is moderate competition.[6] Under perfect competition the advantages that occur because of innovation might be directly negated and under a monopoly situation there might be no incentives to invest, because the firm already possesses monopoly power. However, under moderate competition there might be on the one hand enough competition to stimulate innovative activity and on the other hand the probability that an innovator gets at least some benefits out of his investment is also sufficient[7]. We will investigate these questions in the course of our research.

2. The model

In a simple Cournot setting we investigate the impact of static market structure on one firm's unilateral incentives to invest in R&D in the short run using comparative statics. First, we introduce a static Cournot setting in a one product case in which no firm invests in R&D. Then we explore the question under which degree of competition one deviating, innovating firm among these firms extracts the highest additional profit (i.e. the difference between profits after innovation and profits before innovation) due to its innovation. That is, we assume that firms take a myopic view – they maximize their own behavior given the decisions of the other firms.

2.1 Investing in Process Innovation

Imagine a market for one homogenous commodity in which n identical risk-neutral firms i decide simultaneously what quantity q_i ($i = 1,\dots,n$) of this commodity they want to produce and maximize their profits π_i given the quantities of the other firms. Moreover, we assume for simplicity that every firm i faces the same constant marginal costs c (with $c \leq 1/2$)[8] and there are no fixed costs. The effect of potential entry is neglected. For the inverse demand function $p = 1 - Q$, in which p is the price for the commodity and Q is the total produced quantity, with $Q = \sum_{i=1}^{n} q_i$, the Nash equilibrium quantity is $q_i^* = \frac{1-c}{n+1}$ and the equilibrium price is $p^* = \frac{1+nc}{n+1}$ with profits $\pi_i^* = \frac{(1-c)^2}{(n+1)^2}$.

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[6] There are also both theoretical as well as empirical studies which support this view. See Loury (1979), p. 395.

[7] Among others Kamien and Schwartz (1976) show analytically that under certain circumstances an intermediate degree of technological rivalry increases innovative activity most. Aghion et al (2005) found empirical evidence for an inverted U relationship between competition and innovation.

[8] By this we exclude drastic innovation, so the market size remains constant.

If firm i invests unilaterally in R&D it reduces its former marginal costs c to c_i, where $c_i = \alpha c$ with $0 < \alpha < 1$. α is called the innovation efficiency parameter. Note that the smaller α the better is the innovation. The *n-1* other firms *j* still face costs *c*. If we assume that the fixed costs *F* of the innovation are the same for every firm *i*, we can ignore them ($F = 0$), because we are only interested in the different additional profits of an innovating firm *i* under different degrees of market concentration. After firm *i* invested in R&D the produced quantities are as follows: $q_i^* = \frac{1+(n-1)c-\alpha nc}{n+1}$ for the investing firm *i* and $q_j^* = \frac{1+\alpha c-2c}{n+1}$ for the remaining *n-1* other firms *j*. The equilibrium price is $p^* = \frac{1+(n-1)c+\alpha c}{n+1}$, the profit for firm *i* (neglecting the cost of R&D) is $\pi_i^* = \left(\frac{1+(n-1)c-\alpha nc}{n+1}\right)^2$ and for the other firms *j* is $\pi_j^* = \left(\frac{1-2c+\alpha c}{n+1}\right)^2$.

We define the additional profit D_i of the unilateral investing firm *i* as the difference between its profit *after* the innovation and its profit *before* the innovation. Let us now develop firm *i*´s additional profit D_i for every possible magnitude of α $(0 < \alpha < 1)$ using the equilibrium profits from above. We derive: $D_i = \frac{n^2c^2 + 2nc - 2nc^2 - 2\alpha n^2c^2 - 2\alpha nc + 2\alpha nc^2 + \alpha^2 n^2 c^2}{(n+1)^2}$. D_i depends on the number of firms *n*, the innovation efficiency parameter α and the cost level *c*.

2.2 Comparative statics

We analyze now under which market structure the additional profit D_i is largest. To get the optimal number of firms *n*, we differentiate D_i with respect to *n*:[9] $\frac{\partial D_i}{\partial n} = \frac{2c}{(n+1)^3}\left[(1-\alpha)(1-n-c) + nc(2-3\alpha+\alpha^2)\right]$. Equating this expression with 0 and solving according to *n* yields: $n^* = \frac{1-c}{\alpha c - 2c + 1}$. This is the number of firms in the market which provides the strongest incentives to innovate for firm *i* (neglecting the integer problem). The optimal number n^* varies depending on the cost structure. There even exist

[9] The optimal *n* is defined in the following as the number of firms in a market which provides the strongest incentives for a firm to innovate (i.e. the market structure under which the additional profit D_i is highest for a firm for given *c* and α). Note that it is *not* a deciding variable of the firm.

inner solutions at specific magnitudes of cost reduction α and cost levels c. Figure 1 gives an example for the additional profit D_i subject to n for a given α and a given c.

