The effects of competition on investment – Towards a taxonomy

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Abstract: Using a general two-stage framework, this paper gives sufficient conditions for increasing competition to have negative or positive effects on R&D-investment, respectively. Both possibilities arise in plausible situations, even if one uses relatively narrow concepts of increasing competition. The paper also shows that competition is more likely to increase the investments of leaders than those of laggards. When R&D-spillovers are strong, competition is less likely to increase investments. The paper also identifies conditions under which low initial levels of competition make a positive effects of competition on investment more likely.

Keywords: competition, investment, cost reduction

JEL: L13, L20, L22

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1 Introduction

Even though economists have been trying to understand the effects of the intensity of competition on R&D-investment for decades, the issue remains unsettled. While some authors argue that competitive pressure is essential to induce R&D-investments, 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, investments can be increasing or decreasing functions of competitive intensity.[1]

Assessing what lies behind the different predictions is extremely difficult, because most models rely on specific functional forms. In the following, I will therefore take an entirely different approach. Rather than focusing on specific examples, I will provide a general framework that allows searching for robust predictions, because it captures many different notions of increasing intensity of competition and different types of oligopolistic interaction. To reveal the economic effects in the most transparent fashion, I opted for simplicity in other respects: The game has two stages, with cost-reducing investment followed by product market competition. In most of the paper, I will consider a duopoly.[2] One firm (the *leader*) may be exogenously more efficient than the other one (the *laggard*), that is, it may have lower marginal costs. The initial efficiency levels and the cost-reducing investments determine the efficiency Y_i in the product market stage. Together with a competition parameter θ, the efficiency levels determine the demand $D^i(Y_i, Y_j; \theta)$ and the markup $M^i(Y_i, Y_j; \theta)$ of each firm in product market equilibrium, and hence the gross profit $\Pi^i = D^i \cdot M^i$. By assumption, and in line with many examples higher own efficiency increases both components of a firm's profit: Lower marginal costs lead to lower demand and markup.

The framework covers many familiar cases. In particular, the competition

[1] For 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)

[2] Generalizations of most results to more than two firms are possible at the cost of additional notation.

parameter can be interpreted quite broadly. It does not necessarily refer to a competition *policy* parameter, but more generally to some parameter of the market environment capturing the intensity of competition.[3] Examples include a homogeneous linear Cournot model where θ is the negative of market size; a Hotelling model where θ is the inverse of transportation costs; differentiated linear Cournot or Bertrand models where θ corresponds inversely to the extent of horizontal product differentiation, as captured for instance by the demand functions of Shubik and Levitan (1980) or Singh and Vives (1984). θ may also capture a shift from Cournot to Bertrand competition or an increase in the number of firms for an otherwise given environment. The framework also covers cases with and without spillovers.

Our defining assumptions on the competition parameter θ are inspired by two common properties of these examples (and many others). First, the mark-up M^i of each firm in the product market equilibrium decreases with θ; competition thus has a negative *markup effect*.[4] Second, the *demand sensitivity effect* $D^i_{i\theta} \equiv \frac{\partial^2 D^i}{\partial Y_i \partial \theta}$ is non-negative: The positive effect of greater efficiency on equilibrium demand ($D^i_i \equiv \frac{\partial D^i}{\partial Y_i}$) weakly increases with competition θ.[5]

In this framework, I give sufficent conditions for the effects of competition on investment to be positive and negative, respectively. I also provide conditions under which competition increases the investments of some firms (e.g., leaders) and decreases those of others (e.g., laggards). The analysis shows that there are very natural situations in which each possibility arises, each corresponding to a clear economic intuition. Thus, searching for a general relation between competition and investment is in vain.

However, the conditions derived help to uncover the circumstances under which competition is more likely to have a positive or negative effect on a firm. Based on the general model and the set of examples, the following insights emerge. First, quite generally, competition is more likely to have a positive effect on leaders than on laggards, and the effect on laggards is

[3] See Boone (2000) and Vives (forthcoming) for comparable approaches.

[4] Boone (2000) 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.

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

quite robustly negative.[6] Second, when investments have higher spillovers, competition is more likely to reduce investments. Third, an inverse U-shaped relation between competition and investment is not necessarily more likely than a U-shaped relation.

On a related note, one may argue that the approach presented here is simply too general, and that "natural" restrictions on the class of parameterizations might lead to more conclusive results. I show that this is not the case for two plausible candidates. First, if one identifies "increasing competition" quite narrowly with decreasing product differentiation, the possibility of negative and positive effects still arises, even for symmetric firms. Second, even if competition has an unambiguously positive effect on equilibrium demand $\left(D^i_\theta \equiv \frac{\partial D^i}{\partial \theta} \geq 0\right)$,which works towards a positive effect on investment,[7] it is not necessarily the case that competition increases investments. However, a more definite result can be obtained if one moves beyond the duopoly framework and identifies increasing competition with an increase in the number of firms. Then, there are strong forces suggesting a negative effect on per-firm investment.

The most closely related paper is Vives (forthcoming) who also considers the effects of competition on cost-reducing investments in general two-stage games. Vives arrives at more definite conclusions, suggesting that positive effects arise quite generally. Several reasons explain these different findings. First, Vives does not consider initial asymmetries, so that the robust negative effect of competition on laggards does not show up there. Second, Vives confines himself to product differentiation parameters. Third, even when increasing competition refers to lower product differentiation, there is at least one example where increasing competition has a negative effect on investment in non-degenerate parameter regions even for symmetric firms.[8]

[6] This is related to, but not identical, to the concept of weak increasing dominance, which requires that leaders invest more than laggards (Cabral and Riordan 1994, Athey and Schmutzler 2001, Cabral 2002, 2008): I am arguing that increasing competition works in favor of increasing difference.

[7] Inutitively, if competition leads to higher demand per firm, it becomes more attractive to increase markups by becoming more efficient.

[8] Importantly, 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.

In a broader sense, the paper is related to Fudenberg and Tirole (1984) and Bulow et al. (1985). These papers also consider classes of two-stage investment games, and they identify general properties of the strategic interaction guaranteeing that strategic considerations have a positive or negative effect on investment.

The paper is organized as follows. Section 2 introduces the analytical framework. Section 3 provides comparative statics results. Section 4 applies these results to familiar examples. Section 5 uses the general results and the examples to clarify under which circumstances a positive effect of competition is likely. Section 6 contains the extensions and Section 7 concludes.

