



University of Zurich

Socioeconomic Institute
Sozialökonomisches Institut

Working Paper No. 0716

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Publisher Sozialökonomisches Institut
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The relation between competition and innovation – Why is it such a mess?

Armin Schmutzler*

October 2007

Abstract: Using several simple examples, this paper shows that the effects of increasing competition on cost-reducing investments can be positive, negative or non-monotone. Also, competition is more likely to increase the investments of leaders than of laggards. To explain these findings, I use a reduced-form model. I identify four different transmission channels by which competition affects investments. Competition typically (i) reduces markups, but (ii) increases the sensitivity of equilibrium demand to marginal costs – this already implies countervailing effects on investment incentives. These difficulties are compounded because competition has ambiguous effects on (iii) the level of equilibrium demand and (iv) the extent to which efficiency gains are passed through to consumers as lower prices. Because of these ambiguities, there is not much hope of establishing a robust relation between competition and investment.

Keywords: competition, investment, cost reduction

JEL: L13, L20, L22

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I am grateful to Donja Darai, Dennis Gärtner, Dario Sacco and Xavier Vives for helpful discussions. Lukas Rühli provided valuable research assistance.

1 Introduction

Even though economists have been trying to understand the relation between the intensity of competition and investment for decades, the issue remains unsettled. While some authors argue that competitive pressure is the driver of R&D, others emphasize the Schumpeterian idea that some monopoly power is necessary for innovation. As both arguments have some merit, it is unsurprising that the theoretical analysis of the subject has been inconclusive. Depending on the definition of competitive intensity and the oligopoly framework, it is possible to generate positive, negative, U-shaped or inverted U-shaped relations between competition and investment.¹ Empirical research has not led to clear results either (see, e.g., Gilbert 2006). To some extent, these ambiguities result from data limitations and methodological issues, but they may well reflect a more fundamental problem. The search for *the* relation between competition and investment may simply be in vain. At best one can hope for understanding the relation in specific settings. The present paper elaborates on this view.

The paper intends to uncover the sources behind the ambiguous relation between competition and investment. It clarifies (i) why there is little hope of exposing a simple general relation between competition and investment and (ii) in which specific circumstances there may be clear results. The key to the answer lies in identifying the channels through which competition affects investment. To this end, I use a general model that contains various familiar examples as special cases. The model has two stages, with cost-reducing investment followed by product market competition. Some firms may be exogenously more efficient than others, that is, they may have lower marginal costs. Together with the initial efficiency levels, cost-reducing investments determine the efficiency in the product market stage. Second-stage profits (gross of investment costs) of firm i , π^i , are a function of (i) own efficiency Y_i , (ii) the competitor's efficiency Y_j and (iii) a competition parameter θ . I frequently use a decomposition of gross profits as a product of equilibrium

¹For elementary models on this topic, see Motta (2004, ch.2); Vives (forthcoming) provides a more sophisticated analysis. Similar issues are discussed in a macroeconomic context (Aghion et. al. 1997, 2001)

demand and equilibrium markup,

$$\Pi^i(Y_i, Y_j; \theta) = D^i(Y_i, Y_j; \theta) \cdot M^i(Y_i, Y_j; \theta). \quad (1)$$

In the examples, higher own efficiency increases both components of a firm's profit: Lower costs lead to lower prices and hence higher demand; usually, the price reduction is smaller than the cost reduction by which it was triggered off, so that the absolute markup also increases.² Several specific examples of the framework are treated in more detail.

1. A homogeneous linear Cournot model where θ corresponds to the inverse of market size. In this example, competition has an unambiguously negative effect on investments.
2. A differentiated linear Cournot model where θ corresponds inversely to the extent of differentiation. Here competition has a U-shaped effect on investments, except for firms that are lagging behind substantially. For these firms, the effect of competition is negative. In the corresponding Bertrand model, competition has a negative effect on investments, except for firms that are substantially ahead of the competitors. For these firms, the effect of competition is U-shaped.
3. A Hotelling model where θ corresponds to the inverse of transportation costs. Here competition has a positive effect on the investments of leaders and a negative effect on the investments of laggards.

Our assumptions on θ are inspired by two common properties of the competition parameters that are used in these models (and many others):

1. The mark-up of each firm in the product market equilibrium decreases with θ ; the *absolute markup effect* of competition is negative.³

²In some settings, the price reductions implied by lower marginal costs overcompensate the cost reductions, so that absolute mark-ups fall, but this is relatively rare.

³Boone (2007) provides a reasonable example where this property of a competition parameter is *not* satisfied. The ideas of the following analysis could still be applied, but at the cost of having to distinguish more cases.

2. The positive effect of greater efficiency on equilibrium increases with competition; the *demand sensitivity effect* is positive.

Because more intense competition reduces markups M^i , it reduces the value of increasing demand through greater efficiency, as each additional unit sold is worth less. This effect reduces investment incentives. Because competition also increases the sensitivity of demand to greater efficiency ($D_i^i \equiv \frac{\partial D^i}{\partial Y_i}$), however, there is a countervailing effect: Greater efficiency expands demand more when competition is intense, making investments more attractive. Because of these countervailing effects, the two defining properties already suggest why more competition may have ambiguous effects on investments.

However, there are further sources of complication: Competition affects equilibrium demand D^i of each firm positively or negatively, depending on the details of the model.⁴ This *absolute demand effect* is another source of ambiguity: A positive demand effect suggests a positive effect on investment incentives, because it increases the value of higher mark-ups resulting from greater efficiency; conversely, for negative demand effects.

Finally, there is the *cost-pass-through effect*: Competition not only affects the size of the markup, but also its sensitivity to costs ($M_i^i \equiv \frac{\partial M^i}{\partial Y_i}$). If the price reduction induced by efficiency becomes larger as competition intensifies, the cost-pass-through effect is negative; otherwise it is positive. Interestingly, the direction of the effect will be shown to depend on the nature of product-market competition.