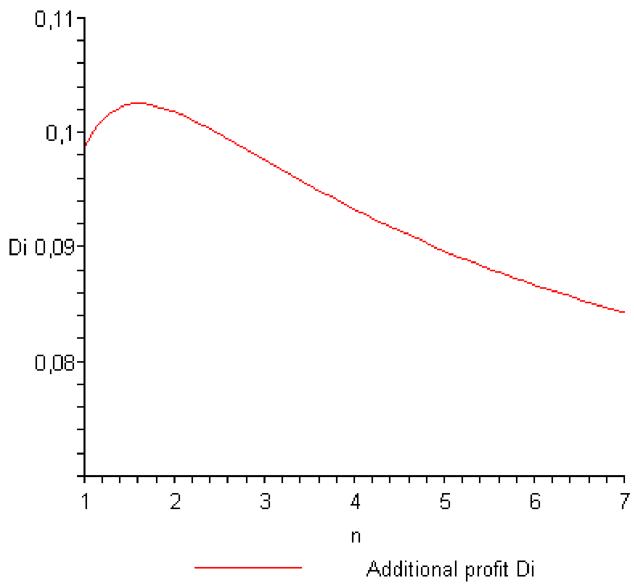

Figure 1: Example for the additional profit D_i as a function of n for α = 1/4 and c = 1/3

The optimal n is 8/5. As there is always a discrete number of firms in the market the optimal number of firms in this case is 2, because if there are 2 firms in the market firm *i*´s additional profit D_i is larger than in a monopoly.

Now we investigate the influence of α on the optimal number of firms in a market. Differentiating the optimal number of firms n^* with respect to α yields:

$\frac{\partial n^*}{\partial \alpha} = \frac{c(c-1)}{(\alpha c - 2c + 1)^2}$. This expression is always smaller than zero which signifies that the optimal n^* decreases as α increases given c. So the "better" the innovation is (the smaller α is) the more profitable is innovation in a more competitive environment. Consider the case $\alpha \to 1$, which would be equivalent with a marginal cost reduction. Here it holds that $n^* \to 1$.[10] Therefore we can predict if the cost reduction is only marginal that in a monopoly the incentives to invest in R&D are the strongest.

We are also interested in the impact of the cost level c on the optimal number of firms in the market. Differentiating the optimal number of firms with respect to c yields:

[10] A proof is given in Appendix 1.

$\frac{\partial n^*}{\partial c} = \frac{1-\alpha}{(\alpha c - 2c + 1)^2}$. This expression is always larger than zero. Thus, the optimal n^* increases as c increases for a given α. As an illustration of the results consider the example given in Table 1.

Cost level / I. e .p. α	$c = \frac{1}{4}$	$c = \frac{1}{3}$	$c = \frac{1}{2}$
$\alpha = \frac{1}{4}$	Monopoly	Duopoly	4 firms
$\alpha = \frac{1}{3}$	Monopoly	Duopoly	3 firms
$\alpha = \frac{1}{2}$	Monopoly	Monopoly	Duopoly
$\alpha = \frac{2}{3}$	Monopoly	Monopoly	Duopoly
$\alpha = \frac{3}{4}$	Monopoly	Monopoly	Monopoly

Table 1: Example: Most profitable market structure for the innovating firm for specific α and c

I. e. p. = innovation efficiency parameter

For the further discussion of our results we have to take into account what happens when we vary the cost level and the magnitude of cost reduction. First, regard the influence of the initial level of **marginal cost** c, holding the cost reduction and the number of firms n constant. The lower the cost level, the larger the produced quantity q_j of the non-innovating firms and the smaller the difference between the produced quantities q_i and q_j. Under a low cost level the additional profit D_i is largest when there is no competition at all. The higher the cost level, the more profitable competition becomes for the investing firm. Intuitively, when there are already low costs, the investing firm does not improve its situation too much by its innovation compared to the other firms. As we have seen above, the difference in the produced quantities q_i and q_j decreases as the cost level decreases. However, under an initially high cost level a cost reduction leads to comparative advantages increasing the additional profit a lot, because the higher the cost level, the larger the difference between the produced quantities q_i and q_j.

Second, what effect does the magnitude of the **cost reduction** have on the quantities? The stronger the cost reduction (i.e. the smaller α), the larger the produced quantity q_i of the investing firm i and the less the quantity q_j of all the other firms j holding the other parameters n and c constant. This implies that also the difference in the produced quantities q_i - q_j increases as the magnitude of the cost reduction increases (i.e. as α decreases). So the comparative advantage of firm *i* is larger the higher the cost reduction.[11] When the new technology leads only to a small cost reduction (e.g. α is close to one), the advantages in innovating are the largest, when there are no other firms in the market or only few firms depending on the cost level. But as the cost reduction increases, the incentives for firm *i* to innovate are larger under competition at least at higher cost levels.