2 Set-up

I shall consider the following 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 cost $c_i = \overline{c} - Y_i^0$ for some exogenous level $\overline{c}$ of marginal costs.[9] In the first stage, given (Y_1^0, Y_2^0), each firm chooses its investment y_i. In the second stage, firm i has marginal costs $c_i = \overline{c} - Y_i$, where $Y_i = Y_i^0 + y_i + \lambda y_j$ is the efficiency level after the investment stage and $\lambda \in [0, 1]$ is a spillover parameter. 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 $p^i(Y_i, Y_j; \theta)$.[10] The following quantities are thus well defined:

1. Equilibrium mark-ups $M^i(Y_i, Y_j; \theta) \equiv p^i(Y_i, Y_j; \theta) - \overline{c} + Y_i$
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 $\Pi^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) \cdot D^i(Y_i, Y_j; \theta)$

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

[10] When firms choose outputs rather than prices, $p_i(Y_i, Y_j; \theta)$ denotes the market clearing price for equilibrium outputs.

I will maintain the following assumptions throughout, all of which hold in the examples to be discussed in Section 3 below.

(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. Because the product market game has a unique equilibrium, the investment game reduces to a one stage game with payoff functions

$$\pi^i(y_i, y_j; \theta) = \Pi^i\left(Y_i^0 + y_i + \lambda y_j, Y_j^0 + y_j + \lambda y_i; \theta\right) - K(y_i). \qquad (1)$$

(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

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

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 all our 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 $M^i(Y_i, Y_j; \theta) = p^i(Y_i, Y_j; \theta) - \overline{c} + Y_i$, the first part of the assumption states that the cost reductions are larger than the induced price reductions. This holds in many, but not all, oligopoly models.[11] Finally, I introduce two defining properties of the competition parameter.

[11] For 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 $Y_i >> Y_j$.

The notion that competition reduces mark-ups is standard.[12] However, the relation between θ and demand is less clear. To see why, note that

$$\frac{\partial D_i}{\partial \theta} = \frac{\partial d_i}{\partial p_i}\frac{\partial p_i}{\partial \theta} + \frac{\partial d_i}{\partial p_j}\frac{\partial p_j}{\partial \theta} + \frac{\partial d_i}{\partial \theta}.$$

If the own price effect dominates over the competitor price effect, the first two terms are positive. However, the direct effect d_θ^i can be negative, potentially compensating the price-induced effects. Thus, equilibrium demand may rise or fall as competition increases. Moreover, as we will see below, competition may have differential impacts on the demand of leaders and laggards.

Next, consider $D_{i\theta}^i = \frac{\partial}{\partial \theta}(\eta^o + \eta^c)$. Clearly, $|\eta^c|$, the demand effect of higher efficiency resulting from lower competitor prices, is small for soft competition, suggesting a negative effect of θ on η^c. 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. In all examples, the own price effect dominates over the competitor price effect. This motivates the following assumption.

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

3 General comparative statics results

I will now provide general results about the effects of competition on investment. Assumptions (A1)-(A6) are not necessary to derive the results, but they are essential for the interpretation. I will suppose for simplicity that investments are chosen from some compact subset of the reals, 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.

[12] 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.

The following results shows that the properties of $\pi^i_{i\theta} \equiv \frac{\partial^2 \pi^i}{\partial y_i \partial \theta}$ are essential for comparative statics. When $\pi^i_{i\theta} > 0$, θ shifts out player i's reaction curve.[13] 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 *$y_i(\theta)$ is non-decreasing in θ for $i = 1, 2$ if, for $i = 1, 2$ and $j \neq i$, one of the following conditions holds:*
(i) $\pi^i_{i\theta} \geq 0$ and $\pi^i_{ij} \equiv \frac{\partial^2 \pi^i}{\partial y_i \partial y_j} \geq 0$.
(ii) $\pi^i(y_i, y_j; \theta)$ is concave in y_i. Near the equilibrium, $\pi^i_{i\theta} \geq \frac{\pi^i_{ij}}{\pi^j_{jj}} \pi^j_{j\theta}$, and the Hahn-stability condition $\pi^i_{ii}\pi^j_{jj} \geq \pi^i_{ij}\pi^j_{ji}$ holds.
(iii) $\pi^i_{i\theta} \geq 0$, $\pi^i(y_i, y_j; \theta)$ is symmetric and concave in y_i; $y_i(\theta) = y_j(\theta)$ in the relevant parameter range, and the Hahn stability condition holds.

Proof. (i) follows from Theorem 5 in Milgrom and Roberts (1990).[14]
(ii) follows from total differentiation of the system of first order conditions.
(iii) By (i), it suffices to consider $\pi^i_{ij} < 0$. Total differentiation of the system of first order conditions shows that a negative effect of θ on investment requires $\pi^j_{j\theta}\pi^i_{ij} < \pi^i_{i\theta}\pi^j_{jj}$, and therefore, using symmetry $\pi^i_{ij} < \pi^j_{jj}$. For $\pi^i_{ij} < 0$ and symmetry, this condition is incompatible with stability. ■

Importantly, by switching the signs in the inequalities $\pi^i_{i\theta} \geq 0$ and $\pi^i_{i\theta} \geq \frac{\pi^i_{ij}}{\pi^j_{jj}} \pi^j_{j\theta}$ in (i) - (iii), one arrives at sufficient conditions for competition to have negative effects on investment. Also, for the benchmark case without spillovers ($\lambda = 0$), $\pi^i_{i\theta} = \Pi^i_{i\theta} \equiv \frac{\partial^2 \Pi^i}{\partial Y_i \partial \theta}$, whereas, with positive spillovers $\pi^i_{i\theta} = \Pi^i_{i\theta} + \lambda \Pi^i_{j\theta}$. Either way, the conditions of the theorem reflect properties of the gross profit function Π^i that are independent of investment costs.

To understand (i), recall that $\pi^i_{i\theta} \geq 0$ implies that reaction functions shift out as θ increases. The supermodularity condition in (i), $\pi^i_{ij} = \Pi^i_{ij} \geq 0$, implies increasing reaction functions, so that the indirect effects of competition reinforce the direct effects. Thus, competition increases both players'

[13] This follows from 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.

