Is Competition Good for Innovation?  
A Simple Approach to an Unresolved Question  
By Armin Schmutzler

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Is Competition Good for Innovation?  
A Simple Approach to an Unresolved Question

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Abstract

The relation between the intensity of competition and R&D investment has received a lot of attention, both in the theoretical and in the empirical literature. Nevertheless, no consensus on the sign of the effect of competition on innovation has emerged. This survey of the literature identifies sources of confusion in the theoretical debate. My discussion is mainly based on a unified model that simplifies the comparison of different results. This model is also applied to show which factors work in favor of a positive relation between competition and innovation.

Keywords: Competition, investment, cost reduction.

JEL Codes: L13, L20, L22.
Many policy issues require an understanding of the relation between competition and innovation. Should competition policy take the effects of mergers on innovative activity into account, and would one expect these effects to be positive or negative? Should entry into monopolistic markets (e.g., in network industries) be supported with a view toward the effects on innovation? Should competitive procurement be encouraged because of potential positive effects on innovation? Does the consideration of effects on innovation provide additional arguments for globalization?

Conceptually, the question whether one should foster competition because of concerns for innovation falls into two parts. First, does more competition lead to more innovation? Second, is more innovation desirable? The second point is often taken for granted. Innovation is regarded as an “engine for economic growth” and growth is regarded as desirable. Clearly, however, innovation has benefits and costs, and it does not take a lot of fantasy to construct simple arguments for why firms may innovate too much.¹ In this monograph, I will focus

¹For instance, Tirole (1988, Ch. 2) argues that even a monopolist may oversupply rather than undersupply quality relative to a social planner.
on the first question, investigating the relation between competition and innovation, without necessarily implying that more innovation is desirable.

The analysis of the question has a long history. On the one hand, there is the Schumpeterian tradition emphasizing that monopoly rents are necessary to give incentives for innovation. On the other hand, there is the view that competition puts the necessary pressure on firms (and, in particular, on managers) to exert innovative effort, which is summarized most succinctly in the famous statement that “The best of all monopoly profits is a quiet life” (Hicks, 1935). The search for a better understanding of the topic has generated a cottage industry of a considerable size. Over several decades, there has been a constant flow of theoretical papers on the topic, both from a partial equilibrium (industrial organization) and from a general equilibrium (growth theory) perspective, and there is no sign that the flow of papers is abating. This interest is reflected in the empirical literature: The question has been dubbed the “second-most tested hypothesis in industrial organization” (Aghion and Tirole, 1994).

Of course, the continuing flow of research reflects a state of affairs that is highly unattractive from a policy point of view, namely that neither the theoretical nor the empirical research on the subject is very conclusive. Depending on the particular notion of competition, the underlying oligopoly model or the type of innovation, one can arrive at positive, negative, inverted-U-shaped, or even U-shaped relations between competition and innovation. This would be no problem if it were easy to say which economic fundamentals drive the different predictions. Unfortunately, in many cases seemingly innocuous modeling details can have a substantial effect on the predictions. The usual solution would be to search enlightenment through empirical analysis. However, it would take a rather selective view of the empirical literature to arrive at a clear conclusion. One can find empirical support for just about any relation between competition and innovation, including the possibility that there is no significant relation at all.

It is therefore not surprising that even distinguished scholars come to quite different conclusions about what we have learnt. In spite of a qualifying footnote, Aghion et al. (2005a,b) are quite definite in their
assessment, at least as far as the theoretical industrial organization literature is concerned.

“Theories of industrial organization typically predict that innovation should decline with competition”.2

Vives (2008, p. 419), one of the leading IO theorists, takes the opposite view:

“Does competition foster innovation? The answer is a qualified yes”.

One might therefore want to side with Gilbert (2006, p. 162) who formulates the state of affairs as follows:

“Economic theory supports neither the view that market power generally threatens innovation by lowering the return to innovative efforts nor the Schumpeterian view that concentrated markets generally promote innovation.”

His assessment of the empirical literature is similar:

“. . . empirical studies have not generated clear conclusions about the relationship between competition and innovation...(Gilbert, 2006, p. 162)”.

In this monograph, I will abstain from giving another full-fledged treatment of the existing literature. The number of surveys in the field is so large that it would be hard to come up with anything but a summary and update of existing surveys. Rather, this monograph has a narrower goal. I will try to provide a simple framework that helps to understand two issues:

1. What are the sources of the ambiguous relation between competition and innovation?

2Importantly, the growth-theoretic work of Aghion and co-authors themselves comes to different conclusions. This will be discussed in Section 6.3.
2. Which factors (firm characteristics, market characteristics, characteristics of the innovation) are conducive to a positive relation between competition and innovation?

This monograph attempts to make some progress on these two issues. To this end, I will take a subjective look at the existing literature. Section 2 identifies the first source of ambiguity. Roughly speaking, innovation incentives are the difference between the profits of a firm if it invests (ex post profits) and profits if it does not invest (ex ante profits). Any change in parameters that reduces ex post profits without affecting ex ante profits reduces innovation incentives and, conversely, any change in parameters that reduces ex ante profits without affecting ex post profits increases innovation incentives. However, most interesting parameterizations of competition tend to reduce ex post and ex ante profits, so that the net effect is unclear without further qualification.

In the remainder of the monograph, I will therefore consider such parameterizations. In Section 3, I will review a simple framework that I introduced in a more technical companion paper (Schmutzler, 2010). This framework is general enough to contain the simple introductory examples and many familiar models from the literature as special cases. It is a two-stage model with an investment stage preceding product market competition. The product market stage is kept general, encompassing most common oligopoly models. The competition parameter is defined through a set of abstract properties that are fulfilled for most standard parameterizations of competition. The analysis reveals four simple transmission channels by which the intensity of competition affects innovation.\(^3\) It becomes clear that these four individual effects work in different directions. Without specifying the framework further, it is impossible to say which effects dominate. Thus, one can clearly understand the sources of the ambiguity. Thereby, one obtains a useful tool for discussing the intuition for the effects of competition on innovation.

\(^3\)Competition affects equilibrium outputs and margins and the sensitivity of these quantities to marginal costs.
As an illustration, I will then consider several simple examples in Section 4. This serves three purposes. First, the examples help to understand the different possible meanings of competition. Second, we see that even within this small set of simple examples, the effects of competition on innovation are ambiguous. Third, the examples are useful to identify the sources of ambiguities.

In Section 5, I then extend the analysis to deal with asymmetric firms. There are several reasons for doing this. First, even though the framework is static, it is useful for discussing some basic ideas about an interesting aspect of market dynamics. A central question on the long-run behavior of markets is whether initial differences between firms are self-reinforcing. A large literature has dealt with the countervailing effects emerging in this context. Some of these effects can already be sketched in the simple static framework introduced here. This discussion is interesting in its own right, but will also be important in the subsequent analysis of the effects of competition on investment with asymmetric firms. Second, the asymmetric framework is useful to obtain a first idea about the circumstances leading to a positive effect of competition on investment. A robust result is that in environments where competition has a positive effect on laggards (relatively inefficient firms), it will typically also have a positive effect on leaders (relatively efficient firms), whereas the converse statement is not true. This suggests that the analysis must take firm-specific effects into account: The aggregate impact of competition on investment may hide heterogeneous effects on different firms.

Even though the two-stage model is general in some respects, it is oversimplified in others. In Section 6, I therefore treat various extensions of the simple framework that have received some attention in the literature. For instance, I consider the possibility of endogenous entry of firms, and separation of ownership and control. I also provide some thoughts on product innovations, even though the literature is less well developed than the literature on process innovations. These modifications tend to suggest a more positive effect of competition on investment. Finally, I briefly deal with growth-theoretic papers. These papers usually contain simple two-stage oligopoly models as a building block, but to obtain a full understanding of the effects of competition
on investment, the interaction between different markets needs to be considered.

I move toward the empirical literature in Section 7. My treatment of this huge body of research is eclectic. I focus on contributions that I find useful in the context of the theoretical ideas that I am pursuing here. Perhaps unsurprisingly, I will argue that, some recent progress notwithstanding, the empirical literature mirrors the unsatisfactory state of affairs in theory, leaving the average reader at least as confused. Moreover, it is often hard to understand the relation between the theoretical models and the empirical approaches. I will therefore also summarize a few contributions that have dealt with the relation between competition and innovation in laboratory experiments. Experiments have the advantage that they can be directly tailored to test specific models. Section 8 contains some concluding remarks.

In line with the restricted scope of this endeavor, I am omitting many interesting papers on the relation between competition and innovation. This is not only true for the empirical work, but also for theory. The treatment of the growth literature, for instance, is very brief, focusing on one paper that is particularly relevant for the purposes of this survey. Also, I do not even touch the literature on patent races and research tournaments. This literature is characterized by the property that, even when many firms exert effort, only a small number of them (usually one) can benefit from the fruits of the innovation. Exploring the relation of this literature to the “non-tournament” approaches discussed here would be interesting, but is beyond the scope of this monograph.

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4 See for instance, Loury (1979) and Lee and Wilde (1980) for examples of the former and Taylor (1995) for examples of the latter; Fullerton et al. (1999) et al. provides an experimental analysis of research tournaments.
Throughout most of this monograph, I shall consider changes in the competitive environment that affect the firms no matter whether they innovate or not. For instance, globalization (integration of markets) typically changes the profits of firms with innovation (ex post) and without innovation (ex ante). For conceptual clarity, it is nevertheless useful to isolate the role of each of these two effects on innovation incentives.

2.1 Ex post Market Structure

Consider an innovation that reduces marginal costs by some amount $\Delta > 0$.\footnote{Unless otherwise mentioned, I will confine myself to firms with constant marginal costs.} Compare two environments which differ only with respect to the ex post situation (after the investment).

Ex ante, there is some set of firms which, for simplicity, we assume to be symmetric, so that each of them earns identical profits $\Pi_0$. Suppose that, with weak competition, the innovator earns monopoly profits $\Pi_1^W = \Pi^M(\Delta)$, whereas with intense competition profits are $\Pi_1^I < \Pi^M(\Delta)$. For instance, one can think of weak competition as
corresponding to strict patent protection, whereas there are spillovers to competitors with intense competition.

The value of the innovation for the case of low ex post competition (the resulting profit increase) is:

\[ V^W = \Pi_1^W - \Pi_0 = \Pi^M(\Delta) - \Pi_0. \]

The value of the innovation for the case of intense ex post competition is:

\[ V^I = \Pi_1^I - \Pi_0 < \Pi^M(\Delta) - \Pi_0. \]

This example is of course a simplistic representation of the argument for patent protection. By guaranteeing an ex post monopoly to the innovator, a patent can provide strong incentives for investment, in particular, when the alternative is a perfectly competitive situation. However, an in-depth discussion of patent policy is not the purpose of this monograph. Instead, the example was constructed to make the following trivial but general point:

**Ex post competition:** Any change in parameters that reduces the ex post profits \( \Pi_1 \) without having an effect on ex ante profits \( \Pi_0 \) reduces the value of innovation.

This point clearly holds even when \( \Pi_1^W \) is not the monopoly profit. If we accept that, whatever an increase in the intensity of ex post competition is, it results in a ceteris paribus reduction in ex post profits of a successful innovator, then more intense ex post competition is clearly bad for innovation.

### 2.2 Ex ante Market Structure

Following Arrow (1962), we now consider the other polar case: We compare two environments which differ only according to the ex ante situation (before the investment).

We now assume that the innovator always obtains the monopoly profit corresponding to the post-innovation marginal costs ex post, that is, \( \Pi_1 = \Pi^M(\Delta) \). Ex ante, we first consider the case that the profit under weak competition (\( \Pi_0^W \)) is the monopoly profit for pre-innovation costs \( \Pi^M(0) \), whereas, under intense competition, firms obtain perfect
competition profits \((\Pi_0^I = 0)\). The value of the innovation for the case of weak ex ante competition is thus:

\[
V^W = \Pi_1 - \Pi_0^W = \Pi^M(\Delta) - \Pi^M(0).
\]

The value of the innovation for the case of intense ex ante competition is:

\[
V^I = \Pi_1 - \Pi_0^I = \Pi^M(\Delta).
\]

Thus, more intense ex ante competition increases innovation incentives: Even though the ex post profits of firms are independent of ex ante competition, the value of innovation is lower for the monopolist because he earns higher profits if he abstains from innovation. This is commonly known as the “replacement effect”: Contrary to the perfectly competitive firm, the monopolist who innovates faces the opportunity cost that, to some extent, his post-innovation profit replaces his positive pre-innovation profit.

Again, the crucial point is more general:

**Ex ante competition:** Any change in parameters that reduces the ex ante profits \(\Pi_0\) for any given realization of marginal costs without having an effect on ex post profits \(\Pi_1\) increases the value of innovation.

### 2.3 Conclusion

Though these two examples are simple, they are useful to illustrate several points.