Combining these two elements we can conclude that a firm has the strongest incentives to unilaterally invest in R&D, when it faces no competition, when the cost reduction due to its innovation is only small and the cost level is small, too. Considering that the cost level increases and the cost reduction is moderate, then firm *i*´s incentives to invest in R&D are strongest in a duopoly or an oligopoly with three or four firms. Moreover, when all the firms face high marginal costs *c* and the innovation of firm *i* leads to a great cost reduction, then the incentives to innovate are strongest under competition.

3. Conclusion

We scrutinized a simple Cournot framework to investigate the impact of market structure on innovative activity. From our comparative statics we derived an interesting result. If the change in the marginal costs is only marginal ($\alpha \rightarrow 1$) the incentives to invest in innovation are the strongest under monopoly power, thus supporting the Schumpeterian hypothesis that innovation increases with market concentration. However, when α is decreasing the optimal number of firms is increasing, which means that more competition is profitable. So our analysis points to the environmental factors which specific market structure stimulates innovation most. In fact, the "optimal" market structure for the innovating firm depends on the circumstances which cost level all the firms face before investing and how "good" the innovation is i.e. how much the marginal costs can be reduced. Therefore, incentives can be the strongest under no as well as under moderate competition.

However, due to the restrictive assumptions the results need to be interpreted carefully. We just investigated the question of an optimal degree of competition under comparative statics by considering the unilateral behavior of one investing firm, having studied the myopic view of one innovating firm. A full equilibrium analysis is beyond the scope of this paper.

[11] A proof is given in Appendix 2.

Appendix

Appendix 1

Limit of n^* *if* $\alpha \to 1$*:* Recall that $n^* = \frac{1-c}{\alpha c - 2c + 1}$. For $\alpha \to 1$ it holds that $\lim n^* = \lim \frac{1-c}{\alpha c - 2c + 1} = \frac{1-c}{1-c} = 1$. Therefore firm *i*'s incentive to invest in R&D is strongest in a monopoly situation if the cost reduction is just marginal.

Appendix 2

Derivation of the impact of c on the quantities: Differentiating firm *i*'s quantity $q_i^* = \frac{1+(n-1)c - \alpha nc}{n+1}$ and firm *j*'s quantitiy $q_j^* = \frac{1+\alpha c - 2c}{n+1}$ with respect to c leads to $\frac{\partial q_i^*}{\partial c} = \frac{n(1-\alpha)-1}{n+1}$ and $\frac{\partial q_j^*}{\partial c} = \frac{\alpha - 2}{n+1}$. According to the quantity q_j we can recognize that the smaller the cost level c is, the more the firms *j* produce ($\frac{\partial q_j^*}{\partial c} < 0$). However, concerning the quantity q_i of the investing firm, we cannot give an unambiguous prediction, because the numerator of the quantity q_i depends not only on the cost level but also on the number of firms n and the magnitude of cost reduction α ($\frac{\partial q_i^*}{\partial c}$ can be smaller or larger than zero). For some values of n and α the quantity q_i is decreasing with an increasing cost level c and for some values of n and α the quantity q_i is increasing. $\frac{n(1-\alpha)-1}{n+1} > 0 \Leftrightarrow n(1-\alpha) > 1 \Leftrightarrow n > \frac{1}{1-\alpha}$ or $\alpha > \frac{n-1}{n}$ respectively.

The impact of c on the difference between the quantities $q_i^* = \frac{1+(n-1)c - \alpha nc}{n+1}$ *and* $q_j^* = \frac{1+\alpha c - 2c}{n+1}$*:* $q_i^* - q_j^* = c(1-\alpha)$. We can see that the higher the cost level c is, the larger the difference is in the produced quantities between the innovating firm and every other firm in the market.

Derivation of the impact of α on the quantities: Differentiating firm *i*'s quantity $q_i^* = \frac{1+(n-1)c-\alpha nc}{n+1}$ and firm *j*'s quantitiy $q_j^* = \frac{1+\alpha c-2c}{n+1}$ with respect to α leads to $\frac{\partial q_i^*}{\partial \alpha} = -\frac{nc}{n+1}$ and $\frac{\partial q_j^*}{\partial \alpha} = \frac{c}{n+1}$. $\frac{\partial q_i^*}{\partial \alpha} < 0$ and $\frac{\partial q_j^*}{\partial \alpha} > 0$.

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