[14] This theorem is a comparative-statics result for supermodular games.

investments. However, unless spillovers are sufficiently large, investments are typically strategic substitutes, so that the direct and indirect effects are countervailing.[15] Even then, part (ii) may still show that competition increases both players' investments, because supermodularity is replaced by the weaker requirement that $\pi^i_{i\theta} \geq \frac{\pi^i_{ij}}{\pi^j_{jj}} \pi^j_{j\theta}$.[16] Also, part (iii) is applicable to investment games with strategic substitutes as long as the functions π^i are symmetric.

The following proposition is useful to identify such situations where competition increases the investments of one firm and decreases those of the other one, which will be shown to arise naturally when one firm is the leader and the other firm is the laggard.

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

Proof. Conditions (a)-(d) imply $\pi^i_{i\theta} \geq 0$; $\pi^j_{j\theta} \leq 0$; $\pi^i_{ij} \leq 0$ and $\pi^j_{ji} \leq 0$. 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 firm i's investment and reducing the investment of firm j. By (c) and (d), these direct effects are mutually reinforcing: An increase of firm i's investment reduces firm j's marginal investment incentives and vice versa.

As $\Pi^i = D^i \cdot M^i$, Proposition 1 implies the following result:

Corollary 1 *Suppose for $i = 1, ..., I$,*

$$\Pi^i_{i\theta} = D^i_i \cdot M^i_\theta + M^i \cdot D^i_{i\theta} + M^i_i \cdot D^i_\theta + D^i \cdot M^i_{i\theta} \tag{2}$$

[15] Specifically, this is true for the linear examples treated in this paper. To understand this, note that $\Pi^i_{ij} = D^i_i \cdot M^i_j + M^i_i \cdot D^i_j + M^i \cdot D^i_{ij} + D^i \cdot M^i_{ij}$. With linearity, the last two terms disappear. The first two terms are typically negative, because of (A3) and the natural assumption that $D^i_j < 0$ and $M^i_j < 0$: If competitors invest a lot, own markups and demands fall. This reduces the benefits from increasing own demands and markups by becoming more efficient.

[16] However, the result requires additional concavity and stability requirements.

is sufficiently large (small). Then $y_i(\theta)$ *is non-decreasing (non-increasing) in* θ *for* $i = 1, ..., I$.

Here, "sufficiently large" reduces to "positive" for symmetric firms and for games with strategic complementarities. For other games, "sufficiently large" means that expression (2) must be greater than $\frac{\pi^i_{ij}}{\pi^j_{jj}}\pi^j_{j\theta}$, which is positive. In spite of its simplicity, the corollary, and, in particular, the decomposition (2) is crucial to understand when competition has positive effects on investments, I investigate each term in (2) separately.

The first term in (2), $D^i_i \cdot M^i_\theta$, reflects the *markup effect* of competition: By (A3), investment has a positive demand effect, D^i_i. Also, by (A5), M^i_θ is negative except when firm i is much more efficient than the laggard. In words, as competition increases, mark-ups decrease, so that the positive effect of expanding demand on profits falls. The second term, $M^i_i \cdot D^i_\theta$, reflects the *demand effect* of competition: By (A5), investment has a positive markup effect, M^i_i. If $D^i_\theta > 0$ the demand effect of competition on marginal investment incentives is positive, if $D^i_\theta < 0$, it is negative. The third term, $D^i \cdot M^i_{i\theta}$, reflects the *cost-pass-through effect* of competition. Because $M^i_{i\theta} = p^i_{i\theta}$, the sign of the cost-pass-through effect is positive if and only if $p^i_{i\theta} \geq 0$, that is, competition reduces the sensitivity of equilibrium prices to costs. The examples below will show that the cost-pass-through effect is ambiguous, depending on whether firms compete à la Bertrand or à la Cournot. The fourth term, $M^i \cdot D^i_{i\theta} = M^i \cdot \frac{\partial}{\partial\theta}(\eta^c + \eta^o)$, contains $\eta^c + \eta^o$, 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 (A6), the demand-sensitivity effect is positive: As θ increases, demand reacts more strongly to efficiency, which enhances the incentive to invest.

Summing up, the analysis in this section suggests why more intense competition does not have clear-cut effects on investment. The effect of competition on marginal investment incentives, $\Pi^i_{i\theta}$, consists of the four transmission channels just discussed. The mark-up effect is negative, whereas the demand-sensitivity effect is positive. The demand effect and the cost-pass-through effect can be positive or negative.

4 Examples

The following examples will further qualify when competition has positive or negative effects. Several of these examples are well-known, but they nevertheless are useful to identify the four transmission channels. Whenever I calculate equilibrium investment levels explicitly, the investment cost function is $K(y_i) = y_i^2$; importantly, however, the comparative statics also hold for more general cost functions.

4.1 Inverse market size

Suppose firms are Cournot competitors, with homogeneous goods and market demand $D(p) = a - p$ for some $a > 0$, and constant marginal costs c_i. Define $\theta = -a$. Hence, more intense competition corresponds to smaller demand.[17] Defining $Y_i = -c_i$,

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

Equilibrium investments can easily be calculated as

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

The effect of increasing competition on investments is thus negative. To see the economic logic behind this, note that $D_i^i = M_i^i = \frac{2}{3}$; $D_\theta^i = M_\theta^i = -\frac{1}{3}$. Thus, in line with (A5), the markup effect is negative. Reflecting the specific functional forms, the demand effect is identical to the 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. Thus, by Proposition 1 the effect of competition on investments is negative (independent of the investment cost function).

[17] Boone (2007) also treats inverse market size as a competition parameter; however, as laid out in footnote , there are reasons why one might not want to do this.

4.2 Substitutability (Shubik-Levitan)

In a market with differentiated goods, let inverse demands be

$$p^i(q_i, q_j) = 1 - q_i - bq_j, \tag{3}$$

where $0 \leq b \leq 1$ (Shubik and Levitan 1980). 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. Higher b corresponds to better substitutability. Thus, define $\theta = b$.

4.2.1 Quantity competition

The middle line in Figure 1 plots investments as a function of the competition parameter for $c_1^0 = c_2^0 = 0.5$.[18] 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.