The preceding discussion shows why the effects of competition on investment are not clear-cut: Competition potentially affects M^i , D^i , D_i^i and M_i^i . The interaction of these four different transmission channels induces potentially ambiguous effects of competition on investment. This can happen no matter whether firms are initially symmetric or asymmetric. When the initial efficiency levels differ, however, matters become more complicated, because the four transmission channels affect leaders and laggards differently. For instance, in many cases competition is more likely to have a positive effect

⁴Lower own prices lead to higher demand, but lower competitor prices lead to lower demand. Direct (not price-induced) effect of competition on demand may also work towards lower demand.

on demand for leaders than for laggards, so that competition tends to have more positive effects for leaders than for laggards.

All told, therefore, the paper uncovers the reasons behind the ambiguous relation between competition and investment. To my knowledge, the most closely related paper is Vives (forthcoming) who also considers the effects of competition on cost-reducing investments in general two-stage games. However, I allow for initial asymmetries between firms and for more general parameterizations of competition.⁵ Also, even though Vives emphasizes the role of demand expansion (or reduction), he does not address the other three transmission channels explicitly.⁶

The paper is organized as follows. Section 2 introduces the set-up. Section 3 provides introductory examples. Section 4 reviews relevant comparative statics results. Section 5 identifies the four transmission mechanisms of competition on investment. Section 6 shows how the transmission mechanisms operate in the introductory examples. Section 7 discusses further examples. Section 8 provides a taxonomy of the examples. Section 9 concludes.

2 Set-up

I shall consider a class of two-stage games. In period 1, firms $i = 1, 2$ carry out a cost-reducing investment. In period 2, they engage in product-market competition. Initially, firm i has marginal costs c_i^0 . Firm i 's cost reductions in stage 1 are denoted as y_i ; thus in stage 2 costs are $c_i = c_i^0 - y_i$. Investment costs are given by an increasing function $K(y_i)$. It is often convenient to express a firm's state positively in terms of efficiency rather than negatively in terms of marginal costs. I therefore define the efficiency level Y_i in stage 2 as $Y_i = \bar{c} - c_i$ for some constant \bar{c} ; similarly for the efficiency level Y_i^0 at the

⁵Vives confines himself to product differentiation parameters, while we can handle other parameterizations treated by Boone (2007) such that inverse market size, the move from Cournot to Bertrand, etc.

⁶Importantly, however, Vives (forthcoming) contains an extension of the analysis to the case of free entry. He also allows for more than two firms and for simultaneous investment and product-market decisions.

beginning of the investment game.⁷ Demand of firm i is $d^i(p^i, p^j; \theta)$, where p^i and p^j are the prices of firm i and firm j , respectively, and θ is a competition parameter from some partially ordered set. Further, the product-market game is assumed to have a unique Nash equilibrium for arbitrary θ and $\mathbf{Y} = (Y_1, Y_2)$, corresponding to prices $p^i(Y_i, Y_j; \theta)$.⁸ The following quantities are thus well defined:

1. Equilibrium mark-ups $M^i(Y_i, Y_j; \theta) \equiv p^i(Y_i, Y_j; \theta) - \bar{c} + Y_i$
2. Equilibrium demands $D^i(Y_i, Y_j; \theta) \equiv d^i(p^i(Y_i, Y_j; \theta), p^j(Y_i, Y_j; \theta); \theta)$
3. Gross equilibrium profits $\Pi^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) \cdot D^i(Y_i, Y_j; \theta)$

I will maintain the following assumptions throughout.

(A1) $d^i(p^i, p^j; \theta)$ is non-increasing in p^i and non-decreasing in p^j , $j \neq i$.

Thus, the firms produce (potentially imperfect) substitutes.

(A2) $p^i(Y_i, Y_j; \theta)$ is non-increasing in Y_i and Y_j , $j \neq i$.

(A2) holds in most oligopoly models, including all the introductory examples. Because the product market game has a unique equilibrium, the investment game reduces to a one stage game with payoff functions

$$\pi^i(y_i, y_j; \theta) = \Pi^i(Y_i^0 + y_i, Y_j^0 + y_j; \theta) - K(y_i). \quad (2)$$

3 Introductory Examples

The following examples all derive from standard oligopoly models and competition parameters. Nevertheless, they lead to very different comparative statics. In all cases, the investment cost function is $K(y_i) = y_i^2$.⁹ The appendix contains equilibrium demands and markups, from which the functions $\pi^i(y_i, y_j; \theta)$ underlying the calculations can easily be derived.

⁷The choice of \bar{c} is arbitrary; to simplify calculations, I usually choose $\bar{c} = 0$ or $\bar{c} = a$, where a is the maximal willingness to pay for any unit of the good.

⁸This formulation even makes sense when firms choose outputs rather than prices; $p_i(Y_i, Y_j; \theta)$ then denotes the market clearing price for equilibrium outputs.

⁹This specification matters only for the explicit calculation of investment costs, not for comparative statics.

3.1 Example 1: Inverse market size

Firms are Cournot competitors, with market demand $D(p) = a - p$ for some $a > 0$, and constant marginal costs c_i . Let $\theta = -a$. Hence, more intense competition corresponds to smaller demand.¹⁰ Figure 1 plots equilibrium investments for $c_i^0 = c_j^0 = 0.5$ and $a \in [0.5, 1]$. More generally, the effect of increasing competition on investment levels is unambiguously negative.

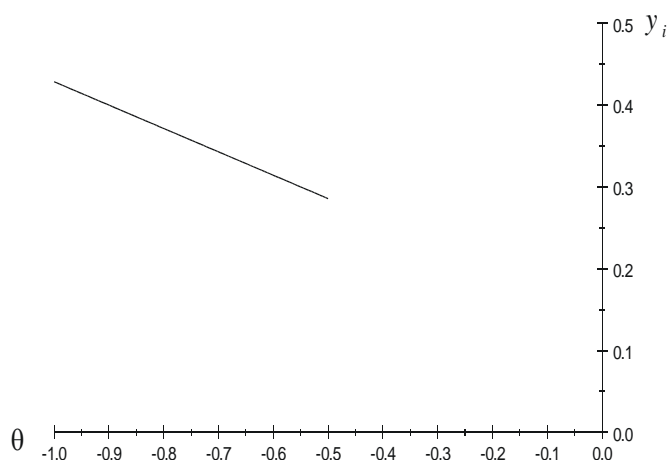


Figure 1: The effects of market size

3.2 Example 2: Substitutability

In a market with differentiated goods, let inverse demands be

$$p^i(q_i, q_j) = 1 - q_i - bq_j, \quad (3)$$

where $0 \leq b \leq 1$. The corresponding demand functions $d^i(p^i, p^j)$ satisfy $\frac{\partial d^i}{\partial p^j} > 0$ for $b > 0$; thus the goods are substitutes. For $b = 0$, firms are monopolists; $b = 1$ corresponds to homogeneous goods. More generally, higher b corresponds to better substitutability. Hence, let $\theta = b$.