First, the examples suggest that it is valuable to think of “increasing competition” in terms of abstract properties: For instance, a move from monopoly to perfect competition clearly has the property that the per-firm profits fall. As we will see below, this property is shared by several other parameter shifts which are usually considered as examples of increasing competition. Nevertheless, one would clearly hesitate to use it as a defining property of an increase in competition. Other parameter shifts that one would usually not associate with increases in competition, such as increases in taxation, have the same property. However, it is a typical implication of increasing competition that is
useful to understand some aspects of the relation between competition and innovation.

**Property 1 of competition:** *An increase of competition has the effect that it leads to lower gross profits per firm as long as firms are sufficiently symmetric.*

Second, the examples help to identify a first simple reason for confusion in the debate on competition and investment. One has to be aware of the distinction between ex post and ex ante competition. While an increase in ex post competition reduces innovation incentives, an increase in ex ante competition increases them. As long as one is clear about the distinction between ex post and ex ante competitions, there is no contradiction between the Schumpeterian view that some monopoly rents ex post are required for innovation and Arrow’s argument that competitive pressure ex ante is helpful to induce innovation. Moreover, there may be circumstances where focusing exclusively on the effects of either ex post or ex ante competition is adequate: For instance, it is useful to think of an increase in appropriability of innovations in terms of a reduction of ex post competition. Similarly, when considering the effects of competition on the propensity to carry out drastic innovations for which the ex post monopoly is guaranteed, it is adequate to focus on changes in ex ante competition.

Nevertheless, many interesting questions about the relation between competition and innovation concern simultaneous changes in the intensity of ex ante and ex post competition. The above examples immediately suggest that such changes may involve the presence of two countervailing effects, providing a first idea of why general unambiguous results on such effects are hard to obtain.

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2 The restriction to “sufficiently symmetric” firms is necessary because, in suitable examples, comparatively efficient firms may benefit from an increase in competition.
“Increasing competition” usually refers to changes in the market environment that make it harder (or even impossible) for firms to exercise monopoly power. But this is still a very vague description of what competition is. A closer look reveals many different possible interpretations. Some of these interpretations relate to institutional changes, such as stricter cartel laws, less stringent enforcement of intellectual property rights, or less rigid entry regulation.

In other cases, the relation to the institutional environment is less direct. For example, an increase in globalization is often associated with increasing competition. In principle, globalization can be brought about by changes that are independent of the regulatory environment in a particular industry. For instance, stronger exposure to exports may be the result of decreasing transportation costs. However, globalization may also reflect changes in the legal environment: Increases in FDI may be the result of liberalization; similarly increasing exports may result from abolishing trade barriers.

In this section, I will introduce a general framework for analyzing such changes in competition, which is a simplified version of Schmutzler (2010). This framework will serve to organize many different examples.
I will argue that standard parameterizations of competition have certain abstract properties which are useful to understand the effects of competition on innovation.¹

The analysis will uncover four intuitive transmission channels by which competition affects innovation. It will transpire that, for most examples, these four effects go into different directions. Moreover, the sign of some of the effects depends on the particular example. Therefore, it is unsurprising that competition has such ambiguous effects on investment.

The following assumptions will be maintained unless stated otherwise.

(A1) The decisions are taken by monopolists or duopolists.²
(A2) The firms take two decisions. First, they choose cost-reducing investments \((y_1, y_2)\). Then they choose quantities or prices in the product market.
(A3) In the product market, each firm \(i\) obtains profits \(\Pi_i(y_i, y_j; \theta)\) that are increasing in their own previous investments \(y_i\) and decreasing in those of the competitor \(y_j\) and also depend on a parameter \(\theta\) measuring the intensity of competition.³
(A4) The gross profit functions are symmetric: For a given level of competition, own investments and competitor investments fully determine gross profits; there are no firm-specific differences in the effects.

Most assumptions will be relaxed later on. For instance, I will consider markets with more than two firms and endogenous entry decisions, and I shall allow for initial asymmetries.

For simplicity, I will further assume that profits are a differentiable function of \(y_i\). I refer to the partial derivative \(\frac{\partial \Pi}{\partial y_i}\) as the innovation incentive. For duopoly games, is straightforward to see that, if an

¹Boone (2000, 2001, 2008) also defines competition in such abstract terms, but the emphasis of his analysis is more on justifying these properties rather than on applying them to the issues we are interested in.
²Most of the general arguments work quite well with arbitrary number so firms.
³Obviously, when I refer to a monopoly, firm \(i\) has no competitor \(j\), so \(\Pi_i(y_i, y_j)\) simplifies to \(\Pi_i(y_i)\).
increase in the competition parameter increases the innovation incentives for all investment levels, this parameter change shifts out the reaction functions in \((y_1, y_2)\)-space. While this does not automatically imply that the equilibrium investment levels are higher, there are fairly innocuous supplementary conditions guaranteeing the result. The following analysis therefore attempts to clarify what determines the relation between \(\theta\) and the innovation incentive, assuming implicitly that a positive effect of \(\theta\) on the innovation incentives corresponds to a positive effect on investments.

The analysis relies on the simple decomposition:

\[
\Pi_i(y_i, y_j; \theta) = Q_i(y_i, y_j; \theta) \cdot M_i(y_i, y_j; \theta), \tag{3.1}
\]

where \(Q_i(y_i, y_j; \theta)\) is the equilibrium output, and \(M_i(y_i, y_j; \theta)\) is the equilibrium margin. Applying the product rule to Equation (3.1), we obtain the following useful expression for the innovation incentive:

\[
\frac{\partial \Pi_i}{\partial y_i} = M_i \frac{\partial Q_i}{\partial y_i} + Q_i \frac{\partial M_i}{\partial y_i}. \tag{3.2}
\]

The term identifies two reasons why innovation is good for firms’ gross profits.

First, investment typically increases equilibrium output. The mechanism is the following: A firm with lower marginal costs typically has a lower equilibrium price. This usually results in higher equilibrium output. The strength of the positive profit effect \(M_i \frac{\partial Q_i}{\partial y_i}\) induced by this output increase obviously depends positively on the size of the profit margin \(M_i\).

Second, investment typically increases equilibrium margins \(M_i = p_i - c_i\), reflecting the lower marginal costs \(c_i\). The strength of the
positive profit effect $Q_i \frac{\partial M_i}{\partial y_i}$ induced by this margin increase obviously depends positively on the size of the output $Q_i$.

Understanding the effects of competition on innovation incentives thus reduces to understanding how $\theta$ affects each of the terms in Equation (3.2). To this end, I now consider several examples.
I will now introduce simple examples to illustrate the effects of competition on investment in different contexts (Section 4.1). In Section 4.2, I will discuss what we can learn from the examples.

4.1 The Examples

I shall consider the following examples of increasing competition:

(i) Less restrictive entry regulation
(ii) Increasing substitutability of products
(iii) Market integration

All three changes can be regarded as instances of increasing competition, as they make it more difficult (or even impossible) for firms to behave in a monopolistic fashion. Even so, the effects on cost-reducing investments will turn out to be very different in the three cases. (i) Allowing entry of a second firm into a previously monopolistic market reduces innovation incentives. (ii) Increasing substitutability of products has a more complex effect, which depends on the details of the situation. As an illustration, I will provide an example where there
is a U-shaped relation: Starting from complete differentiation where each firm is a monopolist, increasing substitutability lowers investments; once a certain threshold has been reached, investments increase as substitutability is increased even further. (iii) Integration of markets increases innovation incentives.

4.1.1 Entry Liberalization

In the 1980s and 1990s, entry has been liberalized in many markets across the world. Monopolists in many industries are now exposed to competition from entrants. While a full model of the effects of entry liberalization on investments must take the asymmetries between incumbent and entrants seriously, as a first approximation we compare investment decisions of a monopolist with those of duopolists with the same technology as the monopolist.

More precisely, suppose that market demand is given by a simple linear function $x = 1 - p$. Before deciding on their outputs, firms can reduce their marginal costs from a common level $C \in (0,1)$ to a new level:

$$c_i = C - y_i.$$  \hfill (4.1)

Though the qualitative insights do not depend on this particular specification, suppose the necessary R&D-investment costs are $K(y_i) = y_i^2$.

**Monopoly** In the original monopoly situation, the price of the monopolistic firm 1 is:

$$p_1 = \frac{1 + c_1}{2} = \frac{1 + C - y_1}{2}.$$  

The resulting output is thus:

$$Q_1 = 1 - \frac{1 + C - y_1}{2} = \frac{1 - C + y_1}{2}. \hfill (4.2)$$

The profit margin is:

$$M_1 = p_1 - c_1 = \frac{1 - C + y_1}{2}. \hfill (4.3)$$

Both Equations (4.2) and (4.3) are very intuitive: Cost reductions translate into higher outputs and profit margins. More precisely, note
the effect of the cost reduction on the profit margin: If prices were unchanged after a cost reduction, it would translate one-to-one into an increase in margins. However, prices adjust downwards, so that only half of the cost reduction shows up as a margin increase.

The two results immediately imply that the firm obtains *gross profits*:

\[
\Pi_1 = M_1 \cdot Q_1 = \left( \frac{1 - C + y_1}{2} \right)^2.
\]  

(4.4)

When the firm chooses its investment, it anticipates this relation between investments and gross profits. It chooses investments so as to maximize *net profits* \( \Pi_i - K(y_i) \). First-order conditions are therefore,

\[
\frac{\partial}{\partial y_1} \left( \left( \frac{1 - C + y_1}{2} \right)^2 - (y_1)^2 \right) = \frac{1 - C + y_1}{2} - 2y_1 = 0.
\]

(4.5)

The resulting optimal investment of the monopolist is:

\[
y_1^* = \frac{1 - C}{3}.
\]

(4.6)

**Duopoly** Next, we move to a case of comparatively intense competition. Suppose there are two firms which act as Cournot competitors. Thus, we are considering a two-stage game where firms first simultaneously choose cost-reducing investments, then outputs.

Therefore, for any pair of investment decisions \( (y_1, y_2) \) with corresponding marginal cost levels \( (c_1, c_2) \), the Cournot outcome results. Standard textbook analysis shows how the equilibrium output \( Q_i \) and price \( p_i \) depend on marginal costs: It is simple to show that:

\[
Q_i = M_i = \frac{(1 - 2c_i + c_j)}{3}.
\]

(4.7)

These results are intuitive: A firm that becomes more efficient puts more output on the market, hence driving down equilibrium prices of both firms. If the competitor \( j \) becomes more efficient, he expands his output, which leads to a reduction of the market price. As a consequence, firm \( i \)'s output declines.
Using Equation (4.1), Equation (4.7) immediately gives the relation between investments and output and margins, respectively, as:

\[ Q_i = M_i = \frac{(1 - C + 2y_i - y_j)}{3}. \]  

(4.8)

Thus, gross profits \( \Pi_i = M_i \cdot Q_i \) in equilibrium are:

\[ \Pi_i = \frac{(1 - C + 2y_i - y_j)^2}{9}. \]  

(4.9)

Now consider first-period investment decisions, still assuming that investment costs are \( K(y_i) = y_i^2 \). Firms who anticipate that profits will behave according to Equation (4.9) thus choose investments so as to maximize:

\[ \pi_i = \frac{(1 - C + 2y_i - y_j)^2}{9} - y_i^2. \]

Profit maximization thus leads to first-order conditions:

\[
\frac{\partial}{\partial y_i} \left( \frac{(1 - C + 2y_i - y_j)^2}{9} - y_i^2 \right) = \frac{8y_i - 4C - 4y_j + 4}{9} - 2y_i = 0.
\]

This immediately results in a symmetric equilibrium:

\[ y = \frac{2(1 - C)}{7}. \]  

(4.10)

**Comparison and Interpretation** By comparing Equations (4.6) and (4.10), we obtain:

**Summary:** An increase in the number of firms leads to a reduction in per-firm investments and hence to higher marginal costs.

Differentiation of Equations (4.4) and (4.9) shows a negative effect of competition on innovation incentives. Whereas they are \( \frac{\partial \Pi}{\partial y_1} = \frac{1-C+y_1}{2} \) in the monopoly case, they are only \( \frac{\partial \Pi}{\partial y_1} = \frac{2}{7}(1-C+y_1) \) in the duopoly case for symmetric firms.

Decomposition (Equation (3.2)) shows the economic intuition quite clearly: In the monopoly case, we obtained:

\[ Q_1 = M_1 = \frac{1 - C + y_1}{2}. \]  

(4.11)
In the Cournot case,

\[
M_i = Q_i = \frac{(1 - C + 2y_i - y_j)}{3}.
\]

(4.12)

Thus, competition (entry liberalization) reduces both outputs and margins when \(y_i = y_j\). Because competition reduces margins, it makes any output expansion of size \(\frac{\partial Q_i}{\partial y_i}\) less attractive. Similarly, by reducing output, competition makes any margin expansion of size \(\frac{\partial M_i}{\partial y_i}\) less attractive. While these negative level effects of competition work against innovation, the positive effects on \(\frac{\partial Q_i}{\partial y_i}\) and \(\frac{\partial M_i}{\partial y_i}\) work in favor of it. Thus, the extent of output expansion induced by any given cost reduction becomes larger as competition increases; it is 2/3 for the duopoly, as opposed to 1/2 for the monopoly. Similarly, the size of the margin expansion induced by any given cost reduction becomes larger as competition increases.