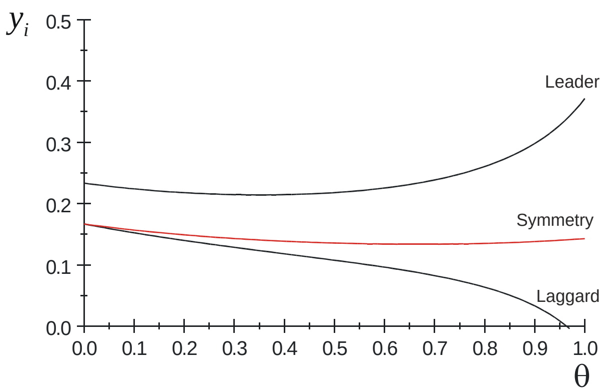

Figure 1: Differentiated Cournot competition

With small heterogeneities between firms, the qualitative pattern is similar: Competition has a U-shaped effects on leaders and laggards.[19] For firms

[18]The results for the Cournot case are taken from Sacco (2008).

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

that lag far behind, however, the effects of competition on investment are negative. For instance, the respective lines in Figure 1 plot the relation between competition and investments for $c_1^0 = 0.3$; $c_2^0 = 0.7$ for leaders (laggards). To understand this pattern, note (see Appendix) that $D_i^i = M_i^i > 0$. $D_\theta^i = M_\theta^i$ 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.[20] 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 demand and markup effects and the positive cost-pass-through and demand-sensitivity effects:[21] Starting from low competition, greater competition, by reducing demands and markups, reduces incentives to increase efficiency. Beyond a certain threshhold, the effect of competition on investment is determined by the positive demand-sensitivity and markup effects. The unambiguously negative effect for firms that are lagging far behind results because their markup and hence the positive demand-sensitivity effect $M^i D_{i\theta}^i$ is small.[22] Therefore, the negative demand and markup effects dominate.

4.2.2 Price competition

Figure 2 plots investments for price competition, with the same initial costs as in Figure 1.[23] Investments decrease with competition when firms are neck-to-neck or laggards, but for the leader they increase as competition becomes very intense.

Hence, even though the fundamentals (demand and technology) are the same as for quantity competition, competition has a strictly negative effect except for strong leaders, for whom the relations is U-shaped. Simple calculations (see Appendix) show that $D_i^i > 0$; $M_i^i > 0$; $M_\theta^i < 0$; $D_{i\theta}^i > 0$;

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

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

[22] By the same token, they have low demand, so that the positive cost-pass-through effect $D^i M_{i\theta}^i$ is small.

[23] Note that, even in the symmetric case, the eqilibria become asymmetric as θ approaches 1.

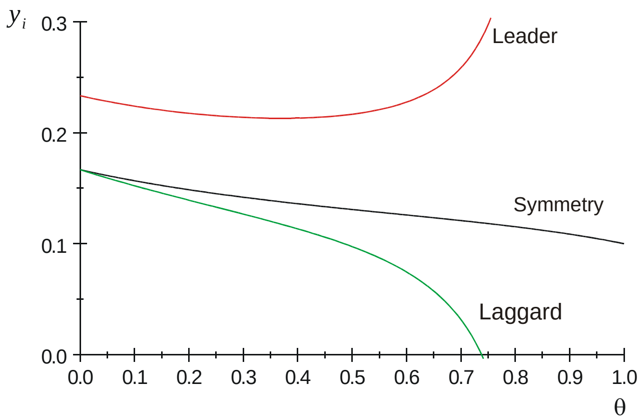

Figure 2: Differentiated Bertrand Competition

$M^i_{i\theta} < 0$. Further, under symmetry $D^i_\theta > 0$ if $\theta > 0.5$.[24] Thus, even though competition affects investments negatively, the economic logic differs from Section 4.1. There, decreasing market size had negative absolute demand and markup effects, and the remaining effects were zero. Here, substitutability has a negative effect on investments in spite of countervailing underlying effects. While the markup effect and the cost-pass-through effect are both negative, the demand-sensitivity effect is always positive and the demand effect is positive for intense competition. The U-shaped rather than decreasing investment function for leaders reflects the fact that the demand effect is more likely to be positive for leaders.

To understand why reducing product differentiation has a more positive effect in the Cournot case than in the Bertrand case, note that $M^i_{i\theta} > 0$ for Cournot competition, whereas $M^i_{i\theta} < 0$ for Bertrand competition. To see why, compare situations where products are essentially monopolists, with situations with relatively close substitutes. In the latter case, for Cournot competition, higher efficiency of a firm induces 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 $|p^i_i|$, so that the cost-pass-through effect should be positive. Under price

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

competition, however, greater efficiency induces lower prices of both firms, enhancing the price-reducing effect of greater efficiency. Thus, compared to the case with little product differentiation where such considerations play no role, cost reductions induce more substantial price reductions, so that $|p_i^i|$ should increase. Summing up, the cost-pass-through effect works towards a positive relation between competition and investment under Cournot competition, and conversely under Bertrand competition.

4.3 Substitutability (Singh-Vives)

In the examples of Section 4.2, an increase in $\theta = b$ not only increases substitutability; in addition, θ shifts both demand functions inwards, so that it mixes two sources of increasing competition. An inverse demand function without this property is

$$p^i\left(q_i, q_j; \theta\right) = 1 - \frac{1}{1+\theta} q_i - \frac{\theta}{1+\theta} q_j. \tag{4}$$

It can be shown that, in both the Bertrand and the Cournot case, investment depends positively on the substitution parameter θ for this demand function, except for firms that are lagging far behind; in which case the relation may become negative.[25] The main reason behind this more positive effect of competition on investment than in the Shubik-Levitan case is that the demand effect is now unambiguously positive (See Appendix).

4.4 Transportation costs

Next, consider a Hotelling duopoly. Consumers buy at most one unit of a homogeneous good, and are uniformly distributed on $[0, 1]$. 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

[25] Again, in the Bertrand case, a restriction on b ($b < 0.85$) is necessary for symmetric investment equilibria to exist.