¹⁰Boone (2007) also treats inverse market size as a competition parameter.

3.2.1 Quantity competition

The middle line in Figure 2 plots the relation between competition and equilibrium investments for $c_1^0 = c_2^0 = 0.5$. The line is U-shaped: Starting from a monopoly, an increase in competition first reduces investment; beyond $\theta = 2/3$ further increases raise investments.

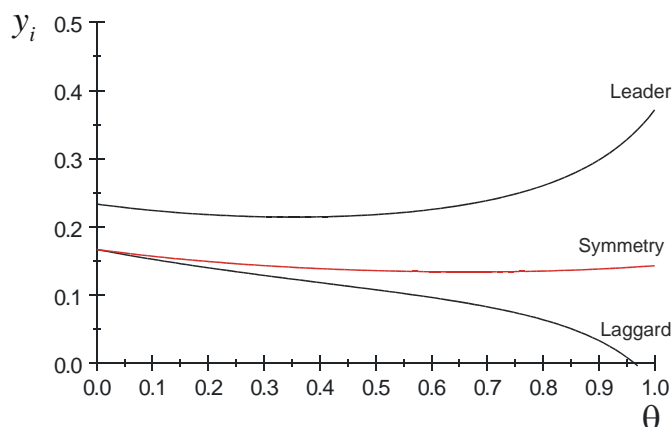


Figure 2: Differentiated Cournot competition

With small heterogeneities between firms, the qualitative pattern is similar.¹¹ As the initial differences increase, the U-shaped relation between competition and investment breaks down for laggards, for whom competition now has a negative effect on investment. For instance, the respective lines in Figure 2 plot the relation between competition and investments for $c_1^0 = 0.3$; $c_2^0 = 0.5$ for leaders (laggards). Summing up, the example has two interesting aspects: (i) a U-shaped relation between competition and investment in the symmetric case and (ii) qualitatively different effects of competition on the investments of leaders and laggards.

¹¹However, the level of competition from which on competition has a positive effect on investment is lower for leaders than for laggards.

3.2.2 Price competition

Figure 3 plots the equilibrium investments for price competition, with the same initial costs as in Figure 2. Investments thus decrease with competition when firms are neck-to-neck or laggards, but for the leader they increase as competition becomes very intense.

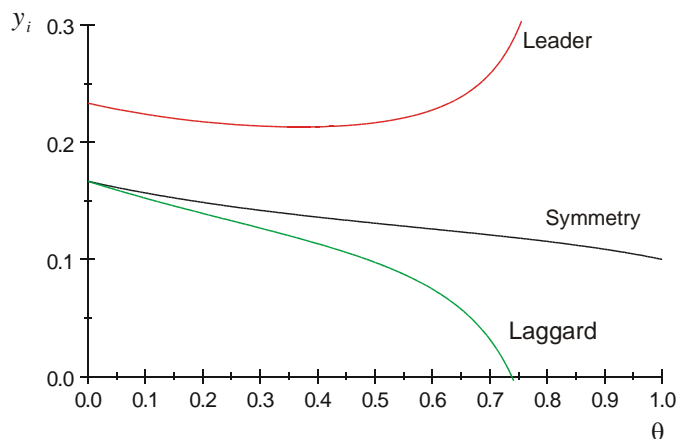


Figure 3: Differentiated Bertrand Competition

Hence, even though the fundamentals are the same as for quantity competition, competition has a strictly negative effect in the symmetric case and for laggards. A U-shape only arises for firms with a substantial lead.

3.3 Example 3: Transportation costs

Next, consider a Hotelling duopoly. Consumers buy at most one unit of a homogeneous good, and are equally distributed along $[0, 1]$. Firms are located at $q_1 = 0$ and $q_2 = 1$. Consumers incur transportation costs t per unit distance in addition to the price p^i . Competition affects the leader's investments positively and the laggard's negatively, as depicted in Figure 4.¹²

¹²We assume that transportation costs are in an intermediate range where second-order conditions hold, both firms are active and all consumers buy one unit.

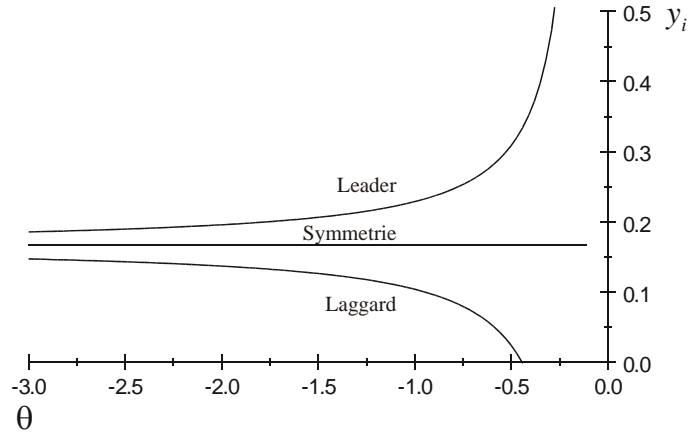


Figure 4: The effects of increasing transportation costs

3.4 Summary of the examples

The examples show that competition does not have a clear-cut effect on investment. Depending on the oligopoly model and the notion of competition, different possibilities arise.