**Summary:** Entry liberalization reduces the innovation incentives of each firm. As a result, the industry cost level is higher. The result reflects the dominance of the negative effects of competition on outputs and margins over the positive effects on \(\frac{\partial Q_i}{\partial y_i}\) and \(\frac{\partial M_i}{\partial y_i}\).

### 4.1.2 Increasing Substitutability

One of the most common interpretations of increasing competition concerns increases in the degree of substitutability between products: As products become closer substitutes, competition becomes more intense.¹

Many models of differentiated oligopoly are available. Following Singh and Vives (1984), for example, suppose both firms have inverse demands:

\[
p^i(q_i, q_j) = 1 - q_i - \theta q_j,
\]

(4.13)

where \(0 \leq \theta \leq 1\). The corresponding demand functions are increasing in the price of the competitor; thus the goods are substitutes. For

¹See for instance Vives (2008) for a general treatment of the relation between substitutability and innovation incentives.
\(\theta = 0\), firms are monopolists; \(\theta = 1\) corresponds to homogeneous goods.\(^2\)

Higher \(\theta\) corresponds to better substitutability. It is simple, but tedious, to calculate outputs and margins as \(^3\)

\[Q_i(y_i, y_j) = M_i(y_i, y_j) = \frac{2(a - C + y_i) - \theta(a - C + y_j)}{4 - \theta^2}, \quad i \neq j.\] \hspace{1cm} (4.14)

Thus gross profits are:

\[\Pi_i(y_i, y_j) = \frac{\left(2(a - C + y_i) - \theta(a - C + y_j)\right)^2}{4 - \theta^2}, \quad i \neq j.\] \hspace{1cm} (4.15)

Using this expression and assuming investment costs \(K(y_i) = y_i^2\), one can easily derive investments in the symmetric equilibrium where \(y_1 = y_2\). The middle line in Figure 4.1 plots these investments for initial cost levels \(C = 0.5\). The line is U-shaped: Starting from a monopoly, an increase in competition first reduces investment; beyond \(\theta = 2/3\) further increases lead to higher investments.

It is potentially fruitful to think of \(\theta\) as a crude representation of intellectual property law (patent breadth). Strict intellectual property

\[y_i \hspace{1cm} 0.5 \hspace{1cm} 0.4 \hspace{1cm} 0.3 \hspace{1cm} 0.2 \hspace{1cm} 0.1 \hspace{1cm} 0.0 \hspace{1cm} 0.0 \hspace{1cm} 0.1 \hspace{1cm} 0.2 \hspace{1cm} 0.3 \hspace{1cm} 0.4 \hspace{1cm} 0.5 \hspace{1cm} 0.6 \hspace{1cm} 0.7 \hspace{1cm} 0.8 \hspace{1cm} 0.9 \hspace{1cm} 1.0 \]

\[\theta \hspace{1cm} 0.0 \hspace{1cm} 0.1 \hspace{1cm} 0.2 \hspace{1cm} 0.3 \hspace{1cm} 0.4 \hspace{1cm} 0.5 \hspace{1cm} 0.6 \hspace{1cm} 0.7 \hspace{1cm} 0.8 \hspace{1cm} 0.9 \hspace{1cm} 1.0 \]

\(y_i\)

\(\theta\)

Fig. 4.1 Differentiated Cournot competition.

\(^2\)Essentially, therefore, the example extends the entry example to intermediate levels of competition.

\(^3\)The results are taken from Sacco and Schmutzler (2010), which also contain experimental evidence for the U-shape in an otherwise identical example with other parameters.
law (low $\theta$) means that the entrant is forced to choose a good that is highly differentiated from the one produced by the patentholder. Even though, for sufficiently symmetric firms, gross profits increase as $\theta$ decreases (competition gets softer), achieving more differentiation may involve greater costs; as entrants need to “invent around” the patented good to enter the market. If the costs of further differentiation outweigh the benefits, entrants will voluntarily choose the maximal allowed value of $\theta$. Though the main point of this example is to illustrate the possibility of non-monotone effects of increasing competition, it also suggests a policy issue that is worthy of further investigation: Intellectual property rights on new products not only influence the incentive to carry out product innovations. They may also have implications for process innovations: By influencing the degree of product differentiation between the patentholder and his competitors, they also influence the willingness of firms to invest in cost reductions.

**Summary:** In the product differentiation example with quantity competition and inverse demand (4.13), the effect of an increase in substitutability on cost-reducing investments is negative for low initial values of competition, positive for higher values.

**Interpretation** Innovation incentives can be obtained by differentiation of gross profits (Equation (4.15)). It is simple to show that, for symmetric firms, this leads to innovation incentives that have a U-shape as a function of $\theta$.\(^4\)

To understand the sources of this U-shape better, it is helpful to consider Equation (4.14). The expression shows that $$$\frac{\partial Q_i}{\partial \theta} = \frac{\partial M_i}{\partial \theta} < 0,$$$ so that output and margin effects are negative. As $$$\frac{\partial^2 Q_i}{\partial y_i \partial \theta} = \frac{\partial^2 M_i}{\partial y_i \partial \theta} > 0,$$$ the remaining effects are positive: An increase in $\theta$ corresponds to an increase in $\frac{\partial Q_i}{\partial y_i}$ and $\frac{\partial M_i}{\partial y_i}$. Hence, the U-shaped relation between competition and investment reflects the interplay between the negative effect of competition on output and margin and the positive effect on $\frac{\partial Q_i}{\partial y_i}$ and $\frac{\partial M_i}{\partial y_i}$: Starting from low competition, greater competition, by reducing outputs and margins, reduces incentives to increase efficiency. Beyond

\(^4\)Sacco and Schmutzler (2010) show this, and they also provide some experimental evidence for the claims.
a certain threshold, however, the effect of competition on investment is positive, reflecting the positive output sensitivity and margin effects.

**Modifications**  A cautionary remark on the U-shape obtained here is in order: The effects of strengthening competition by increasing substitutability depend substantially on the exact model of product differentiation. For instance, with the above demand system and price rather than quantity competition, the effects of stricter competition are negative. This is driven by the fact that, with price competition, $\frac{\partial^2 M_i}{\partial y_i \partial \theta} < 0$, because investments trigger lower competitor prices. Also, alternative demand systems are often considered. For instance, consider

$$p^i(q_i, q_j; \theta) = 1 - \frac{1}{1 + \theta q_i} - \frac{\theta}{1 + \theta q_j},$$  

(4.16)

where $\theta \in [0, 1]$. Contrary to Equation (4.13), this function does not have the property that an increase in $\theta$ shifts overall demand inwards. This difference leads to a strictly positive effect of more intense competition on investment for both output and price competition.\(^5\) It is precisely this kind of sensitivity of results to details of the model that motivates this monograph.

The most complete analysis of the effects of greater substitutability on innovation incentives is Vives (2008). Apart from a general analysis, he also provides a large number of examples, including some of those mentioned above as well as the Salop model of competition on the circle, models with constant elasticity demand, and constant expenditure models. The reader is referred to this rich collection of examples for further information on the effects of substitutability on investments.\(^6\)

### 4.1.3 Market Integration

Suppose initially there are two identical countries, each served by a local monopolist as described above, with demand function $D(p) = 1 - p$.

\(^5\) For a slightly more detailed treatment, see Schmutzler (2010).

\(^6\) However, Vives only considers the case of symmetric firms. In Schmutzler (2010), I show how some of the standard examples have to be modified in the presence of asymmetric firms. The examples show that the picture obtained from the symmetric case can be misleading: For instance, in a Hotelling duopoly a reduction in transportation costs has no effect on investments for symmetric firms, whereas there are positive effects for leaders and negative effects for laggards.
Suppose then that perfect integration of markets takes place, so that each firm can serve both markets without incurring transportation costs. Thus, there is one world market with total demand function $D(p) = 2(1 - p)$. Assume for the moment that both firms continue to serve the integrated market. Then the new market is a Cournot duopoly with larger total demand than before. Hence, we can think of this simplistic model of market integration as a combination of the entry liberalization model with a doubling of demand.

Thus, pre-integration outputs, margins, and gross profits are given by Equations (4.2)–(4.4), resulting as before in equilibrium investments:

$$y^*_1 = \frac{1 - C}{3}.$$  \hspace{1cm} (4.17)

Post-integration outputs and margins can easily be seen to be:

$$Q_i = \frac{2(1 - C + 2y_i - y_j)}{3} \quad \text{and} \quad M_i = \frac{(1 - C + 2y_i - y_j)}{3}.$$  \hspace{1cm} (4.18)

Thus, gross profits $\Pi_i = M_i \cdot Q_i$ in equilibrium are:

$$\Pi_i = \frac{2(1 - C + 2y_i - y_j)^2}{9}. \hspace{1cm} (4.17)$$

Simple calculations lead to a symmetric equilibrium:

$$y = \frac{4(1 - C)}{5}. \hspace{1cm} (4.18)$$

Thus, in spite of the superficial similarity with the entry liberalization example, the opposite result holds.

**Summary:** Integration of two monopolistic markets leads to an increase in per-firm investments.

**Interpretation** It is straightforward to see from Equations (4.4) and (4.17) that innovation incentives after integration are higher than before integration. Outputs and profit margins before integration correspond to those of the monopoly case,

$$Q_1 = M_1 = \frac{1 - C + y_1}{2}.$$
With open markets, the corresponding quantities for the duopolists become:

$$Q_i = \frac{2(1 - C + 2y_i - y_j)}{3} \quad \text{and} \quad M_i = \frac{1 - C + 2y_i - y_j}{3}. \quad (4.19)$$

Thus, the effect of integration on margins $M_i$ is negative, but the positive effect on $Q_i$, $\frac{\partial M_i}{\partial y_i}$ and $\frac{\partial Q_i}{\partial y_i}$ dominates.

### 4.1.4 Summary and Outlook

So far, our analysis has shown that the effects of competition on cost-reducing investments depend heavily on the precise way in which competition is increased.

1. Entry liberalization leads to lower investments.
2. The effects of decreasing product differentiation are more subtle. In the case of quantity competition with inverse demand Equation (4.13), the effect is U-shaped, but depending on the details of oligopolistic competition, other results will obtain.
3. Integration of monopolistic markets leads to larger investments.

These observations are in need of explanation. In all the examples under consideration, increasing competition refers to changes in the economic environment that make monopolistic pricing more likely. Why do these changes have such different effects even so?

### 4.2 General Lessons

Summing up, what have we learnt from the examples? Quite generally, Equation (3.2) helps to identify the four channels by which competition affects investment. Roughly speaking, each transmission channel corresponds to the effects of competition on one of the four terms on the right-hand side. To understand each transmission channel, we must understand how each of the terms $M_i$, $Q_i$, $\frac{\partial M_i}{\partial y_i}$, and $\frac{\partial Q_i}{\partial y_i}$ depends on competition.

Table 4.1 summarizes the effects of competition on the variables of interest.
4.2.1 The Transmission Channels

I will now address each of the four transmission channels individually. In doing so, I will identify further properties that competition typically has.

Margins All examples have one thing in common: Profit margins $M_i$ are decreasing in competition for given investment levels. Everything else would have been a surprise: It is a defining feature of standard notions of competition that they correspond to greater pressure on margins.\(^7\) We thus will frequently invoke the following.

**Property 2 of Competition:** An increase of competition leads to lower margins for arbitrary symmetric cost levels.

The main implication is immediate: Because profit margins $M_i$ are decreasing in competition, an output increase $\frac{\partial Q_i}{\partial y_i}$ of any given size resulting from investment leads to a smaller profit increase $M_i \frac{\partial Q_i}{\partial y_i}$ when competition is intense. We call this the negative margin effect of competition on innovation incentives.

Output The effects of competition on output $Q_i$ differ across examples. Clearly, there is an obvious reason why the effect should be positive: The downward pressure of competition on a firm's own prices should result in an expansion of own output (which is dampened by the simultaneous reduction of the competitor's price). Even so, we only observe a positive effect of competition on the equilibrium output of each firm in the integration example. In the entry example and the product differentiation example with inverse demand Equation (4.13), equilibrium output falls as competition increases. The reasons are

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\(^7\) Boone (2008) points out counterexamples, however.
slightly different in these two examples. In the entry case, the result comes from the fact that output is split across two firms rather than produced by one. Thus, in spite of the lower prices (which correspond to a higher market output), output per firm is lower when competition increases. In the product differentiation case, the negative effect of closer substitutes reflects a direct (not price-induced) negative effect on the parameter increase on outputs.

Summing up, the effect of competition on output is ambiguous. Thus, so is the output effect of competition on innovation incentives. Whenever competition has a positive effect on $Q_i$, it increases the value $Q_i \frac{\partial M_i}{\partial y_i}$ of any margin increase $\frac{\partial M_i}{\partial y_i}$ brought about by investment; other things equal, this increases the investment incentive. The converse argument applies when competition has a negative effect on $Q_i$.