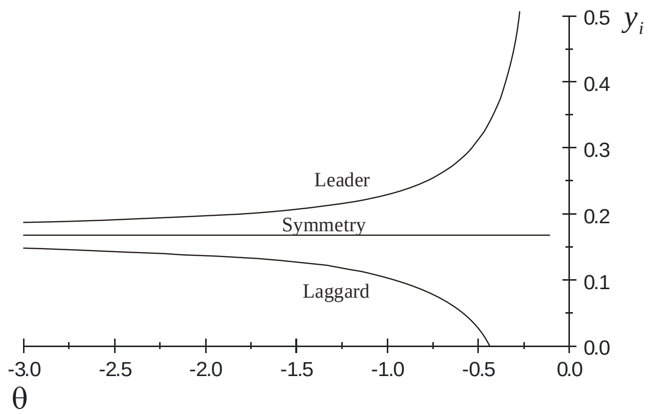

Figure 3: The effects of increasing transportation costs

3.[26] This figure is drawn for $c_1^0 = c_2^0 = 0.5$ (symmetric case), $c_1^0 = 0.3$ (leader) and $c_2^0 = 0.7$ (laggard).

Simple calculations show that $M_\theta^i < 0$; $D_i^i > 0$; $M_i^i > 0$; $D_{i\theta}^i > 0$; $M_{i\theta}^i = 0$ (See the Appendix). Crucially, $D_\theta^i > 0$ if and only if i is a leader; hence the same is true of the demand effect.[27] As a result, the sign of $\Pi_{i\theta}^i$ is determined by whether a firm is leader or laggard. Also, 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, because competition has a positive demand effect for leaders and a negative demand effect for laggards, increasing θ has the direct effect that it raises the leader's investment incentives and reduces those of the laggard. As investments are strategic substitutes, both effects are mutually reinforcing.

4.5 Cournot vs. Bertrand

Our framework can be adapted to understand how switching from Cournot competition to Bertrand competition affects investments. To this end, re-

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

[27] The remaining two non-zero effects, the positive demand-sensitivity effect and the negative 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.

consider the differentiated goods examples of Section 4.2. Let $\theta \in \{0, 1\}$, where $\theta = 0$ 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 4 plots the investments displayed in Figures 1 and 2 in one diagram for $c_1^0 = c_2^0 = 0.5$. Investments are thus always higher for soft (Cournot) competition, though the difference approaches zero as b does.[28]

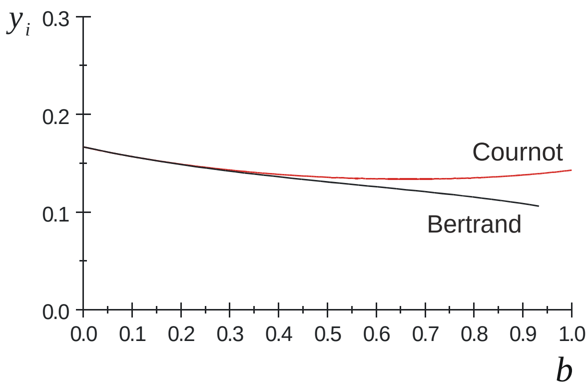

Figure 4: Cournot vs. Bertrand competition

What lies behind this clear negative effect of competitive intensity (in the sense of moving from Cournot to Bertrand competition) on investments? To understand this, we compare $\Pi_i^i = D^i M_i^i + M^i D_i^i$ for $\theta = 0$ and $\theta = 1$. In Figure 5, 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.[29] The lower line describes equilibrium markup in the Bertrand case. The figure thus shows that the markup effect is negative, that is, M^i is greater for $\theta = 0$ than for $\theta = 1$, and the demand effect is positive, that is, D^i is smaller for $\theta = 0$ than for $\theta = 1$. 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.

[28] For the Bertrand case, the figure is drawn for the parameter region where the second-order condition holds ($b < 0.933$).

[29] Recall that a symmetric equilibrium only exists for $b < 0.923$.

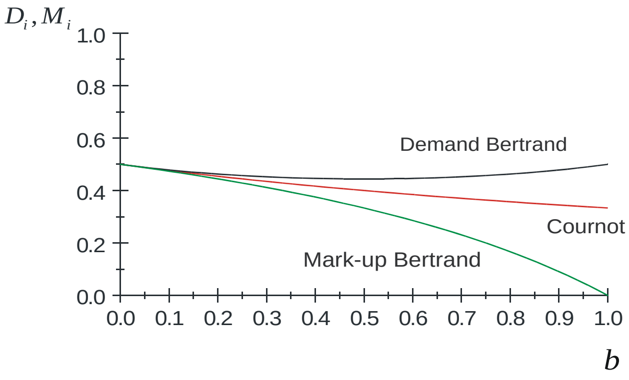

Figure 5: Cournot vs. Bertrand: Absolute demand and markup effects

Figure 6 shows that the demand-sensitivity effect is positive, whereas the cost-pass-through effect is negative.

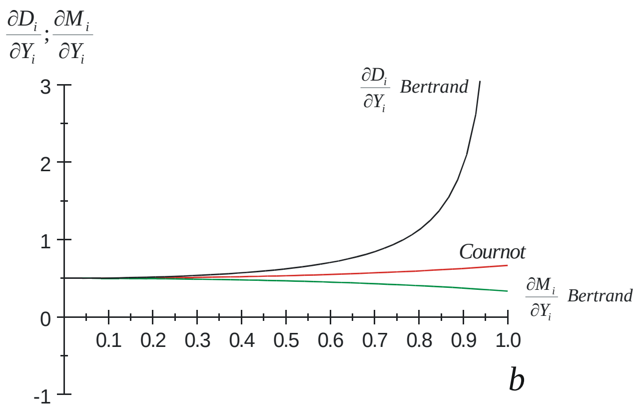

Figure 6: Cournot vs. Bertrand: Cost-pass-through and demand-sensitivity

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

4.6 Towards a taxonomy

Table 7 summarizes the examples.[30]

	Absolute Demand	Absolute Markup	Demand Sensitivity	Cost-Pass-Through	Total Effect
Linear Cournot	-	-	0	0	-
Differentiated Cournot (3)	-	-	+	+	∪
Differentiated Bertrand (3)	+	-	+	-	-
Differentiated Cournot (4)	+	-	+	+	+
Differentiated Bertrand (4)	+	-	+	-	+
Hotelling	0	-	+	0	0
Bertrand vs. Cournot	+	-	+	-	-

Figure 7: Summary of examples (Symmetric Case)

For simplicity, it only contains the symmetric cases. In line with (A5) and (A6), the markup effect is always non-positive, and the demand sensitivity effect is always non-negative, suggesting countervailing effects. The demand effect and the cost-pass through effect are ambiguous, which complicates matters further. Table 8 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.[31] Note that there is no example where both the demand effect and the cost-pass through effect are negative.[32] Otherwise, however, arbitrary combinations of the two effects arise.