1. Competition may reduce investments of all firms, no matter whether firms are initially symmetric or asymmetric.
2. Competition may have a U-shaped effect on investment, with negative effects of moving from very low to medium intensity of competition, but positive effects of moving from medium to high levels of competition.
3. Competition may result in more investments of leaders and less investments of laggards.

I now attempt to identify the source of these ambiguities.

4 Reduced-form comparative statics

Some familiar comparative statics results are useful in the following. Suppose for simplicity that investments are chosen from some compact subset

of the real numbers, and $\Pi^i(Y_i, Y_j; \theta)$ and $\pi^i(y_i, y_j; \theta)$ are twice continuously differentiable. Also, I assume existence and uniqueness of the equilibrium in the investment game.¹³ The relation between θ and marginal investment incentives $\frac{\partial \pi^i}{\partial y_i}$ is crucial for the effects of competition on investment. From (2), $\frac{\partial \pi^i}{\partial y_i} = \frac{\partial \Pi^i}{\partial Y_i}$, and hence $\frac{\partial^2 \pi^i}{\partial y_i \partial \theta} = \frac{\partial^2 \Pi^i}{\partial Y_i \partial \theta} \equiv \Pi_{i\theta}^i$.¹⁴ A positive sign of $\Pi_{i\theta}^i$ indicates that θ shifts out player i 's reaction curve.¹⁵ This does not guarantee that competition increases player i 's investment, but there are several different sets of additional conditions that lead to this outcome.

Proposition 1 (i) *If, for $i = 1, 2$ and $j \neq i$, $\Pi_{i\theta}^i \geq 0$ and $\Pi_{ij}^i \equiv \frac{\partial^2 \Pi^i}{\partial Y_i \partial Y_j} \geq 0$, then $y_i(\theta)$ is non-decreasing in θ for $i = 1, 2$.*

(ii) *Suppose for $i = 1, 2$ and $j \neq i$, $\pi^i(y_i, y_j; \theta)$ is concave in y_i . If near the equilibrium, the Hahn-stability condition $\pi_{ii}^i \pi_{jj}^j \geq \pi_{ij}^i \pi_{ji}^j$ holds and $\pi_{i\theta}^i \geq \frac{\pi_{ij}^i}{\pi_{jj}^j} \pi_{j\theta}^j$, then $y_i(\theta)$ is non-decreasing in θ for $i = 1, 2$.*

(iii) *Suppose, for $i = 1, 2$ and $j \neq i$, $\Pi_{i\theta}^i \geq 0$, $\pi^i(y_i, y_j; \theta)$ is symmetric and concave in y_i ; $y_i(\theta) = y_j(\theta)$ in the relevant parameter range, and the Hahn stability condition holds. Then $y_i(\theta)$ is non-decreasing in θ for $i = 1, 2$.*

Proof. (i) follows from Theorem 5 in Milgrom and Roberts (1990).

(ii) follows from total differentiation of the system of first order conditions

(iii) By (i), it suffices to consider $\pi_{ij}^i < 0$. Total differentiation of the system of first order conditions shows that a negative effect of θ on investment requires $\pi_{j\theta}^j \pi_{ij}^i < \pi_{i\theta}^i \pi_{jj}^j$. For $\pi_{ij}^i < 0$ and symmetry, this condition is incompatible with stability. ■

The supermodularity condition in (i) ($\Pi_{ij}^i \geq 0$ and hence $\pi_{ij}^i \geq 0$) implies increasing reaction functions, so that the indirect effects of competition reinforce the direct effects. Thus, competition increases both players' investments. However, there are many examples where investments are strate-

¹³The analysis can be extended easily to cases with multiple equilibria. Simple intuitive uniqueness conditions can be obtained from the requirement that one reaction function should always be steeper than the other one.

¹⁴Throughout the paper, we use subscripts to denote partial derivatives, with indices i referring to Y_i, y_i , etc.

¹⁵This is an immediate implication of a well-known comparative statics result of Topkis (1978) for the maximizer of a supermodular function, as positivity of the relevant mixed partials for differentiable functions guarantees supermodularity.

gic substitutes, so that the direct and indirect effects are countervailing.¹⁶ In such situations, part (ii) may still show that competition increases both players' investments, because supermodularity is replaced by the weaker requirement that $\pi_{i\theta}^i \geq \frac{\pi_{ij}^i}{\pi_{jj}^j} \pi_{j\theta}^j$.¹⁷ Also, part (iii) is useful for investment games with strategic substitutes when the functions π^i are symmetric.

The introductory examples show that competition may have differential impacts on the two firms. Specifically, the leader may invest more when competition increases, whereas the laggard may invest less. The following proposition is useful to identify such situations.

Proposition 2 *Suppose for some $i \in \{1, 2\}$ and $j \neq i$, the following conditions hold: (a) $\Pi_{i\theta}^i \geq 0$; (b) $\Pi_{j\theta}^j \leq 0$; (c) $\Pi_{ij}^i \leq 0$ and (d) $\Pi_{ji}^j \leq 0$. Then y_i is non-decreasing in θ and y_j is non-increasing.*

Proof. Conditions (a)-(d) imply $\pi_{i\theta}^i \geq 0$; $\pi_{j\theta}^j \leq 0$; $\pi_{ij}^i \leq 0$ and $\pi_{ji}^j \leq 0$. The result therefore follows from Theorem 5 in Milgrom and Roberts (1990) by reversing the order on the strategy space of one firm. ■

Intuitively, by (a) and (b), θ has the direct effect of increasing each firm's investment, holding the competitor's investment constant. By (c), these direct effects are mutually reinforcing: An increase of firm i 's investment reduces firm j 's marginal investment incentives and vice versa.

This section has shown that the sign of $\Pi_{i\theta}^i$ is crucial for the effects of competition on investment. With suitable qualifications, $\Pi_{i\theta}^i \geq 0$ implies that competition increases investments. I therefore now analyze this expression in detail.

5 The transmission mechanisms

The ambiguous relation between competition and investment exposed in the examples can be understood best by analyzing the different channels through

¹⁶Specifically, this is true for the examples treated in this paper. Examples where investments are strategic complements arise naturally when there are knowledge spillovers between firms (see, e.g., Leahy and Neary 1997, Halbheer et al. 2007).