**Cost-pass-through**  
Competition affects the extent to which efficiency gains are passed on to customers via lower prices. From the definition of profit margins, $M_i = p_i - c_i = p_i - C + y_i$, it follows immediately that $\frac{\partial M_i}{\partial y_i} = \frac{\partial p_i}{\partial y_i} + 1$, so that competition has a positive effect on $\frac{\partial M_i}{\partial y_i}$ if and only if it reduces $|\frac{\partial p_i}{\partial y_i}|$, that is, if it reduces the extent to which efficiency gains are passed on as lower prices.

The examples show that competition may lead to more or less cost-pass-through: For entry liberalization, integration and differentiation with quantity competition and inverse demand Equation (4.13), competition always has a positive effect on $\frac{\partial M_i}{\partial y_i}$, reflecting a reduction in pass-through. However, the opposite effect emerges. For instance, in the differentiation example with price rather than quantity competition, the effect is negative. Hence, the cost-pass-through effect of competition is also ambiguous: When competition increases $\frac{\partial M_i}{\partial y_i}$, then, everything else equal, this will also increase the effects on $Q_i \frac{\partial M_i}{\partial y_i}$, the part of Equation (3.2) that reflects the effect of a higher margin; conversely, when competition reduces $\frac{\partial M_i}{\partial y_i}$.

**Output Sensitivity**  
Finally, consider the effects of competition on the sensitivity of output with respect to efficiency, $\frac{\partial Q_i}{\partial y_i}$. In all examples, this effect is positive. Intuitively, this reflects that the demand-stealing property of greater efficiency becomes more important as competition
Learning from Examples

increases. Or, as Syverson (2004, p. 1187) puts it,

“Markets with greater substitutability are more competitive in the sense that their higher cross-price elasticities more greatly reward (punish) relatively low(high)-cost producers in terms of market share.”

We therefore state the following property of competition:

**Property 3:** An increase in competition leads to an increase in the sensitivity of output with respect to investment, $\frac{\partial Q_i}{\partial y_i}$.

Thus, in the following, we shall assume that the output-sensitivity effect of competition on investment is positive: As $\theta$ increases, the sensitivity of output with respect to efficiency ($\frac{\partial Q_i}{\partial y_i}$) increases. Everything else equal, this will also increase the effects of competition on $M_i \frac{\partial Q_i}{\partial y_i}$, the part of Equation (3.2) that reflects the profit increase induced by investment that comes from a higher output.

**Summary** Of the four transmission channels identified for the general framework, the margin effect is always negative. The output-sensitivity effect is positive. The output and cost-pass-through effect are ambiguous. Therefore, it is unsurprising that competition has no robust effect on investment, not even in the simple framework identified here.

4.2.2 Further Examples: Cournot versus Bertrand

The general framework contains many examples that have been treated in the literature. For instance, the distinction between Cournot and Bertrand competition has also received a lot of attention in the innovation literature. The intuition for treating a shift from Cournot to Bertrand as an increase in competition is that price competition tends to drive down prices, and thereby margins and gross profits. Thus, Properties 1 and 2 typically hold. In itself, this would suggest a negative effect of competition on investment. On the other hand, the lower prices typically also imply a higher equilibrium output. Also, consistent with Property 3, however, a shift from Cournot to Bertrand competition typically increases the positive output effect of higher efficiency.
Together, these last two forces work toward a positive effect of competition on innovation incentives. These forces already suggest that the aggregate effect of shifting from Bertrand to Cournot may not be entirely clear-cut. In the existing literature, this problem is compounded by additional modeling differences. I will briefly review several contributions.

Delbono and Denicolò (1990) considered the case of homogeneous products in a setting where the investment stage is modeled as a stochastic patent race where firms continuously exert an effort to find a cost-reducing innovation. They show that innovation incentives are higher for Cournot competition than for Bester and Petrakis (1993) showed that the result of Delbono and Denicolo extends to the case of low product differentiation. As product differentiation becomes sufficiently large, however, the ranking changes, and incentives are higher for Bertrand competition. However, as argued by Qiu (1997), Bester and Petrakis considered the innovation incentives in a situation where only one firm has investment opportunities. He shows that in a symmetric equilibrium of the corresponding investment game, there is more R&D in the Cournot case than in the Bertrand case. The result also holds with positive spillovers.

Bonanno and Haworth (1998) show that, in a model of vertical product differentiation à la Mussa and Rosen (1978), incentives for cost reductions are higher under quantity competition than under price competition. This reflects familiar strategic effects. For Cournot competition, innovation incentives are strengthened by the strategic consideration that they induce desirable actions of the competitor (quantity reductions), whereas they are weakened under Bertrand competition, because they induce undesirable actions (price reductions). In the terminology of Section 3, the cost-pass-through effect of moving from Cournot to Bertrand competition is negative.

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8 They do not explicitly deal with a patent race; instead, they directly compare the incremental profit increase from an innovation for price and quantity competition.

9 Gersbach and Schmutzler (2003) show that Qiu’s result can be reversed when spillovers are endogenized.
So far, we have assumed that there are no initial cost differences between firms. However, as a result of historical circumstances or past investment decisions, initial asymmetries may well be relevant. There are several reasons to deal with such asymmetries between leaders who have low marginal costs $C_i$ before the investment decisions are taken, and laggards who have comparatively high marginal costs.

First, while it may make perfect sense to cast a purely theoretical analysis in terms of symmetric firms, empirical work must deal with the obvious fact that firms may be asymmetric.

Second, it is interesting to see how the effects of competition on investments differ for leaders and laggards. This is a first step toward identifying circumstances fostering a positive effect of competition on investment.

Third, even for a fixed degree of competition, an interesting question arises: Do leaders invest more than laggards? This question lies at the heart of important policy issues. For instance, a large part of competition policy is motivated by worries that market dominance might have a tendency to be self-reinforcing. Though this is not necessarily implied by larger investments of leaders, it is clear that, if larger firms with lower marginal cost invest more than small firms with high
marginal costs, this should at least work in the direction of increasing market shares of leaders.\footnote{For some clarifying ideas on this issue, consider the discussion of weak increasing dominance versus strong increasing dominance in Athey and Schmutzler (2001).} We start with this issue.

\section*{5.1 Increasing Dominance}

A large literature deals with the differences in the investments of leaders and laggards. A major goal of this literature is to understand the circumstances under which the investment decisions of firms lead to endogenous monopolization.

Several authors have provided reasons why endogenous monopolization might arise. Flaherty (1980) does so in the context of cost-reducing investments; similarly Budd et al. (1993). Beggs and Klemperer (1992), Cabral and Riordan (1994), and Cabral (forthcoming) do not treat cost-reducing investments directly; instead they are concerned with similar issues in the context of switching costs, learning-by-doing and network effects.\footnote{Cabral (2001) analyzes the potential for self-reinforcing dominance in a situation where firms take different types of investments. Aydemir and Schmutzler (2008) show under which circumstances increasing dominance can arise in a setting where large firms can take over small firms, whereas small firms can enter.}

Athey and Schmutzler (2001) provide a general approach that encompasses explicit investments into cost reduction or other improvements of the state of the firm, but can also be used to address “investments” that take the form of aggressive pricing (to obtain loyal customers in the presence of switching costs) or producing high outputs to benefit from learning-by-doing or network effects. They provide several general conditions for “weak increasing dominance” to emerge, that is, for firms with low marginal costs to invest more than their competitors. The authors consider the Markov-perfect equilibrium of a dynamic model, but two of the countervailing forces can be identified even in a simple static version of a cost-reduction model.

The most obvious reason why weak increasing dominance might \textit{not} hold is that firms that already have low initial marginal costs typically require higher investment efforts to reduce marginal costs further: A laggard may just have to take an existing technology from “off the
Asymmetric Firms

shelf”, whereas a leader might have to carry out cutting-edge research to reduce costs further.³

Even though marginal investment costs should typically be higher for leaders, weak increasing dominance may well arise because the marginal benefits are also higher. To see this, it is helpful to reconsider Equation (3.2), which, to repeat, says that:

$$\frac{\partial \Pi_i}{\partial y_i} = M_i \frac{\partial Q_i}{\partial y_i} + Q_i \frac{\partial M_i}{\partial y_i}.$$ 

Now suppose that firms differ in their initial marginal costs $C_i$. Then, the higher a firm’s initial efficiency level, the higher is its initial profit margin $M_i$. Therefore, the higher is the value of an output increase of any given size $\frac{\partial Q_i}{\partial y_i}$. Similarly, the higher a firm’s initial efficiency level, the higher is its initial equilibrium output $Q_i$. Therefore, the higher is the value of a margin increase of any given size $\frac{\partial M_i}{\partial y_i}$. Thus, there are clear complementarities between having high outputs and high margins. These complementarities provide leaders with higher incentives to increase their efficiency than laggards.⁴

In a general setting that allows for these countervailing effects, Athey and Schmutzler (2001) provide conditions under which weak increasing dominance arises.⁵ The conditions address both the case that investments are strategic substitutes and that they are strategic complements. The former case is more common; at least when spillovers are weak, investments are typically strategic substitutes. Again, decomposition Equation (3.2) is helpful to obtain the intuition. To understand the effects of competitor investments (higher $y_j$) on innovation incentives $M_i \frac{\partial Q_i}{\partial y_i} + Q_i \frac{\partial M_i}{\partial y_i}$, consider the effects on the individual terms. Crucially, as the competitors marginal costs fall, so do own margins $M_i$ and outputs $Q_i$. This reduces the value of any output increase of given size

³This can be captured by allowing for investment cost functions of the form $K(C_i, y_i)$ (where marginal investment costs are increasing in $C_i$) rather than just $K(y_i)$.

⁴However, even if one abstracts from the issue that the costs of becoming more efficient may be higher for leaders than for laggards, there may still be countervailing effects: Even though for standard linear models $\frac{\partial Q_i}{\partial y_i}$ and $\frac{\partial M_i}{\partial y_i}$ are both independent of the initial efficiency levels, this need not be the case for more general demand functions. If at least one of the two terms is strongly concave, investment incentives could be lower for firms with low marginal costs.

⁵They also provide such conditions for the dynamic case where additional countervailing effects arise.
5.2 The Effects of Competition with Asymmetric Firms

5.2.1 The Effects of Competition with Asymmetric Firms

For the static case, Figure 4.1 illustrates the occurrence of weak increasing dominance for the particular product differentiation example given there. Leaders invest more than laggards. This behavior reflects the “output-margin complementarities” just described, together with the simple investment cost function \(K(y_i) = y_i^2\), that rules out the realistic possibility that laggards have lower investment costs than leaders.

\[
\frac{\partial Q_i}{\partial y_i} \text{ and the value of any margin increase of size } \frac{\partial M_i}{\partial y_i}. \text{ This is why the investments are often strategic substitutes, no matter whether there is price or quantity competition in the output market.}^{6,7}
\]

In principle, both \(\frac{\partial Q_i}{\partial y_i}\) and \(\frac{\partial M_i}{\partial y_i}\) could depend positively on the competitor’s marginal costs, thereby working against increasing dominance. In standard linear models, there is no such effect.

Interestingly, a well-known paper of Gilbert and Newbery (1982) which argues in favor of a negative effect of competition and investment, uses a special case of the strategic property. The authors compare the investment incentive of a monopolist with marginal costs \(M\) threatened by entry with those of the entrant. They argue that the monopolist has stronger incentives to reduce costs to \(L\), essentially because a successful duopolist will still have to live with the competition of the monopolist. Technically, \(\pi^*(L,H) ≥ \pi^*(M,H) ≥ \pi^*(L,M) - \pi^*(M,M)\), where \(H\) corresponds to a cost level that is so high that \(\pi^*(M,H)\) is the monopoly profit. Clearly, this is a strategic substitutes property for the relevant cost levels.

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Laggards have initial marginal costs of 0.7; leaders have initial marginal costs of 0.3.
\]

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7 Interestingly, a well-known paper of Gilbert and Newbery (1982) which argues in favor of a negative effect of competition and investment, uses a special case of the strategic property. The authors compare the investment incentive of a monopolist with marginal costs \(M\) threatened by entry with those of the entrant. They argue that the monopolist has stronger incentives to reduce costs to \(L\), essentially because a successful duopolist will still have to live with the competition of the monopolist. Technically, \(\pi^*(L,H) ≥ \pi^*(M,H) ≥ \pi^*(L,M) - \pi^*(M,M)\), where \(H\) corresponds to a cost level that is so high that \(\pi^*(M,H)\) is the monopoly profit. Clearly, this is a strategic substitutes property for the relevant cost levels.

8 Laggards have initial marginal costs of 0.7; leaders have initial marginal costs of 0.3.
which refers to Cournot competition with demand functions as in Equation (4.13). As in the case of symmetric firms, the investments of leaders are a U-shaped function of $\theta$. However, the upward-sloping part of the curve starts earlier than for symmetric firms. The investments of laggards decline as competition grows. Thus, competition tends to have a more positive effect on the investments of leaders than on those of laggards. Similar observations can be made for many other duopoly models, including the Hotelling Model, price competition with demand function (Equation (4.13)) and price and quantity competition with demand function (Equation (4.16)); see Schmutzler (2010). There I also use the decomposition (Equation (3.2)) to explain why the observation that competition tends to have a more negative effect on laggards than on leaders is not a coincidence.