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

[31] Again, the numbers in brackets refer to the number of the underlying demand function.

[32] When asymmetries are allowed, some modifications are necessary. For instance, in the differentiated Bertrand example from Section 4.2, both the cost-pass-through and the demand effect are negative for laggards.

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 (4): +		Diff. Cournot (4): +

Figure 8: Towards a taxonomy of examples

5 When does competition raise investments?

The examples show that, depending on the oligopoly model and the notion of competition, the effect on investment may be positive or negative. I now use the general approach of Section 3 and the examples to identify which factors work towards a positive or negative effect of competition. Such factors refer to firm-specific characteristics as well as market characteristics and the underlying notion of competition.

5.1 Leaders vs. laggards

In the Hotelling case, competition increases the investments of leaders and decreases those of laggards. In the Cournot example with differentiated goods (Shubik-Levitan), competition has a negative effect on strong laggards, but a U-shaped effect for leaders, symmetric firms and firms that are not lagging behind too far. With price competition, the effect is only U-shaped for strong leaders; it is negative for all other firms. With Singh-Vives demand, the effects are positive except for strong laggards. Based on the examples, we therefore obtain the following results:

Observation 1: Investment tends to have a more positive effect for leaders than for laggards; and they are robustly negative for laggards.

More generally, suppose $\Pi^i_{i\theta}$ is increasing in Y_i and decreasing in Y_j: Then, starting from the perspective of a laggard, increasing his efficiency and decreasing the efficiency of the competitor until the roles of both parties are changed, must increase his investment incentives. Indeed, $\Pi^i_{i\theta}$ is increasing in Y_i and decreasing in Y_j in all the examples. There are two reasons why increasing competition is more likely to have a positive investment effect for leaders than for laggards, and why the effect is robustly negative for laggards. Both relate to (A6). First, the positive demand sensitivity effect $M^i D^i_{i\theta}$ implied by (A6) is substantial only when markups are large – but when firms are lagging far behind, their markups are low. Second, because of (A6), D^i_θ and hence the demand effect $M^i_i D^i_\theta$ is more likely to be positive when a firm is efficient.

5.2 Spillovers

Though Section 2 applies to cases with spillovers ($\lambda > 0$), we have not treated this case in the examples. The following result suggests a tendency for spillovers to make a negative effect of competition on investments more likely.

Proposition 3 *Suppose (i) investment costs are sufficiently large and (ii)* $\frac{\partial^2 \Pi^i}{\partial Y_j \partial \theta} < 0$. *As spillovers* ($\lambda$) *increase,* $\pi^i_{i\theta}$ *falls.*

Proof. First note that

$$\frac{\partial^2 \pi^i (y_i, y_j; \theta)}{\partial y_i \partial \theta} = \frac{\partial^2 \Pi^i \left(Y_i^0 + y_i + \lambda y_j, Y_j^0 + y_j + \lambda y_i; \theta\right)}{\partial Y_i \partial \theta} + \lambda \frac{\partial^2 \Pi^i \left(Y_i^0 + y_i + \lambda y_j, Y_j^0 + y_j + \lambda y_i; \theta\right)}{\partial Y_j \partial \theta}.$$

Therefore,

$$\frac{\partial^3 \pi^i (y_i, y_j; \theta)}{\partial y_i \partial \theta \partial \lambda} = \frac{\partial^2 \Pi^i}{\partial Y_j \partial \theta} + y_j \left(\frac{\partial^3 \Pi^i}{(\partial Y_i)^2 \partial \theta} + \frac{\partial^3 \Pi^i}{\partial Y_i \partial Y_j \partial \theta} \right) + y_i \left(\frac{\partial^3 \Pi^i}{\partial Y_i \partial Y_j \partial \theta} + \frac{\partial^3 \Pi^i}{(\partial Y_j)^2 \partial \theta} \right).$$

Thus, if y_i and y_j are sufficently small, $\frac{\partial^3 \pi^i (y_i, y_j; \theta)}{\partial y_i \partial \theta \partial \lambda} < 0$. For sufficiently large investment costs, the statement thus holds. ■

The condition $\frac{\partial^2 \Pi^i}{\partial Y_j \partial \theta} < 0$ is appealing: As competition increases, the adverse effect of a more efficient competitor on own profits becomes larger in absolute value. In the Hotelling example, for instance, the assumption holds. We are left with the following conclusion.

Observation 2: If investments have higher spillovers, marginal investment incentives are more likely to be negatively affected by competition.

5.3 The effects of pre-existing 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 competiton and investment. In other words, low initial levels of competition would appear to make it more likely that further increases of competition increase investments. The above examples already show that such a general statement cannot be supported. In fact, the only non-monotone examples feature a U-shape. Even so, (A6) suggests two reasons why increasing competition is more likely to have positive effects when the initial level of competition is low. First, with low competition, markups and hence the demand sensitivity effect ($M_i D^i_{i\theta}$) should be high. Second, by (A6), D^i_i is higher when competition is intense, suggesting that the negative markup effect $D^i_i M^i_\theta$ is more pronounced when competition is intense. A potential countereffect arises if, $D^i_\theta > 0$, and, as for quantity competition, $M^i_{i\theta} > 0$; because this suggests that the cost-pass-through effect $D^i M^i_{i\theta} > 0$ is higher for higher demand. We summarize the discussion as follows:

Observation 3: Competition is not necessarily more likely to have a positive effect on investments when the initial level of competition is lower.

5.4 Positive Demand Effects

One might argue that it is "natural" for competition to have a positive effect on demand ($D_\theta > 0$): If the demand-enhancing effect of lower own price dominates over the demand-reducing effect of lower competitor prices, demand can only fall if there is direct negative demand effect.[33] Even this does not

[33] This holds, for instance, in the homogeneous Cournot example with decreasing market size.

necessarily make for less ambiguity: There are several examples where the demand effect is positive, but competition nevertheless reduces investments, even in the symmetric case. For instance, this is true for the substitution parameter in the differentiated Bertrand model of Shubik and Levitan,[34] and it also holds when one moves from Cournot to Bertrand competition in the Shubik-Levitan case. Intuitively, while competition increases demand (and also by (A6), the sensitivity of demand to investment), it also reduces markups, which reduces investment incentives. Hence:

Observation 4: Even when competition increases demand, a positive effect of competition on investment does not follow.