¹⁷However, the result requires additional concavity and stability requirements.

which competition affects marginal investment incentives. This section identifies four such channels.

5.1 Assumptions

The demand-markup composition (1) immediately implies

$$\Pi_{i\theta}^i = D_i^i \cdot M_\theta^i + M_i^i \cdot D_\theta^i + D^i \cdot M_{i\theta}^i + M^i \cdot D_{i\theta}^i \quad (4)$$

Each term corresponds to an intuitive transmission channel. To understand each channel, additional assumptions are necessary.

(A3) $D^i(Y_i, Y_j; \theta)$ is non-decreasing in Y_i and non-increasing in Y_j , $j \neq i$.

This assumption is related to (A1) and (A2). To see this, define

$$\begin{aligned} \eta^o &\equiv \frac{\partial d^i}{\partial p^i} (p^i((Y_i, Y_j; \theta), p^j(Y_i, Y_j; \theta))) \cdot \frac{\partial p^i}{\partial Y_i} (Y_i, Y_j; \theta); \\ \eta^c &\equiv \frac{\partial d^i}{\partial p^j} (p^i((Y_i, Y_j; \theta), p^j(Y_i, Y_j; \theta))) \cdot \frac{\partial p^j}{\partial Y_i} (Y_i, Y_j; \theta). \end{aligned}$$

η^o reflects the *own-price effect* of efficiency on demand: By (A2), lower costs of firm i reduce its equilibrium price p^i and hence, by (A1) its demand D^i . η^c reflects the *competitor-price effect*: As c_i falls, the competitor's price falls by (A2), which reduces firm i 's demand D^i . As $D_i^i = \eta^o - \eta^c$, (A3) says that the own price effect dominates over the competitor price effect. Indeed, this is true in the above examples. The next assumption is slightly more problematic.

(A4) $M^i(Y_i, Y_j; \theta)$ is non-decreasing in Y_i and non-increasing in Y_j , $j \neq i$.

As $M^i(Y_i, Y_j; \theta) = p^i(Y_i, Y_j; \theta) - \bar{c} + Y_i$, the assumption states that the cost reductions are lower than the induced price reductions. This holds in many oligopoly models, but not always.¹⁸ Finally, I introduce two defining properties of the competition parameter.

¹⁸For instance, it does not hold globally in a Cournot duopoly with demand generated from CES utility functions.

(A5) $M^i(Y_i, Y_j; \theta)$ is non-increasing in θ unless $Y_i \gg Y_j$.

The notion that competition reduces mark-ups is standard. Note, however, that competition may increase the mark-up for a firm that is considerably more efficient than its competitor. With this qualification, (A5) is fulfilled in all the examples.

There is no reason to assume a general monotone relation between θ and demand. To see why, recall that

$$D^i(Y_i, Y_j; \theta) = d^i(p^i(Y_i, Y_j; \theta), p^j(Y_i, Y_j; \theta), \theta).$$

θ has a direct demand effect, captured by d_θ^i , and indirect price-induced effects. Competition reduces own equilibrium prices p^i , which affects demand positively, but it also reduces firm j 's prices, which affects own demand negatively. Finally, the direct effect, d_θ^i , can be negative. Thus, equilibrium demand may rise or fall as competition increases. Moreover, competition may have differential impacts on the demand of leaders and laggards. For instance, in the Hotelling model, increasing competition increases the leader's demand and reduces the laggard's. Next, note that $D_{i\theta}^i = \frac{\partial}{\partial \theta}(\eta^o - \eta^c)$. Clearly, η^c , the demand effect of higher efficiency that results from lower competitor prices, is small for soft competition, so that η^c should increase in θ . Indeed, the examples below confirm this. However, η^o is more likely to increase in θ : Part of the effect of higher efficiency on own demand that is induced by lower own prices comes from a business-stealing effect that is absent with weak competition. The examples suggest that the own price effect dominates over the competitor price effect. This leads to the following assumption.

(A6) $D_{i\theta}^i \geq 0$.

5.2 The influence channels

The preceding discussion helps to sign the four terms in Decomposition (4).

5.2.1 The absolute markup effect

The first term in (4), $D_i^i \cdot M_\theta^i$, reflects the *absolute markup effect* of competition: By (A3), investment has a positive demand effect, D_i^i . Also, by (A5),

M_θ^i is negative except when firm i is much more efficient than the laggard. In words, as competition becomes more intense, mark-ups decrease, so that the positive effect of expanding demand falls.

5.2.2 The absolute demand effect

The second term, $M_i^i \cdot D_\theta^i$, reflects the *absolute demand effect* of competition: By (A5), investment has a positive markup effect, M_i^i . Whether this effect increases with competition depends on the sign of D_θ^i . Thus, the absolute demand effect of competition can be positive or negative.

5.2.3 The cost-pass-through effect

The third term, $D^i \cdot M_{i\theta}^i$, reflects the *cost-pass-through effect* of competition. Because $M_{i\theta}^i = p_{i\theta}^i$, the sign of the cost-pass-through effect is positive if and only if $p_{i\theta}^i \geq 0$, that is, competition reduces the sensitivity of equilibrium prices to costs. Intuition suggests that the strategic interaction of firms in the product market stage may influence $p_{i\theta}^i$. For instance, compare situations where products are strongly differentiated, so that firms are essentially monopolists, with situations with virtually homogeneous goods. In the latter case, under Cournot competition (with strategic substitutes), higher efficiency of a firm induces it to increase its output, resulting in an output reduction of the competitor. Compared to the case of strong differentiation with little competitive interaction, this output reduction dampens the price-reducing effect of greater efficiency. Thus, $|p^i|$ should decline with intense competition, and the cost-pass-through effect should be positive. Under price competition, however, more efficient firms have lower prices, leading to lower prices of the competitor. This output reduction enhances the price-reducing effect of greater efficiency. Thus, compared to the case with little product differentiation where such considerations play no role, one should expect $|p^i|$ to increase. Thus, the cost-pass-through effect should be negative. Section 6 will show that this intuition is correct. Therefore, the cost-pass-through effect is ambiguous.