The key intuition is that the only one of the four effects outlined in Section 4.2 that is robustly positive, the output-sensitivity effect, tends to zero for firms that lag strongly behind their competitors. Intuitively, because such firms have small margins $M^i$, the positive effect of competition on the increase of output resulting from an increase in efficiency does not translate into a strong positive effect on the increase in the corresponding value of this output. Also, the output effect is more likely to be positive when a firm is efficient: Because of Property 3, there is a complementarity between increasing competition and increasing efficiency in increasing equilibrium output.

The analysis of this section suggests an interesting conclusion. When designing institutions to foster competition, policy faces an important tradeoff. Institutions that are good for competition in the short term (in the sense that they tend to reduce margins) may foster the destruction of competition in the long run, because they strengthen the tendency for markets toward self-reinforcing dominance. As this long-term destruction of competition results from greater efficiency of the leaders, the net welfare effects are non-obvious.

$^9$Contrary to the weak increasing dominance result that leaders invest more than laggards, these observations are unrelated to the fact that the investment costs are independent of initial marginal costs $C^i$; As long as there is no effect of the competition parameter on marginal investment costs, the entire effect of competition on investments must come from the gross profit term.
6

Extensions

Even though the above analysis was general with respect to the nature of product market interaction and the underlying notion of competition, it was oversimplified in several other respects. In the following, I therefore introduce a number of extensions. I will discuss endogenous market participation, separation of ownership and control, and product innovations. I will also deal with extensions to a growth-theoretic framework.

Some of these extensions have received considerable attention in the literature. However, the modeling approaches often differ from the basic model in more than one dimension. The economic intuition for the change in the effects of competition on investment is therefore not immediate. I will therefore explain in each case what the source of variation with respect to the basic model is.

6.1 Endogenous Entry

Building from ideas introduced by Sutton (1991, 1998), authors such as Raith (2003) and Vives (2008) have modified oligopoly models of
innovation as above so as to allow for entry decisions of firms.¹ To illustrate the essence of the approach, suppose firms incur a fixed cost of market participation. Suppose further that the decision to enter the market has to be taken before the investment decision, with an investment game as described before. To understand how increases in competition parameters such as the substitutability of goods affect cost-reducing investments, note that the following results hold quite generally.

First, consider the investment subgame. In many examples, the investments of each firm will be decreasing in the number of firms in the market, at least when firms are not too asymmetric.² This is a generalization of the earlier entry liberalization example. Intuitively, firms expect lower margins and lower outputs when there are more competitors. This makes investments less attractive.³

Second, according to Property 1, an increase in the intensity of competition for any given number of firms will tend to reduce gross profits. Hence, the number of firms that can survive in the market falls as competition increase. Taking into account that a lower number of firms increase innovation incentives, ignoring the effects of competition on market participation biases the effects of competition on innovation downwards.

We shall return to the issue of endogenous market participation at the end of the next section, when we discuss the model of Raith (2003), who incorporates both endogenous entry and separation of ownership and control. In the meantime, we deal with the latter issue in isolation.

### 6.2 Separation of Ownership and Control

The statement of Hicks (1935), according to which “the best of all monopoly profits is a quiet life” suggests that positive effects of competition on innovation might be particularly relevant when

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¹ Raith (2003) also allows for separation of ownership and control, see Section 6.2.
² Figure 4.1 already shows that the statement is not necessary true for asymmetric firms: For \( \theta = 0 \) (monopoly), the investments of a leader are lower than for \( \theta = 1 \) (homogeneous firm duopoly).
³ The effects of the number of firms on cost-pass through and output sensitivity of investments are less obvious, but nevertheless the overall effect is negative in most examples.
managerial efforts are required. The preceding analysis has already shown that positive effects may well arise even for owner-controlled firms. A number of authors (e.g., Hermalin, 1992; Schmidt, 1997; Raith, 2003) have introduced separation of ownership and control. Typically, these authors consider the effects of competition on the efforts of chief executives to engage in cost-reducing activities. Even though the details depend on how agency conflicts are introduced, the general message is that, with separation of ownership and control, the effects of competition on process innovations tend to be more positive. In the following, I briefly review some of the main contributions.

### 6.2.1 The Threat of Liquidation (Schmidt, 1997)

Schmidt (1997) introduces a simple reduced-form model in which a principal (the firm) chooses an incentive contract for an agent (the manager). The contract is designed to induce the optimal effort level from the manager, taking into account his incentive, participation, and wealth constraints. Together with a probabilistic state of the world, efforts determine the firm’s cost level. The firm’s profit depends on cost and an exogenous parameter, the level of competition. Hence, there is no modeling of the interaction between different firms; a firm’s competitor only shows up indirectly in the competition parameter. The profit depends negatively on costs and (in line with Property 1) on the competition parameter. Moreover, with some probability the firm will get liquidated. The liquidation probability depends negatively on managerial efforts.

The agent’s preferences are standard in that they depend positively on monetary rewards and negatively on efforts. An important twist is that the manager dislikes liquidation. The simplest interpretation is that he loses his job, which is costly for him.

Under some technical conditions, the constrained optimization problem of the owner can be shown to be equivalent to an unconstrained optimization problem where he maximizes expected gross profits minus

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4 An interesting related paper by Theilen (2009) deals with the effects of competition on the efforts of lower tier employees.

5 The model can be adjusted to fit into an oligopolistic framework (see Schmutzler, 2010).
the costs of inducing effort (which factor in the managerial constraints). This looks very similar to the benchmark model of Section 3, but there is one important exception: Contrary to the investment costs of Section 3, the costs required to induce managerial effort depend on the intensity of competition: As competition increases, so does the probability of liquidation. As the manager dislikes liquidation, this provides him with incentives to avoid liquidation by inducing effort. So starting from a reference case of a profit-maximizing owner-managed firm, the separation of ownership and control introduces a reason why competition might induce stronger incentives for investment than in the reference case.

The main result that Schmidt himself highlights is slightly different. He emphasizes that the relation between competition and innovation has an inverse U-shape. In view of the above considerations, it would appear that this specific prediction of the model results from a particular aspect of the underlying competitive environment that implicitly rules out some of the models discussed above. In particular, any model that predicts a monotone positive relation between competition and innovation in owner-managed firms should predict a strictly monotone relation with separation of ownership and control.

**Summary:** By reducing the costs of inducing efforts, separation of ownership and control typically introduces an additional positive effect of competition on innovation when owners propose contracts.

### 6.2.2 Income Effects (Hermalin, 1992)

The conclusion that separation of ownership and control tends to imply more positive effects of competition on investments is shared by Hermalin (1992). However, the underlying economic intuition is very different. Hermalin works with the appealing modification that managers rather than firms propose contracts, and that contracts are designed so as to make firms indifferent between accepting and not accepting. Thus, the manager is the residual claimant to the fruits of his effort. In the simplest case that additional competition corresponds to an additive reduction of gross profits, a manager with decreasing marginal utility of income will therefore supply more effort
as competition increases. Like Schmidt (1997), Hermalin therefore relies on Property 1 of competition. He also extends the analysis to allow for more general changes in competition where the underlying oligopoly models are subject to the ambiguities of our basic model. In this context, separation of ownership and control still works toward more positive effects of competition on efforts.\textsuperscript{6}

Summary: \textit{Separation of ownership and control typically introduces an additional positive effect of competition on innovation when managers propose contracts.}

6.2.3 Managerial Contracts under Endogenous Entry Raith (2003)

In an interesting contribution, Raith (2003) modifies the basic set-up in two dimensions simultaneously: He allows for endogenous entry and for separation of ownership and control. In a first stage of the game, a sufficiently large number of firms decide whether to enter. In the second stage, the \( n \) firms that have decided to enter choose the contracts for their managers. A contract has the form:

\[
{w_i} = {s_i} + {b_i}(\bar{c} - c_i),
\]

where \( s_i \) is a salary and \( b_i \) is a piece rate that depends on the firms marginal costs relative to the industry average \( \bar{c} \). In the third stage, agents simultaneously choose efforts \( e_i \) so that:

\[
c_i = \bar{c} - e_i - u_i,
\]

where \( u_i \) is a normally distributed random variable with mean 0 and variance \( \sigma^2 \). The agents are assumed to have utility functions with constant absolute risk aversion.

In the product market stage, firms compete on a unit circle à la Salop (1979). Consumers are assumed to be uniformly distributed with density \( m \), whereas firms are located unidistantly at location

\textsuperscript{6}Another argument for the view that separation of ownership and control tends to enhance the positive effects of competition on investment goes back to Hart (1983). He argues that, with competition, principals receive better information about the agents’ performance. Therefore, it becomes less costly to induce efforts.
Extensions

\( z_i \in \{0, \frac{1}{n}, \ldots, \frac{n-1}{n}\} \). The net utility of the consumers has the form:

\[
A - p_i - t(x - z_i)^2,
\]

(6.1)

where \( A \) is a positive constant, \( p_i \) is the price, and \( t \) is the transportation-cost parameter.

It is instructive to first consider the corresponding investment game for owner-managed firms with exogenous market participation. To make it easier to embed the game into a principal — agent structure later on, we take the uncertainty about competitor costs into account and denote expected competitor costs as \( E(c) \). Straightforward calculations yield:

\[
M_i = \frac{t}{n^2} + \frac{E(c) - c_i}{2},
\]

(6.2a)

\[
Q_i = \frac{m}{n} + \frac{nm E(c) - c_i}{2t}.
\]

(6.2b)

Using \( \theta = -t \) and \( y_i = -c_i \), it is evident that \( \theta \) has a negative effect on \( M_i \) and no effect on \( \partial M_i / \partial y_i \). As required by Property 3, the effect on \( \partial Q_i / \partial y_i \) is positive, whereas the effect on \( Q_i \) is positive only for leaders \((E(c) > c_i)\). In symmetric situations where \( E(c) = c_i \), the investment incentive is thus:

\[
-\frac{\partial \Pi^i}{\partial c_i} = -M^i \frac{\partial Q^i}{\partial c_i} - Q^i \frac{\partial M^i}{\partial c_i} = \frac{t}{n^2} \frac{nm}{2t} + \frac{m}{n} \frac{1}{2} = \frac{m}{n}.
\]

(6.3)

With the number of firms as an exogenous variable, the innovation incentive thus depends positively on market size and negatively on the number of firms. However, it is independent of transportation costs (that is, the extent of product differentiation). For asymmetric firms, competition has a positive effect on the investments of leaders and a negative effect on those of laggards. These observations are very much in line with the results of Section 4.2.

Before considering managerial incentives, let us add the possibility of entry for an owner-managed firm. The number of firms is then no longer an exogenous parameter, but is to be determined jointly with investments. With entry costs of \( F \), the number of firms entering would be \((\frac{tm}{F})^{1/3}\) (abstracting from integer constraints). With the equilibrium
number of firms, Equation (6.3) therefore implies that innovation incentives are \( \frac{m}{n} = m^{2/3}(F_T)^{1/3} \). Thus, incentives are increasing in market size and entry costs, and decreasing in transportation costs.

Several points are worth mentioning. First, entry costs have a positive effect on innovation: By making entry unattractive, they increase the incentives for the remaining firms in the market to invest. Second, contrary to the case of an exogenous number of firms, innovation incentives grow less than proportionally as market size increases. Third, even though decreasing product differentiation has no effect on innovation incentives in the symmetric case when the number of firms is exogenous, the effect becomes positive with endogenous entry, reflecting the negative effect of decreasing product differentiation on the number of firms. This reinforces the general point made in Section 6.1 that endogenous entry tends to strengthen the case for a positive effect of competition on investment. Again, the driving force is the negative effect of competition on gross profits (Property 1).

The comparative statics are robust to the introduction of managerial incentives (Raith, 2003, Proposition 5). Increases in substitutability, entry costs, and market size lead to higher piece rates and thus efforts will be higher. In view of the preceding considerations, however, the source of the positive effects on cost reduction is actually the possibility of free entry rather than the separation of ownership and control. In fact, Raith’s model contains none of the elements discussed above which introduce positive effects of separation of ownership and control.\(^7\)

It is interesting to note the different effects of different notions of increasing competition: Decreasing product differentiation and increasing entry costs both have a positive effect on innovation incentives and hence on piece rates. However, whereas increasing product differentiation corresponds unambiguously to an increase in competition, increasing entry costs are usually associated with weaker competition (see, e.g., Boone, 2008). In spite of this difference, the common underlying logic is clear. Both parameter changes lead to a lower number of firms, which foster the investments of the remaining firms.