5.5 The effects of the number of firms

Rather than changes in the intensity of competition for a given number of firms, consider now increases in the number of firms for an otherwise unchanged environment. Suppose there are $n \geq 2$ firms. Replace the parameter θ by n and write

$$\Pi^i \left(Y^i, \mathbf{Y}_{-i}; n\right) = M^i \left(Y^i, \mathbf{Y}_{-i}; n\right) \cdot D^i \left(Y^i, \mathbf{Y}_{-i}; n\right).$$

Apart from that, suppose everything is as in Section 2. Write net profits written as $\pi^i (y^i, \mathbf{y}_{-i}; n)$. For any investment level y, let $\mathbf{y}_n$ be the $n-1$-dimensional vector consisting of entries y. Finally, introduce the following variant of the strategic substitutes condition.

Definition 1 *The investment game satisfies **strategic substitutes at the diagonal** (SSD) if $\frac{\partial \pi^i}{\partial y^i} (y^i, \mathbf{y}_n; n)$ is non-increasing in $\mathbf{y}_n$ for all y_i and y.*

Thus, (SSD) requires player i's investment incentives to fall as the other players' investments increase symmetrically along the diagonal. The condition is motivated by the observation that strategic substitutes typically hold in duopoly investment games with no spillovers. The following result holds.

[34] In the Singh-Vives case, the effect is negative for sufficiently large initial levels of competition.

Proposition 4 *Consider a symmetric investment game with objective functions* $\pi^i(y_i, \mathbf{y}_{-i}; n)$ *that are concave in* y_i *and satisfy (SSD). Suppose for all* $i \in \{1, 2, ..., n\}$ *and* $n^L < n^H$,

$$\frac{\partial \pi^i}{\partial y_i}\left(y, \mathbf{y}_L; n^L\right) > \frac{\partial \pi^i}{\partial y_i}\left(y, \mathbf{y}_H; n^H\right).$$

For symmetric equilibria $\mathbf{y}^L \equiv \mathbf{y}(n^L)$ *and* $\mathbf{y}^H \equiv \mathbf{y}(n^H)$, $\mathbf{y}^L > \mathbf{y}^H$.

Proof. As $\frac{\partial \pi^i}{\partial y^i}\left(y^H, \mathbf{y}^H_{n^H}; n^H\right) = 0$, (4) implies $\frac{\partial \pi^i}{\partial y^i}\left(y^H, \mathbf{y}^H_{n^L}; n^L\right) > 0$. By concavity, $\frac{\partial \pi^i}{\partial y_i}\left(y_i, \mathbf{y}^H_{n^L}; n^L\right) > 0$ for any $y_i < y^H$. Finally, (SSD) implies $\frac{\partial \pi^i}{\partial y^i}\left(y_i, \mathbf{y}^i_{n^L}; n^L\right) > 0$. Therefore, $\mathbf{y}^L < \mathbf{y}^H$ is impossible. ∎

Under the conditions of Proposition 4, if an increase in the number of firms reduces marginal investment incentives of each firm, it also reduces symmetric equilibria. Using (4) with θ replaced by n,

$$\Pi^i_{in} = D^i_i \cdot M^i_n + M^i_i \cdot D^i_n + D^i \cdot M^i_{in} + M^i \cdot D^i_{in}.$$

Thus, as in Section 3, we can identify four transmission channels by which the number of firms affects marginal incentives. However, a higher number of firms quite robustly reduces both markups and demands, so that both the markup effect $D^i_i \cdot M^i_n$ and the demand effect $M^i_i \cdot D^i_n$ are negative. This suggests a clearer negative effect of increasing competition on investments, unless M^i_{in} and D^i_{in} are positive and very large.

Observation 5: An increase in the number of firms tend to reduce investments per firm.

6 Welfare considerations

While a full welfare analysis cannot be given at this level of generality, some remarks on the effects of competition on welfare are possible. Denote the consumer surplus corresponding to prices p^1 and p^2 as $\widetilde{\kappa}(p^1, p^2; \theta)$, and define $\kappa(Y_1, Y_2; \theta) = \widetilde{\kappa}(p^1(Y_1, Y_2; \theta), p^2(Y_1, Y_2; \theta); \theta)$. Write welfare as

$$W(\theta) = \sum_{i=1}^{2} \pi^i(y_i(\theta), y_j(\theta); \theta) + \kappa\left(Y_1^0 + y_1(\theta), Y_2^0 + y_2(\theta); \theta\right)$$

Using the logic of the envelope theorem ($\frac{\partial \pi^i}{\partial y^i} = 0$ in equilibrium), $\frac{d\pi^i}{d\theta} = \frac{\partial \pi^i}{\partial y^j}\frac{\partial y^j}{\partial \theta} + \frac{\partial \pi^i}{\partial \theta}$. Defining $\widetilde{\Pi}^i\left(p^i, p^j; \theta\right) = \left(p^i - c^i\right) d^i\left(p^i, p^j; \theta\right)$,

$$\pi^i\left(y_i(\theta), y_j(\theta); \theta\right) =$$
$$\widetilde{\Pi}^i\left(p^i\left(Y_i^0 + y_i(\theta), Y_j^0 + y_j(\theta); \theta\right), p^j\left(Y_i^0 + y_i(\theta), Y_j^0 + y_j(\theta); \theta\right), Y_i; \theta\right) - k(y^i).$$

From $\frac{\partial \widetilde{\Pi}^i}{\partial p^i} = 0$, the direct effect is

$$\frac{\partial \pi^i}{\partial \theta} = \frac{\partial \widetilde{\Pi}^i}{\partial p^j}\frac{\partial p^j}{\partial \theta} + \frac{\partial \widetilde{\Pi}^i}{\partial \theta},$$

where $\frac{\partial \widetilde{\Pi}^i}{\partial \theta} = d^i_\theta m$. Even ignoring the investment effect, competition thus affects profits in two ways. First, there is a direct (positive or negative) effect via d^i_θ. Second, lower competitor prices work towards lower profits ($\frac{\partial \widetilde{\Pi}^i}{\partial p^j}\frac{\partial p^j}{\partial \theta} < 0$). In addition, there is the investment-induced effect $\frac{\partial \pi^i}{\partial y^j}\frac{\partial y^j}{\partial \theta}$. If $\frac{\partial \pi^i}{\partial y^j} < 0$, which holds quite generally with no spillovers, the effect is positive or negative according as competition decreases or increases the competitor's investments. The effect of competition on consumer surplus is

$$\frac{d\kappa}{d\theta} = \frac{\partial \kappa}{\partial \theta} + \sum_{i=1}^{2} \frac{\partial \kappa}{\partial Y^i}\frac{\partial y^i}{d\theta}.$$