5.2.4 The demand-sensitivity effect

The fourth term, $M^i \cdot D_{i\theta}^i = M^i \cdot \frac{\partial}{\partial \theta} (\eta^c - \eta^0)$, contains $\eta^c - \eta^0$, which aggregates the own-price effect and the competitor-price effect of higher efficiency on demand. It thus reflects the *demand-sensitivity effect* of competition. Under (A7), the demand-sensitivity effect is positive.

5.2.5 Summary

The analysis in this section suggests why the effects of increasing competition on investment are not clear-cut. The effect of competition on marginal investment incentives, $\Pi_{i\theta}^i$, consists of the four components just discussed. The absolute mark-up effect is negative, whereas the demand-sensitivity effect is positive. The absolute demand effect may be positive or negative; in particular, its sign may differ for leaders and laggards. Similarly, the cost-pass-through effect can be positive or negative.

6 Interpreting the Examples

I now interpret our four introductory examples in view of the preceding analysis. The appendix contains equilibrium demands and markups, from which all claims can easily be derived.

6.1 Example 1

In the homogeneous Cournot example with $D(p) = a - p$ and $\theta = -a$, $D_i^i = M_i^i = \frac{2}{3}$; $D_\theta^i = M_\theta^i = -\frac{1}{3}$. Thus, in line with (A5), the absolute markup effect is negative. Reflecting the specific functional forms, the absolute demand effect is identical to the absolute markup effect and thus negative. Finally, as $D_{i\theta}^i = M_{i\theta}^i = 0$, the marginal effect of competition on investment is fully determined by the negative absolute demand and mark-up effects.

6.2 Example 2

Next, return to the differentiated goods case of Section 3.2.

6.2.1 Quantity Competition

In the Cournot case, $D_i^i = M_i^i > 0$. $D_\theta^i = M_\theta^i$ is negative unless firm i has a very strong lead; $\frac{Y_i}{Y_j} > \frac{4+\theta^2}{4\theta} (> 1.25)$. Thus, quite generally, absolute demand and markup effects are negative.¹⁹ As $D_{i\theta}^i = M_{i\theta}^i > 0$, the remaining effects are positive. Hence, the U-shaped relation between competition and investment for all firms except strong laggards reflects the interplay between the negative absolute demand and markup effects and the positive cost-pass-through and demand-sensitivity effects.²⁰

6.2.2 Price Competition

In the Bertrand example, simple calculations show that $D_i^i > 0$; $M_i^i > 0$; $M_\theta^i < 0$; $D_{i\theta}^i > 0$; $M_{i\theta}^i < 0$. Further, under symmetry $D_\theta^i > 0$ if $\theta > 0.5$.²¹ Thus, even though competition affects investments negatively, the economic logic differs from Example 1. There, decreasing market size had negative absolute demand and markup effects, and the remaining effects were zero. In the present example, substitutability has a negative effect on investments in spite of countervailing underlying effects. While the absolute markup effect and the cost-pass-through effect are both negative, the demand-sensitivity effect is always positive and the absolute demand effect is positive for intense competition. The fact that investments are U-shaped rather than decreasing for leaders reflects the absolute demand effect, which is more likely to be positive for leaders.

The demand-markup composition also explains why increasing competition has a more positive effect in the Cournot case than in the Bertrand case. Under Bertrand competition, as product differentiation decreases, firms have to bear in mind that efficiency improvements trigger lower competitor prices (from which $M_{i\theta}^i < 0$), whereas, for Cournot competition, efficiency improvements induce a desirable reactions of the competitor, namely lower quantities (from which $M_{i\theta}^i > 0$).

¹⁹The fact that the markup effect becomes positive for strong leaders is the reason behind the qualification in (A5).

²⁰Firms that lag far behind have a small markup, so that the positive demand-sensitivity effect ($M^i D_{i\theta}^i$) is small.

²¹More generally, $\frac{Y_i}{Y_j}$ has to be above a critical level that is a suitable function of θ .

6.3 Example 3

Next, reconsider the Hotelling duopoly with $\theta = -t$. Simple calculations show that $M_\theta^i < 0$; $D_i^i > 0$; $M_i^i > 0$; $D_{i\theta}^i > 0$; $M_{i\theta}^i = 0$. Crucially, $D_\theta^i > 0$ if and only if i is a leader; hence the same is true of the absolute demand effect. The remaining two non-zero effects, the positive demand-sensitivity effect and the negative absolute markup effect, happen to sum up to a positive effect for leaders, a negative effect for laggards, and they cancel out in the symmetric case. As a result, the sign of $\Pi_{i\theta}^i$ is determined by whether a firm is leader or laggard. Finally, it is straightforward to show that $\Pi_{ij}^i < 0$. Therefore, Proposition 2 can explain the differential impact of competition on the investments of the two firms: Intuitively, increasing θ has the direct effect that it raises the leader's investment incentives and reduces those of the laggard. By strategic substitutability, both effects are mutually reinforcing.

7 Additional examples

I now sketch some examples that have not been mentioned in Section 3.

7.1 Differentiated goods (modified demand functions)

In the examples of Section 3.2, the parameter $\theta = b$ not only increases substitutability; in addition, it shifts out both demand functions.²² This tends to reduce the competition-enhancing effect of θ . An inverse demand function without this property is

$$p^i(q_i, q_j; \theta) = 1 - \frac{1}{1 + \theta}q_i - \frac{\theta}{1 + \theta}q_j. \quad (5)$$

It can be shown that, in the Cournot case, competition has positive effects on investments for this demand function, except for firms that are lagging far behind; in which case the relation may be inverted-U shaped or even negative. In the Bertrand case, the effect of competition on investment also tends to be more positive (positive rather than U-shaped for leaders, inverted

²²Again, the appendix provides equilibrium demand and markup.

U-shaped rather than negative for symmetric firms or laggards). The main reason behind this more positive effect of competition on investment than for demand functions (3) is that the absolute demand effect is now unambiguously positive.