\(^7\)There are no income effects (Hermalin, 1992), information effects (Hart, 1983) or liquidation effects (Schmidt, 1997).
6.3 Growth

The relation between competition and innovation has also been addressed in endogenous growth models. These models are typically formulated in a multi-industry context, which makes comparison with the preceding analysis difficult. However, they contain duopoly models like those treated above as building blocks. To understand the statements of the growth literature on the relation between competition and innovation, a careful look at these duopoly models is helpful. Several observations will emerge. First, the competition parameters in these models have some unusual properties that contradict our general approach. Second, the basic ideas from the underlying oligopoly models go a long way toward explaining the essence of the growth models. Third, the multi-industry approach adds some new insights.

6.3.1 The Underlying Oligopoly Model(s)

Each of the growth models under consideration is built around a simple duopoly model similar to the ones considered so far. This already suggests that there are considerable degrees of freedom in the construction of these growth models. Different functional forms and different notions of “increasing competition” are used. Whereas Aghion et al. (1997) compare homogeneous Bertrand and homogeneous Cournot competition, Aghion et al. (2001) consider the degree of substitutability as an inverse measure of competition. In the following, I will focus on the latter model.

The authors consider a duopoly where each firm has a demand function:

\[ q_i = \frac{p_i^{\alpha-1}}{p_i^{\alpha-1} + p_j^{\alpha-1}}. \]

The parameter \( \alpha \in [0,1] \) is interpreted as a measure of the degree of substitutability.\(^8\) Unit costs are assumed to be constant. The authors show that gross profits of each firm are a function:

\[ \hat{\Pi}_i(c_i/c_j, \alpha), \quad (6.4) \]

\(^8\) \( \alpha \) is a monotone transformation of the elasticity of demand substitution.
with the following properties:

1. Profits of firm $i$ are decreasing in the cost ratio $c_i/c_j$ for $\alpha \in (0,1]$.
2. Profits are independent of the cost ratio and more generally of marginal costs in the monopoly case ($\alpha = 0$).
3. Joint profits are increasing in the degree of cost asymmetry between firms.

While these properties turn out to be convenient, they are not very plausible. It seems hard to imagine that profits only depend on cost ratios and that there is no effect of costs at all when firms are monopolists: a decisive property of competition should be that the cost ratio gets less relevant as competition becomes weaker, whereas lower own costs should still increase profits even for the monopoly case. By assuming away any such positive effects, the authors must necessarily obtain a positive effect of moving from monopoly to competition, but there is no convincing economic intuition behind it.

However, there are some more interesting results for the oligopoly model. First, innovation incentives are strictly increasing in the degree of competition for firms that are initially “neck-and-neck”, that is, have the same marginal costs. Second, for leaders or laggards incremental innovation incentives can become inverse U-shaped in the degree of competition.

### 6.3.2 Further Considerations

The authors then extend the model in three ways that differ from the basic structure treated so far.

First, innovations are treated in a somewhat different way than in the IO literature. Firms can advance stepwise, starting from relative costs of 1. A firm that is $n$ steps ahead of the competitor has relative costs of $\gamma^{-n}$, where $\gamma > 1$. An innovation that moves the firm up one step thus corresponds to a multiplication of the cost ratio by $\frac{1}{\gamma}$. Second, the R&D model is stochastic. Firms that are at the technological frontier (leaders or neck-and-neck firms) can choose the R&D intensity $x$ at a cost of $\psi(x) = \beta x^2/2$, where $\beta > 0$. The firm then moves one step...
ahead on the technology ladder with Poisson hazard rate $x$. Laggards that exert the same effort move ahead with a higher hazard rate $x + h$, where $h$ should be thought of as reflecting the extent of R&D spillovers. Third, the authors embed their model into a setting with many industries, each of which consists of a duopoly as described. They consider a large number of industries, each of which is as described above.

Note that, because the costs of moving from step $n$ to $n + 1$ are independent of $n$ and the size of the cost reduction is decreasing in $n$, firms with a high initial efficiency need to incur greater investment costs to reach a marginal cost reduction of a given size. This reasonable property has an important implication: Firms in neck-and-neck situations invest more than leaders. In view of the discussion in Section 5.1, however, one should at least recall the possibility that leaders invest more than laggards because they have higher benefits of investment.

The relevance of the different investment technologies only becomes apparent when general equilibrium considerations are taken into account. To analyze the total effect of competition on innovation, it is no longer sufficient to investigate the effects of competition on the investments of firms in neck-and-neck and leader-laggard constellations, respectively. In addition, one must take into account the effects of competition on the probability of being in the different states. Here, the authors arrive at very intuitive results: Because competition increases the firms’ incentives to escape neck-and-neck constellations, intense competition also means that neck-and-neck states are rare. Thus, intense competition drives firms into the leader-laggard constellation where firms have relatively weak innovation incentives. These countervailing effects of competition imply that growth rates often have an inverse U-shape: Reflecting the assumption that monopolists have no innovation incentives, a small dose of competition is always good for growth, whereas too much competition can be bad.

### 6.3.3 Comments

The analysis of Aghion et al. (2001) is interesting for a number of reasons. First, it emphasizes differences in the effects of competitions on investments, depending on whether the industry is of a neck-and-neck
A more problematic issue is the robustness of the inverse U-shape. Because the underlying oligopoly model is constructed so that there must be a positive effect of competition at least for low initial amounts of competition, there are reasons to be skeptical. As we have seen above, many more plausible models do not have this property.

Even if one hesitates to take the inverse-U conclusion for granted, one can still accept that the paper is making an important point: Even in a situation where competition has a clear positive effect on investment in neck-and-neck situations in the underlying oligopoly model by assumption, industry composition effects can lead to a negative effect if competition becomes too strong. In this sense, it may be regarded as strength of the paper that it starts from an oligopoly model with an in-built bias toward a positive effect of competition on investment. Nevertheless, it would be interesting to see how the analysis would work out in a context where competition does not have a positive effect on investments in the underlying oligopoly model in a neck-and-neck situation.

Another point in favor of the paper is that, apart from the intuitive appeal of the inverse U-shape, it also seems to have some empirical support. We shall get back to this issue in Section 7.

**Summary:** Recent growth models predict an inverse-U relation between competition and investments. This effect is driven by a combination of a specific choice of oligopoly model, the investment technology and an industry composition effect.

### 6.4 Product Innovations

While the relation between competition and process innovation has been studied a lot, the corresponding issues for product innovations have received less attention. In the following, I shall nevertheless provide some thoughts on the relation between competition and product innovation, including a brief review of the relevant papers. I shall

type or has a leader-laggard structure. Second, on a related note, it shows that competition may also affect growth by the effects on industry composition. The paper deserves credit for these two related contributions.
confine myself to innovations of existing products that raise the quality level in the sense that they increase the willingness of all consumers to pay for the product.\footnote{One could also consider the introduction of new products that are horizontally rather than vertically differentiated from their predecessors.}

In the following, I will distinguish into two dimensions:

1. Do innovating firms continue to sell the old product as well as the new product?
2. Are the products homogeneous except for the quality level, or is there also horizontal differentiation?

I will confine myself to vertical improvements, but I will distinguish between the case where the new product replaces the old product and the case where both products continue to be produced.

6.4.1 Product Replacements

The case that is closest to the analysis of process innovations concerns vertical product innovations that replace existing products fully.

**Pure vertical differentiation** First consider the case that there is only one dimension of product differentiation, that is, firms are homogeneous except for the quality differences. Then a slightly better product is further away from the competitor (for a leader) or closer (for a laggard). For instance, take the model of Shaked and Sutton (1982) in the simple version presented by (Tirole, 1988, Ch. 7.5). There are two firms who differ with respect to their quality level $A_i$, where $A_1 > A_2$. Consumer utility is given by $\gamma A_i - p_i$, where $\gamma$ is distributed uniformly between $\gamma \geq 0$ and $\bar{\gamma} = \gamma + 1$. Tirole shows that, under some technical assumptions that include “sufficient consumer heterogeneity” ($\bar{\gamma} - 2\gamma \geq 0$),

\[
Q_1 = \frac{2\bar{\gamma} - \gamma}{3}; \quad Q_2 = \frac{\bar{\gamma} - 2\gamma}{3};
\]

\[
M_1 = \frac{(2\bar{\gamma} - \gamma)^2 \Delta_1}{9}; \quad M_2 = \frac{(\bar{\gamma} - 2\gamma)^2 \Delta_1}{9}.
\]
Now suppose firms are allowed to invest in quality improvements. A full-fledged treatment of the effects of increasing competition on innovation incentives in this setting is beyond the scope of the paper. Nevertheless, one important observation suffices to show why the analysis will differ substantially from the case of process innovations: Contrary to that case, both firms face higher margins and gross profits when the leader innovates, and both firms face lower margins when the laggard innovates. It is thus clear that the economics for the case of vertical quality improvements can differ substantially from the case of cost reductions: One would expect an increasingly competitive environment to induce activities that “soften competition” by increasing differentiation.

**Vertical and horizontal differentiation** As an illustration, consider the Salop model discussed in Section 6.2. For simplicity, specify \( m = 1 \) and \( n = 2 \). Modify the expression for consumer net utilities to allow for firm-specific willingness to pay \( A_i \) (\( i = 1, 2 \)):

\[
U_i = A_i - p_i - t(x - z_i)^2.
\]

An increase in \( A_i \) can then be regarded as a vertical product innovation. It is simple to show that, with \( \Delta_i = A_i - A_j \), the expressions for outputs and margins become

\[
M_i = \frac{t}{4} + \frac{\Delta_i}{3},
\]

\[
Q_i = \frac{1}{2} + \frac{2 \Delta_i}{3 t}. \tag{6.5a}
\]

It is immediate that these terms are almost the same as the corresponding terms for cost reduction.\(^{11}\) It is thus not surprising that the qualitative properties obtained for the effects of competition on process innovation incentives in Section 6.2 carry over to the case of

\(^{10}\) Specifically, this would require an adequate definition of increasing competition in this context. One natural way to go would be to define increasing competition in terms of properties of the density of consumers (that is, the values of \( \bar{\gamma} \) and \( \gamma \)): When \( \bar{\gamma} - 2\gamma \) is low, so are margins.

\(^{11}\) Let \( \Delta_i^C = c_j - c_i \). Then \( M_i = \frac{t}{4} + \frac{\Delta_i^C}{2} \) and \( Q_i = 0.5 + \frac{\Delta_i^C}{t} \).
product innovations. For the product innovation incentive, we obtain
\[
\frac{\partial \Pi_i}{\partial A_i} = \frac{4}{q} \Delta_i + \frac{1}{q}.
\]
Hence, increasing competition has a positive effect on the innovation incentives if and only if a firm is a leader (\(\Delta_i > 0\)). As in the case of process innovations, this reflects the fact that the output effects of greater competition (reduction of \(t\)) are positive for leaders and negative for laggards.

**Changes in the number of firms** Dubey and Wu (2002) consider the relation between the number of firms and innovation incentives in a setting where firms initially all produce low-quality products. Before setting prices, they can then decide whether to make a stochastic investment which, with some probability, improves the quality of the product by a fixed amount. Firms face a continuum of consumers who differ in their valuation of quality. The authors show that innovation incentives have an inverse U-shape in a very specific parameterization. On the one hand, when the number of firms become very large, the incentives to invest become very small, for reasons that are similar to the case of process innovation (compare our discussion of the entry liberalization example in Section 4.1.1). On the other hand, when the number of firms is small, the replacement effect kicks in, and firms earn high profits even without innovation. The example seems plausible, but it is not entirely clear to which extent the result is really driven by the fact that product rather than process innovations are considered. As argued earlier, standard models typically predict a negative effect of an increase in the number of firms on process innovation. However, these models differ in more than one dimension from the example considered here.

### 6.4.2 Additional Products

Several authors allow firms that have innovated to produce the old version of the good along with the new version. Doing so will allow the firms to price discriminate between consumers with high willingness to pay who receive the new good at a high price and consumers with low willingness to pay who receive the old good at a low price.

**Pure vertical differentiation** For instance, Greenstein and Ramey (1998) consider product innovations in a model of vertical product
differentiation à la Shaked and Sutton (1982) as sketched above. In this setting, the authors compare the innovation incentives of firms under varying degrees of competition. Translated to our notation, they consider innovation as an activity that introduces a new good with quality $A_i^H$ which is above the old quality $A_i^L$. In one of several comparisons, $\theta = \theta_L$ refers to a case of a monopolist. His gross profit is $\Pi^i(A_i^L, \theta_L)$ if he sells only the old low-quality product. If he innovates, he obtains a total profit of $\Pi^i(A_i^H, \theta_L)$ which consists of sales from both the high-quality and the low-quality product.