$\frac{\partial \kappa}{\partial \theta}$ reflects the price-reducing effect of competition and therefore should be positive.[35] The investment-induced effect, $\sum_{i=1}^{2} \frac{\partial \kappa}{\partial Y^i}\frac{\partial y^i}{d\theta}$, typically has the opposite sign as the corresponding part of the profit effect, $\sum_{i=1, j\neq i}^{2} \frac{\partial \pi^i}{\partial y^j}\frac{\partial y^j}{\partial \theta} = \sum_{i=1, j\neq i}^{2} \frac{\partial \pi^j}{\partial y^i}\frac{\partial y^i}{\partial \theta}$. Thus, if competition has a positive effect on investment, it increases consumer surplus, whereas it reduces total profits.

Several related questions remain open. First, when competition reduces investments, can the beneficial effect on firms from reducing the negative

[35] An obvious counterexample is the inverse market size example: Though increasing competition reduces prices, it also reduces consumer surplus. One might therefore opt for a narrower definition of increasing competition that would exclude such an example.

externality $\frac{\partial \pi^i}{\partial y^j}$ be so strong that competition increases profits even when the direct effect $\frac{\partial \pi^i}{\partial \theta}$ is negative, as one would typically expect? Second, can such a reduction in investments be so strong that consumer surplus falls?

7 Conclusion

The paper has identified the channels by which competition affects investment. In the main part of the paper, increasing competition refers not to an increase in the number of firms, but to a more aggressive strategic interaction for a given number of firms, resulting for example from closer substitutability of their products. By assumption and consistent with many examples, competition reduces markups, and increases the sensitivity of equilibrium demand with respect to efficiency. Adding to these ambiguities, competition can have positive or negative effects on equilibrium demands and on the sensitivity of prices with respect to marginal costs. Unless one opts for very narrow notions of increasing competitions, the ambiguities do not disappear. Further, a positive effect of competition is more likely for leaders than for laggards, and it is less likely when spillovers are strong. Finally, there is no general case that an inverse relation between competition and investment is more likely than a U-shaped relation.Finally, with the alternative interpretation of increasing competition as an increase in the number of firms, however, competition has a clear negative effect.

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 influences the investment decisions of the relatively efficient firms who face less competitors than in the case were exit is precluded.[36]

[36] Obviously, such an extension would also involve moving beyond the duopoly case.

8 Appendix: The Examples

8.1 Substitutability (Shubik-Levitan)

8.1.1 Quantity competition

Define $Y_i = 1 - c_i$, that is, $\overline{c} = 1$. For $2Y_i \geq \theta Y_j$; $2Y_j \geq \theta Y_i$,[37]

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

8.1.2 Price competition

With price competition,

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

8.2 Substitutability (Singh-Vives)

With quantity competition,

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

With price competition,

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

8.3 Hotelling

In the Hotelling model, demand functions are given by

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

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

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

[37] The following results are taken from Sacco and Schmutzler (work in progress).

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

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

References

Aghion, P., Harris, C., Vickers, J.: "Competition and growth with step-by-step innovation: An example." *European Economic Review* 41: 771-782 (1997).

Aghion, P., Harris, C., Howitt, P., Vickers, J.: "Competition, imitation and growth with step-by-step innovation." *Review of Economic Studies* 68: 467-492 (2001).

Athey, S., Schmutzler, A. (2001). Investment and market dominance. *RAND Journal of Economics* 32, 1-26.

Bagwell, K., and Staiger, R.W., 1994. The sensitivity of strategic and corrective R&D policy in oligopolistic industries. *Journal of International Economics* 36, 133-150.

Boone, J. (2000), "Competition", CEPR Working Paper.

Bulow, J., Geanakoplos, J., Klemperer, P.(1985), "Multimarket Oligopoly: Strategic Substitutes and Complements", *Journal of Political Economy*93, 488-511

Cabral, L.M.B., "Increasing Dominance with No Efficiency Effect", (2001) *Journal of Economic Theory* 102, 471-479

Cabral, L.M.B., Riordan, M.H., "The Learning Curve, Market Dominance, and Predatory Pricing", *Econometrica* (1994), 62, 1115-1140

Cabral, L.M.B., "Dynamic Price Competition with Network Effects", *mimeo*, New York University.

Fudenberg, D., Tirole, J., 1984. The fat-cat effect, the puppy-dog ploy, and the lean and hungry look. *American Economic Review Papers and Proceedings* 74, 361-366.

Gilbert, R.: "Looking for Mr. Schumpeter: Where are we in the Competition-Innovation Debate?" In: J. Lerner and S. Stern (Ed.), *Innovation Policy and Economy.* NBER, MIT Press (2006).

Halbheer, D., Fehr, E., Götte, L., and Schmutzler, A., "Self-reinforcing market dominance", SOI working paper no. 0711

Leahy, D., and Neary, J.P. (1997), "Public Policy Towards R&D in Oligopolistic Industries", *American Economic Review* 87,642-662.

Milgrom, P., Roberts, J., 1990. Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica* 58, 1255-1277.

Motta M., "Competition Policy, Theory and Practice", *Cambridge University Press.*

Sacco, D. (2008): Is there a U-shaped relation between competition and investment? *Work in progress.*

Shubik, M., and Levitan, R. (1980), *Market Structure and Behavior.* Cambridge, MA: Harvard University Press.

Singh, N., and Vives, X. (1984), "Price and quantity competition in a differentiated duopoly", *RAND Journal of Economics* 15, 546-554.

Topkis, D.M. (1978), "Minimizing a Submodular Function on a Lattice", *Operations Research* 26, 305 – 321.

Vives, X. Innovation and Competitive Pressure, *Journal of Industrial Economics*, forthcoming.