7.2 Cournot vs. Bertrand

Our framework can be adapted to understand how switching from Cournot competition to Bertrand competition affects investments. To this end, reconsider the two differentiated goods examples of Section 3. Let $\theta \in \{0, 1\}$ parametrize the nature of competitive interaction, with $\theta = 0$ for Cournot and $\theta = 1$ for Bertrand. Even though θ does not affect demand functions $d^i(p^i, p^j)$, it affects equilibrium demands, markups and profits. Therefore, the terms $D^i(Y_i, Y_j; \theta)$, $M^i(Y_i, Y_j; \theta)$, $\Pi^i(Y_i, Y_j; \theta)$ still make sense.

Figure 5 plots the investments in one diagram for $c_1^0 = c_2^0 = 0.5$. The U-shaped curve corresponds to Cournot competition; the decreasing curve to Bertrand. Investments are thus always higher for soft (Cournot) competition, though the difference approaches zero as b does.

The downward-sloping line in Figure 5 plots the investments for $k = 1$ and $Y = 1$ and the parameter region where the second-order condition holds ($b < 0.933$), which excludes situations with almost homogeneous goods.²³

What lies behind this clear negative effect of competitive intensity on investments? The obvious analogue of the procedure described in Section 5 is to compare $\Pi_i^i = D^i M_i^i + M^i D_i^i$ for $\theta = 0$ and $\theta = 1$. The absolute demand (markup) effect is positive if $D^i(M^i)$ is greater in the Bertrand case than in the Cournot case. Similarly, the cost-pass-through (demand-sensitivity) effects can be obtained by comparing $M_i^i (D_i^i)$ in the Bertrand and the Cournot case. Figure 6 shows that the absolute markup effect is negative and the absolute demand effect is positive. The middle line describes equilibrium demand and markup as a function of b in the Cournot case. The upper line describes equilibrium demand in the Bertrand case, which is higher than for Cournot; hence the positive absolute demand effect of increasing competition.

²³The U-shaped line corresponds to the symmetric Cournot case (see Figure 2).

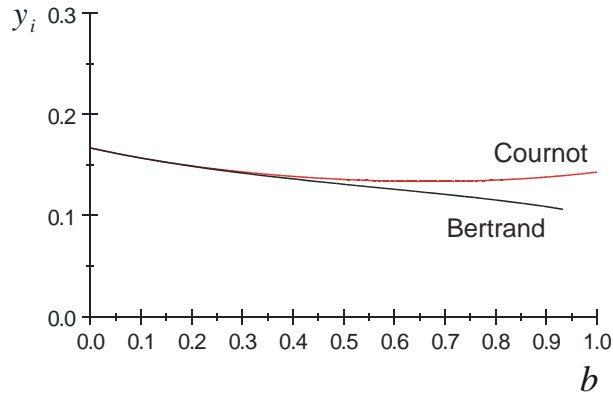


Figure 5: Cournot vs. Bertrand competition

The lower line describes equilibrium markup in the Bertrand case, which is lower than the markup for Cournot; hence the negative markup effect.

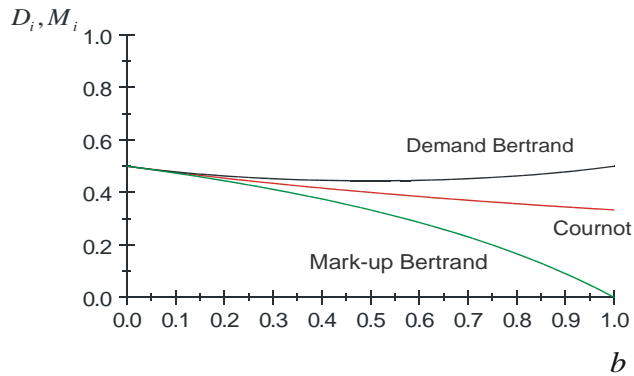


Figure 6: Cournot vs. Bertrand: Absolute demand and markup effects

Figure 7 has a similar interpretation. Thus the demand-sensitivity effect is positive, whereas the cost-pass-through effect is negative.

Summing up, increasing competition by moving from Cournot to Bertrand competition has a robust negative effect on investments for two reasons. First, under Bertrand competition, the equilibrium markup is lower, which reduces the incentive to increase equilibrium demand. Second, the positive reaction of markups to increasing own efficiency is lower. However, there are

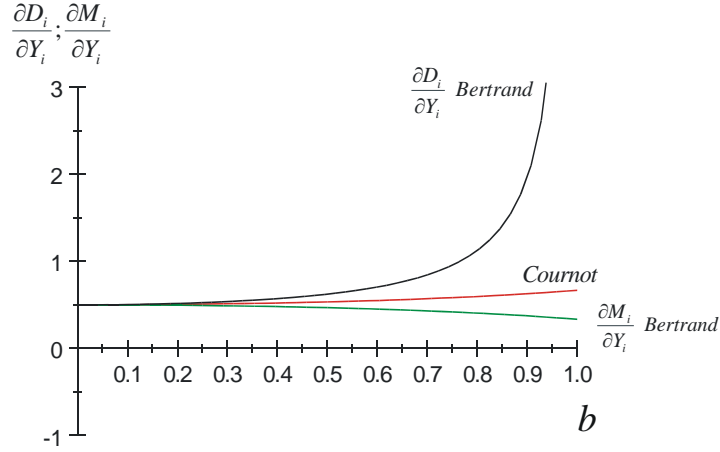


Figure 7: Cournot vs. Bertrand: Cost-pass-through and demand-sensitivity

countervailing effects: Under Bertrand competition, equilibrium demand is higher, making mark-up increases through investments more attractive. Also, the sensitivity of equilibrium demand to efficiency is higher. Nevertheless, the negative effects dominate.

8 Towards a taxonomy

Table 8 summarizes the examples.²⁴ For simplicity, it only contains the symmetric cases. In line with (A5), the absolute markup effect is always non-positive and, as required by (A6), the demand sensitivity effect is always non-negative. The absolute demand effect and the cost-pass through effect are ambiguous. Table 9 shows which combinations of absolute demand effects and cost-pass through effects arise in the different cases. In each case, the sign after the colon shows whether the marginal investment incentive is negative, positive, zero or U-shaped.²⁵

Because the absolute markup effect and the demand sensitivity effect

²⁴In the differentiated Bertrand and Cournot examples the number in brackets refers to the number of the underlying demand function.