The case $\theta = \theta_H$ corresponds to the existence of several perfectly competitive firms. If one of these firms does not invest, it obtains gross profits of $\Pi^i(A_i^L, \theta_H) = 0$. If it innovates, its profits $\Pi^i(A_i^H, \theta_H)$ are those of a firm with a high-quality and a low-quality product facing a competitive fringe of firms producing low-quality products. It is straightforward to see that the innovation incentives $\Pi^i(A_i^H, \theta) - \Pi^i(A_i^L, \theta)$ are higher with higher competition if and only if:

$$\Pi^i(A_i^L, \theta_L) > \Pi^i(A_i^H, \theta_L) - \Pi^i(A_i^H, \theta_H).$$ (6.6)

The left-hand side reflects the familiar “replacement effect” that captures the positive effect of ex ante competition on innovation (Section 2): A monopolist who produces the new and the old product must take into consideration that even without the innovation, he would obtain the profits $\Pi^i(A_i^L, \theta_L)$ from the sales of the old good. This effect provides a reason why he would invest less than a competitive firm.

On the other hand, there is also a reason why a competitive firm might invest less: The competitive firm, even after innovation, will still face the pressure from the fringe firms. Thus, it will earn less after the innovation than the monopolist who carries out the same innovation. This corresponds to the negative effect of ex post competition on investments discussed in Section 2, and it is captured by the term $\Pi^i(A_i^H, \theta_L) - \Pi^i(A_i^H, \theta_H)$. Of course such an effect also arises for process innovations, but the possibility of price coordination for multiproduct monopolists in the product innovation setting makes it more pronounced.
Greenstein and Ramey (1998) then go on to check which of the two terms in Equation (6.6) is larger. For drastic innovations, they still obtain the result from the process innovation case that competition leads to greater incentives. For nondrastic innovations, it turns out that the innovation incentives are identical in the two cases. Hence, the intensity of competition has no effect on innovation. The authors also show that a suitable monotone perturbation of the utility function derived from the model of Shaked and Sutton (1982) changes the demand structure in such a way that competition even leads to greater innovation incentives.

**Vertical and horizontal differentiation** Chen and Schwartz (2008) modify the approach of Greenstein and Ramey (1998) by considering products that are differentiated horizontally, located at the ends of the Hotelling interval (with uniformly distributed consumers). The product innovation leads to an increase in the willingness to pay by the same constant amount for each consumer. The authors compare the innovation incentives in three settings:

1. A monopoly where one firm produces both products.
2. A duopoly where an incumbent produces one product and only another firm can innovate and then produce the new product.
3. Competition where the equilibrium price for the old product equals the marginal cost.

It is fairly straightforward to show that innovation incentives for the duopoly are always higher than for competition: In both cases, the potential innovator has no profits if it does not innovate; if it innovates, it is better off if it faces a duopolistic competitor than a competitive fringe.

The comparison between innovation incentives in the monopoly and duopoly cases is more subtle. It is driven by a simple observation: When both products are sold by the same firm, an increase in the value of the innovative product leads to a price increase for the other good, whereas a competing duopolist would reduce the price of the old good. Thus
6.4 Product Innovations

as the value of a product grows, so does the “coordination advantage” that a monopolist can engage in joint pricing for both goods (which works toward larger incentives for the monopolist). However, the same is true of the “diversion effect”, which is essentially the replacement effect that the innovating monopolist loses at least part of the profits that he originally earned on the old good: The more valuable the new good, the lower are the profits that the monopolist earns from the old good. It turns out that the former effect always dominates. This illustrates the possibility that, in a horizontally differentiated setting, innovation incentives can be stronger for a monopolist.

Both Greenstein and Ramey (1998) and Chen and Schwartz (2008) claim that their results reverse the corresponding results for product innovation. It appears, however, that they are making the claim by comparison with Arrow (1962), who focuses on the effects of ex ante competition. It seems that the differences in the predictions really result from the fact that the authors are also considering effects on ex post competition. As we have seen throughout the monograph, such effects may also result for process innovations. For a cleaner comparison, it would be helpful to juxtapose the models with otherwise identical models of process innovation.

6.4.3 The Direction of Technical Change

Of course, firms are usually not restricted to carrying out either a product or a process innovation. Instead, they have to decide on how much of each activity they want to carry out. Then, it becomes interesting to ask how competition affects the choice between product and process innovation. Bonanno and Haworth (1998) approach this question in the Mussa–Rosen setting mentioned in Section 22. While they do not allow firms to choose arbitrary combinations of product and process innovations, they at least endogenize the choice between product and process innovations. They show that, as competition switches from Cournot to Bertrand, the high-quality firm will tend to switch from process innovation to a product innovation that increases the quality of its product, thereby increasing the extent of vertical differentiation. The result is intuitive: In a setting where prices are strategic complements, process
innovations tend to induce price cuts of the competitor, whereas product innovations that lead to more differentiation soften competition and induce price increases. This makes product innovations relatively more attractive as competition increases.

6.4.4 Summary

All in all, the theory of the relation between competition and product innovations seems a lot less developed than the corresponding theory for process innovations. In principle, of course, the tools for the analysis exist: Models of vertical product differentiation are suitable for addressing the question. To improve the understanding of the different effects of competition on product and process innovation, it will most likely be helpful to start from a decomposition such as Equation (3.2), which immediately reveals an important difference between product and process innovations: At least in some settings (e.g., Shaked and Sutton (1982) only quality investments of leaders increase own margins, whereas the investments of laggards tend to reduce them, because they intensify competition. A more thorough analysis of the relation therefore seems called for.

6.5 Other Determinants

Overall, the extensions of this section suggest that the basic model of Section 3 may underestimate the positive effects of competition on investment. For instance, with free entry, product innovations and separation of ownership and control, additional sources of positive effects arise. In Schmutzler (2010), I provide several other thoughts on factors supporting a positive relation between competition and innovation. I summarize the main ideas here.

**Spillovers:** A massive literature discusses innovation incentives in situations with spillovers where competing firms gain access to a part of the knowledge produced by the innovator.\(^\text{12}\) It has long been recognized that spillovers have adverse effects on innovation incentives, at

\(^{12}\text{See for instance Spence (1984), D’Aspremont and Jacquemin (1988), and Leahy and Neary (1997).}\)
least in simple settings. More intense competition often reinforces these adverse effects. The most important condition for the conclusion is the following:

**Property 4:** As competition increases, a marginal cost reduction of the competitor has stronger negative effects on own gross profits.

Intuitively, as competition increases, innovators are more concerned about the fact that they are strengthening the competitor by innovating more.\(^{13}\)

**Cumulative investments:** Compared with the one-shot case, cumulative investments work toward positive effects of competition on investment. As discussed in Section 5.1, investments are typically strategic substitutes, at least when spillovers are not too strong. Also, investments of the competitor are not desired. Thus, following the Top-Dog logic of Fudenberg and Tirole (1984) and Bulow et al. (1985), it is useful to invest in early stages, so as to make the competitor invest less in the future. Intuitively, as competition increases, this strategic effect becomes more important, which introduces an additional reason why competition might have a positive effect on investment.

**The initial level of competition:** There is a quite common rough intuition that, while some competition is good for investments, “excessive competition” may have negative effects, suggesting an inverted-U relation between competition and investment. The example of Section 4.1.2 shows that such a general statement cannot be supported in our partial equilibrium framework: In this example, a U-shape rather than an inverse U-shape emerges. The intuition in this particular case is as follows. The negative margin effect of competition becomes less pronounced when initial competition is high: With high competition, margins are close to zero, so that further reductions do not reduce margins much more.\(^{14}\)

However, as we saw in Section 6.3, which reports results by Aghion et al. (1997), there are indeed cases with inverse-U relations. A general

\(^{13}\)Obviously, this condition needs to be taken with a grain of salt. While it makes perfect sense for changes from small to intermediate competition, it is a lot less palatable for changes from intermediate to intense competition: For very intense competition, the level of profits may be so small that the adverse effects of increases competitor efficiency become negligible.

\(^{14}\)Technically, margins are a convex function of the competition parameter.
statement on the effects of the initial level of competition on the effects of further increases in competition is therefore not possible without qualification.

**Vertical industry structures:** Recent research has dealt with the incentives for R&D investments in network industries and successive oligopolies. In Schmutzler (2010), I sketch how the effects of downstream competition on downstream investments depend on the presence of imperfect competition in the upstream market. Roughly speaking, imperfect upstream competition tends to reduce the effects of downstream competition on investment, because changes in demand for R&D inputs affect their price.

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\(^{15}\) See Bühler and Schmutzler (2005) for downstream investment and Chen and Sappington (2009) for upstream investments.

\(^{16}\) The effects of downstream competition on upstream investments are more complex and add further countervailing sources (Schmutzler, 2010).
Doing justice to the large empirical literature on the relation between competition and investment is beyond the scope of this monograph that focuses on theory. The following short reflections have a much more restricted purpose. Rather than surveying the empirical literature, I will start by formulating some ideas that follow from the previous theoretical considerations and are relevant for empirical research. I will then ask to which extent these ideas are reflected in the existing empirical literature. For reasons that will hopefully become apparent, I consider both field research and experiments.

The theoretical analysis leads to the following implications for empirical research.

1. It may be of limited use to test the relation between competition and investment. As emphasized above, the predicted relation depends on the details of the underlying model, and, to a large extent, the differences can be explained by economic intuition. In view of the initial examples, it may make a substantial difference whether one looks at entry liberalization, decreasing substitutability or globalization as examples of increasing competition. Thus one should
view empirical research on competition and innovation not so much as an attempt to deal with the second-most tested hypothesis in industrial organization, but as a broad research project that deals with tests of related, but distinct hypotheses.

2. On a related note, even when one confines attention to a comparatively narrow concept of increasing competition (such as an increase in the substitutability of products or a reduction in transportation costs), the analysis strongly suggests that additional factors will determine the predicted relation. Possible candidates include the ease of entry Section (6.1), the ownership structure of the firm Section (6.2), whether firms are leaders or laggards Section (5.2), whether one considers product or process innovations Section (6.4), etc. Thus, one would hope that empirical research takes these factors into account.

3. The theoretical analysis not only provides predictions for the relation between competition and investment, it also suggests more specifically through which channels competition affects investments. In the basic model, competition impacts on innovation incentives via its effect on output, margins, output sensitivity, and cost-pass-through (Section 4.2). In the model of cumulative investments, there are additional effects that come through strategic effects of present investments on future investments (Section 6.5). In the model with endogenous market participation (Section 6.1), the reason why the effects of more intense competition (defined as closer substitutability between products) on investments tend to be more positive than with an exogenously given set of firms is that intense competition tends to reduce the number of firms in the market. It would greatly enhance the value of empirical tests of the relation between competition and investment if we had any evidence about which of the transmission channels exposed in theory are responsible for the observed relation between competition and investment.
7.1 Field Evidence

During the last 50 years, many authors have addressed the relation between competition and innovation empirically. This research has been summarized and discussed in several surveys already, including Kamien and Schwartz (1982), Baldwin and Scott (1987), Cohen and Levin (1989), Cohen (1995), and Gilbert (2006). In spite of what has been said above, at least until recently this research does seem to have been directed toward finding the relation between competition and investment. There are several related strands of literature that deal with the relation between innovation and measures of firm size, market share, or industry concentration, which are meant to capture the intensity of competition.

Neither of these related strands of literature maps easily into the theoretical discussions summarized above. Firm size is often captured by sales volume. In the theoretical literature, sales are endogenous, determined in the last stage of the innovation game, after firms have chosen their innovation levels. The relation between firm size and the theoretical measures of $\theta$ is unclear.

Industry concentration is also potentially endogenous. Similarly, it is not clear what the relation between a firm’s market share and its investment activities should be, unless one is sufficiently specific about details. A simple argument for a clear relation could be made in a setting with an exogenous number of perfectly symmetric firms, where the market share is the reciprocal of the number of firms. Then one would typically expect a strictly positive relation between concentration and process innovation, but with asymmetric firms the relation is much less clear.\footnote{For instance, suppose in a duopoly a higher market share of a firm reflects lower marginal costs. Then the relation between market share and process innovation essentially boils down to the issue of the differences in the innovations of leaders and laggards. As argued in Section 5.1, it is quite conceivable that leaders invest more than laggards, because they face higher benefits from cost reductions. This would indeed correspond to a positive relation between market share and innovation. On the other hand, leaders may want to invest less, because the costs of investing are higher. Also, a positive correlation between market share and innovation may reflect market share gains from innovation rather than positive effects of market share on innovation. Finally, omitted variables may pose a substantial problem. It is quite possible that firms with high market share may have some exogenous characteristics that make them better innovators.}
Some of these issues have been pointed out long ago (see, e.g., Phillips, 1966), and it has been widely accepted that they are most likely to be relevant for the failure of empirical analysis to uncover a clear relation between competition and innovation. More recent empirical research has therefore moved in two related directions. First, it has tried to identify competition variables that relate more closely to theoretical concepts and are less likely to be endogenous. Second, to some extent, it has abandoned the search for a general relationship between competition and innovation, focussing more on identifying which factors determine the nature of the relation. For instance, the literature has highlighted potential differences in the effects of competition on the investments of leaders and laggards and it has also begun to separate the effects of competition on product innovations from those on process innovations.

7.1.1 Selected Examples

I will provide some examples for these developments in the following.

Positive Effects of Competition on Innovation  Nickell (1996) starts from the premise that there is a widespread belief “... that competition exerts downward pressure on costs, reduces slack, provides incentives for the efficient organization of production and even drives innovation forward (p.724/725)". In line with the arguments made above, he is skeptical about the existing theoretical foundations for this belief and about solid empirical evidence in favor of it.2

He therefore uses a panel with data from the U.K. manufacturing industry between 1972 and 1986 to provide evidence in favor of the hypothesis. He uses various different measures of competition. He not only includes firm-level market shares and measures of concentration and import penetration at the market level, he also uses survey-based measures. He finds evidence that competition is indeed associated with higher total factor productivity growth. He acknowledges the possibility

2However, he acknowledges some supportive anecdotal evidence. For instance, he points to the case studies of Porter (1990) who shows that domestic competition has a positive effect on the ability of firms to be successful in international markets.
of reverse causality, but he argues that this should reduce the measured impact, because firms with faster growth of total factor productivity would become more dominant, thereby reducing competition.

**On inverse U-shape** Aghion et al.’s (2005a, b) is one of the clearest attempts to test a sophisticated theoretical model with field data. The authors build from the work of Aghion et al. (2001) presented in Section 6.3. To repeat, their model makes several testable predictions:

H1 There is an inverted-U relationship between product market competition and the average innovation rate.

H2 As competition increases, industries tend to be in a neck-and-neck state less often.

H3 The closer firms are to each other, the stronger is the positive effect of product market competition on innovation and the larger the average number of innovations.

Hence, the model not only contains a hypothesis on the relation between competition and innovation, but additional hypotheses that relate to the precise mechanism: By H2 and H3, even though, for a given set of neck-and-neck firms, an increase in competition increases innovation, a countervailing force arises because competition drives industries into states where innovations arise less often.

The empirical test confirms not only the central inverse-U hypothesis H1, but also the related hypotheses H2 and H3. The analysis obtains credibility because the authors do not restrict themselves to measures of competition that are suspect of endogeneity. While they choose the Lerner index as an explanatory variable, they also introduce a set of policy instruments that provide exogenous variation in competition. These instruments included measures from the EU single market program, large-scale privatizations and measures imposed by the Monopoly and Merger Commission.

**Competition and endogenous entry** Syverson’s (2004) is a theory-based empirical contribution that relates closely to several of the issues discussed in this monograph, even though it does not deal directly with innovation. The paper investigates the relation between
local competition and the productivity distributions within the ready mixed concrete-industry. It explores the variation in these distributions across geographical regions in the United States. It shows that in high-demand regions, the productivity distribution has more weight on high realizations, and it has lower dispersion. Syverson explains the observation using a variant of the model of Raith (2003) presented in Section 6.2. To repeat, this model is based on the Salop model with exogenous cost asymmetries. Syverson considers the effect of an exogenous demand increase. As this demand increase attracts further entry, the substitution possibilities for consumers increase (even though there is no change in the substitution parameter as such). As a result, relatively inefficient firms have a harder time surviving, so that the distribution of firms in the market changes in a way corresponding to the empirical observations.

The effect described by Syverson relies purely on firm selection. Hence, to explain the observations in the paper, it is not necessary to refer to any relation between competition and innovation. However, the observations at least confirm important ingredients of Raith’s (2003) model: The changes in exogenous parameters induce an adjustment in the number (and distribution) of firms that is consistent with the model. Whether the increases in productivity actually come from a positive effect on innovation or merely from a selection effect remains an open issue.

**Entry threat, leaders and laggards** Aghion et al. 2009 provides an interesting investigation of the effects of foreign entry on the productivity of incumbents. They use various policy reforms to instrument for the entry threat. The authors show that the threat of entry induces greater innovations in industries that are close to the technological frontier, whereas it discourages entry in industries that are lagging behind. This is broadly consistent with the patterns exposed in Section 4.2, where I argued that increasing competition tends to increase the investments of leaders rather than those of laggards.

**Product and Process innovations** Kretschmer et al. (2008) emphasize the multi-dimensional nature of innovations: In line with
the discussion in Section 6.4, they argue that competition may affect product and process innovations in different ways. More specifically, the authors consider a data set for the French automobile retail industry. They analyze the effects of a change in European competition policy toward vertical restraints. Essentially, this policy increased competition by abolishing territorial exclusivity of dealers.

The main results are as follows. Liberalization has a positive effect on product innovation. This effect is mediated through an increase in the scale of operations which correlates with higher returns to product innovation. The effect on process innovations is negative, which reflects a negative relation between product and process innovation. Though these results are not motivated directly by any of the above models, they are broadly consistent with the ideas discussed in Section 6.4, where it was argued that, as competition increases, product innovations become relatively more attractive. Also, the authors pay particular attention to the interaction between innovation strategies and the scale of the firm. Consistent with the discussion of transmission mechanisms in Section 4.2 (in particular, the output effect), process innovations and large scale tend to be correlated.

7.1.2 Conclusions

The gulf between the early empirical research on competition and innovation and the models presented in this monograph was substantial. The search for correlation between concentration and various measures of R&D activities seemed too far removed from the theoretical considerations.

More recently, there has been a convergence between theoretical and empirical research. Several papers attempt to find measures of competition that are closer to the theoretical concepts, and are less prone to endogeneity problems. Also, several recent studies take into account that the predicted effect of competition on investment will depend on firm and industry characteristics. This is exemplified by

\[^3\]For process innovations, the authors use the adoption of certain human resource software; for product innovations, they use the adoption of software packages that improved the customization of orders.
the studies that distinguish between leaders and laggards or between product and process innovations. Also, careful studies that deal with particular industries are promising in this respect, because they remind us of the possibility that there may be quite different patterns in different industries. Finally, it is encouraging that some papers not only aim at finding the relation between competition and innovation, but also test-related hypotheses which provide some support for the specific mechanisms advanced by theory.

These improvements not only reflect changes in the empirical analysis, but also in the underlying models. Not all the theoretical models presented in this monograph are particularly well-suited for empirical analysis. Models with an exogenous number of symmetric firms are unlikely to provide a very useful basis for empirical analysis. A shift from Cournot to Bertrand competition is hard to translate into empirical categories. It is clear that our theoretical understanding of the relationship would have remained highly incomplete without the more recent extensions to asymmetric firms and endogenous entry. Also, it is hardly surprising that the more recent theory-based empirical analysis made heavy use of these extensions.

The recent progress notwithstanding, the match between theory and empirical analysis is still not perfect. I will therefore briefly report on a complementary approach to testing theories of competition and innovation.

### 7.2 Experimental Evidence

A small group of authors has used laboratory experiments to shed light on the strategic issues related to innovation. For instance, Suetens (2005) and Halbheer et al. (2009) confirm the well-known negative effects of spillovers on investments. Halbheer et al. (2009) also provide support for weak increasing dominance, as discussed in Section 5.1. In the following, I shall, however, focus on the small group of authors who have dealt directly with the relation between competition and investment.

There are some obvious shortcomings of using experiments in this context. Most importantly, a laboratory experiment is always a test of
one out of many conceivable models of competition and innovation. It cannot inform us about which model is adequate. Expressed differently, if we find a particular effect of competition on investment in any single laboratory experiment, we cannot take this as any serious evidence in favor of such a relation in the field, as long as we know that there are many other models around that predict the opposite. As the paper should have shown, there is not much a priori reason to favor any one model over another one.

Precisely for this reason, however, laboratory experiments can play a useful role. They allow the researcher to communicate the rules of the game to the players in exactly the way prescribed by theory, and they allow the researcher to carry out one-parameter variations of the environment that make it very credible that changing behavior in different treatments must necessarily result from this particular treatment variation. Thus, if we find that a particular effect that is predicted by theory is actually observed in the lab, it provides us with some support for the idea that, if such subjects are ever confronted with a structurally similar setting in the field, they might behave in a similar fashion. Conversely, if certain effects that we take for granted in theory are not observed in the lab, then we should take this as a warning that the effects may not be very robust.

### 7.2.1 Number Effects

The entry liberalization example of Section 4.1.1 predicts a negative effect of an increase of the number of players on investments for Cournot competition. This effect also played an important role for the analysis of innovation incentives under endogenous entry Section (6.1).

Darai et al. (2010) consider homogenous goods models with two and four firms. They show that an increase in the number of firms reduces investments, as predicted. They also make an analogous comparison for the Bertrand game. The game is similar to an all-pay auction, because only the firm with the lowest marginal costs will earn a positive profit, even though everybody incurs the investment costs. Contrary to standard all-pay auctions, the game typically has asymmetric pure-strategy equilibria. In addition, symmetric mixed-strategy
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equilibria arise. No matter which benchmark is used, theory predicts a negative number effect of investments. Even though the point predictions are not quite consistent with the observations (there is mild overinvestment in both the two-player and the four-player case), the comparative statics are clearly confirmed for Cournot as well as for Bertrand competition.\(^4\)

7.2.2 Increasing Substitutability

Sacco and Schmutzler (2010) took the Cournot model of differentiated price competition sketched in Section 4.1.2 to the lab, considering both symmetric and asymmetric settings and one-stage and two-stage treatments.\(^5\) In both cases, they compared the investments for weak competition (\(\theta = 1/10\)) to intermediate competition (\(\theta = 2/3\)) and intense competition (\(\theta = 1\)). The one-stage treatments provide some evidence for the predicted U-shape: In the symmetric case and for leaders in the asymmetric case, investments are lowest for intermediate competition. However, in both cases, the positive effect of moving from intermediate to intense competition is insignificant. For laggards, the predicted negative effect of competition on investment holds, but it is also less pronounced: Laggards overinvest, and more so for \(\theta = 1\).

More substantial deviations from the theoretical predictions arise in the two-stage treatments, where Sacco and Schmutzler (2010) only consider the symmetric cases with \(\theta = 0.67\) and \(\theta = 1\). There, contrary to the one-stage treatments, subjects underinvest. The deviation is more pronounced for intense competition, so that moving from intermediate to intense competition has no significant effect on investments.

Cournot versus Bertrand  Darai et al. (2010) also deal with the effects of switching from Cournot to Bertrand investments, considering both the case of two and of four players: Increasing competition in

\(^4\) In the same spirit, two early contributions of Isaac and Reynolds (1988, 1992) deal with patent races and show that an increase in competition in the sense of a larger number of firms indeed has a negative effect on investments.

\(^5\) The two-stage treatments correspond exactly to the theoretical structure of the game. In the one-stage treatments, for each investment vector, subjects obtained the payoffs from the Nash equilibrium of the induced subgame. This approach allows to understand deviations from the subgame-perfect equilibrium in the investment game more clearly.
this sense has a positive effect on investments. In the two-player case, this is consistent with the theoretical prediction. In the four-player case, the experimental observation contradicts the prediction. Broadly speaking, the analysis leads to the tentative conclusion that increasing competition might have positive behavioral effects on investment.

### 7.2.3 Conclusions

Even though only a fairly small number of experiments on competition and investment have been carried out so far, some suggestive conclusions are possible.

The effects of competition and investment are broadly confirmed, with some qualifications. The negative number effects of competition come out clearly. The U-shaped and negative relations in the specific differentiated goods example are broadly consistent with the observations, with some qualifications regarding significance levels. When comparing Cournot and Bertrand investment games, there seems to be more reason for skepticism: Broadly, there tends too much investment in the Bertrand setting, so that even in cases when moving from Cournot to Bertrand competition should reduce investments, it has the opposite effect. This may have something to do with the complex strategic situation in Bertrand investment games, which makes it very unclear what optimal behavior is. However, even though this situation is presumably extreme in the Bertrand case, the strong sensitivity of optimal decisions to those of other players is an important feature of intense competition.

The possibly most interesting observation does not relate specifically to the relation between competition and experiments in such a simple setting, but to the well-known strategic effects of intertemporal decisions that drive a large part of the theoretical industrial organization literature (Fudenberg and Tirole, 1984; Bulow et al., 1985). It seems that, while subjects understand how second-period actions (e.g., outputs) should vary with own first-period actions (e.g., investments), they hardly seem to adjust to the first-period actions of competitors.\(^6\)

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6. The finding that the strategic effects of investments are imperfectly understood by subjects is also familiar from other two-stage models (see Engelmann and Normann, 2007; for
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It is probably not a good sign for the underlying theory that the fundamental strategic mechanisms cannot even be observed in a very clean and stylized two-stage setting.

strategic trade models, Huck et al., 2004; for the delegation game of Fershtman and Judd, 1987; Oechssler and Schuhmacher, 2004; for the debt model of Brander and Lewis, 1986).
Conclusions

If this monograph has a conclusion, it is probably that understanding the relation between competition and innovation is not a particularly well-defined task. Rather, there appears to be a set of separate, but related questions which are often addressed under the same heading. To make sure that it is indeed beneficial to regard these questions as belonging to one broad research project, it is crucial to understand what the commonalities and the differences of these various questions are. This paper made an attempt to do so. I hope this approach has helped to clarify why there is so little consensus on the relation between competition and innovation. I also hope it has contributed to understanding which factors are conducive to a positive or negative relation, respectively.
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