²⁵Again, the numbers in brackets refer to the number of the underlying demand function.

	Absolute Demand	Absolute Markup	Demand Sensitivity	Cost-Pass-Through	Total Effect
Linear Cournot	-	-	0	0	-
Differentiated Cournot (3)	-	-	+	+	U
Differentiated Bertrand (3)	+	-	+	-	-
Differentiated Cournot (5)	+	-	+	+	+
Differentiated Bertrand (5)	+	-	+	-	\cap
Hotelling	0	-	+	0	0
Bertrand vs. Cournot	+	-	+	-	-

Figure 8: Summary of Examples (Symmetric Case)

point into different directions, we cannot even hope for unambiguous conclusions about the effects of competition on investment when the absolute demand effect and the cost-pass through effect have the same sign. In addition, there are several cases where the aggregate demand effect and the cost-pass-through effect have different signs, which makes a prediction about the net effect even more complicated.

Nevertheless, several observations are instructive:

1. There is no example where both the absolute demand effect and the cost-pass through effect are negative.
2. Otherwise, arbitrary combinations of the two effects can arise.

When asymmetries are allowed, some modifications are necessary. For instance, in the differentiated Bertrand example from Section 3.2, both the

Cost-Pass-Through → Absolute Demand ↓	negative	zero	positive
negative		Hom. Cournot : -	Diff. Cournot (3): -
zero		Hotelling: 0	
positive	Diff. Bertrand (3): - Bertrand vs. Cournot: - Diff. Bertrand (5): \cap		Diff. Cournot (5): +

Figure 9: Taxonomy of Examples (Symmetric Case)

cost-pass-through and the absolute demand effect are negative for laggards. On a related note, compared to the symmetric case, the investment effects of competition tend to be higher for leaders and lower for laggards. The clearest reason behind this tendency is that the absolute demand effect is typically greater for leaders than for laggards.

9 Conclusion

The paper has clarified the channels by which competition affects investment, thus providing the basis for a taxonomy of examples. Competition reduces markups, and increases the sensitivity of equilibrium demand with respect to efficiency. The former effect suggests a negative relation between competition and investment; the latter effect would explain a positive relation. The ambiguities are confounded by the fact that competition can have positive or negative effects on equilibrium demands and on the sensitivity of prices with respect to marginal costs.

Contrary to Vives (forthcoming), I have emphasized the differential impact of competition on leaders and laggards. This suggests that it may be valuable to allow for endogenous exit decisions of firms. Firms that anticipate falling behind in an investment game may decide to exit even when they would not do so without the possibility of investment, because the investment game reinforces the asymmetry between firms. This in turn will influence the investment decisions of the relatively efficient firms who will face less com-

petitors than in the case where exit is precluded.²⁶ Related extensions of our approach would concern the effects of competition on profits and welfare. These effects would of course not only include the standard effects on prices, but also indirect effects resulting from changes in investment decisions.

10 Appendix: The Examples

10.1 Example 1: Inverse market size

In the Cournot example, define $Y_i = -c_i$, that is, $\bar{c} = 0$. Then

$$D^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) = (2Y_i - Y_j - \theta) / 3$$

The equilibrium investments can easily be calculated as

$$y_i = \frac{1}{7} (-2\theta + 8Y_i^0 - 6Y_j^0).$$

10.2 Example 2: Substitutability

10.2.1 Quantity competition

Define $Y_i = 1 - c_i$, that is, $\bar{c} = 1$. For $2Y_i \geq \theta Y_j$; $2Y_j \geq \theta Y_i$ ²⁷

$$D^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) = \frac{2Y_i - \theta Y_j}{4 - \theta^2}.$$

10.2.2 Price competition

With price competition,

$$D^i(Y_i, Y_j; \theta) = \frac{(2 - \theta^2) Y_i - \theta Y_j}{(4 - \theta^2)(1 - \theta^2)}; M^i(Y_i, Y_j; \theta) = \frac{(2 - \theta^2) Y_i - \theta Y_j}{4 - \theta^2}.$$

²⁶Obviously, such an extension would also involve moving beyond the duopoly case.

²⁷The following results are taken from Sacco and Schmutzler (work in progress).

10.3 Example 3: Transportation costs

In the Hotelling model, demand functions are given by

$$d^1(p^1, p^2; \theta) = (p^1 - p^2 + \theta) / 2\theta \text{ and } d^2(p^2, p^1; \theta) = (p^2 - p^1 + \theta) / 2\theta.$$

Defining $Y_i = -c_i$, it is straightforward to show that

$$D^i(Y_i, Y_j; \theta) = (Y_j - Y_i + 3\theta) / 6\theta; M^i(Y_i, Y_j; \theta) = (Y_i - Y_j - 3\theta) / 3.$$

Thus,

$$D_\theta^i = (Y_i - Y_j) / 6\theta^2; M_\theta^i = -1; D_i^i = -1/6\theta; M_i^i = 1/3; D_{i\theta}^i = 1/6\theta^2; M_{i\theta}^i = 0$$

Simple but tedious calculations show that equilibrium investments are

$$y_i = \frac{1}{6} + \frac{Y_j^0 - Y_i^0}{2(9\theta + 1)}.$$

10.4 Modified demand functions (Section 7.1)

With quantity competition,

$$D^i(Y_i, Y_j; \theta) = \frac{(1 + \theta)(2Y_i - \theta Y_j)}{(4 - \theta^2)}; M^i(Y_i, Y_j; \theta) = \frac{2Y_i - \theta Y_j}{4 - \theta^2}.$$

With price competition,

$$D^i(Y_i, Y_j; \theta) = \frac{(2 - \theta^2) Y_i - \theta Y_j}{(4 - \theta^2)(1 - \theta)}; M^i(Y_i, Y_j; \theta) = \frac{(2 - \theta^2) Y_i - \theta Y_j}{4 - \theta^2}.$$

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