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Competition and investment — A unified approach☆,☆☆

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ABSTRACT

Using a simple but general two-stage framework, this paper identifies the circumstances under which increasing competition leads to more cost-reducing investments. The framework can, for instance, capture increasing substitutability for different types of oligopoly models or changes from Cournot to Bertrand competition. The paper identifies four transmission mechanisms by which competition affects investment. For a firm with lower initial marginal costs (higher efficiency), a positive effect of competition on investment is more likely. Positive spillovers support a negative effect of competition on investment. The relation between competition and investment is not affected in an unambiguous way by the level of pre-existing competition.

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. Reasonable theoretical models can support positive, negative or non-monotone relations between competition and investment. These ambiguities reflect many modeling differences, concerning in particular the meaning of increasing competition.[1] Similarly, empirical research also has been inconclusive.[2]

This paper provides a uniform framework for analyzing the effects of competition on investment in a transparent way. Rather than attempting to identify an unambiguous relation between competition and investment, I ask: How does the effect of increasing competition on cost-reducing investments depend on characteristics of firms, technologies, markets and institutions, and on the specific notion of competition? The paper is not just of theoretical value. It provides a framework for empirical analysis, because it leads to various testable implications.

The model captures several notions of increasing competition and different types of oligopolies. To reveal the intuition in the most transparent fashion, I opted for simplicity otherwise by considering a two stage-duopoly. One firm (the leader) may be exogenously more efficient than the other one (the laggard), that is, it may have lower marginal costs.[3] Firms simultaneously choose cost-reducing investments before they engage in product market competition, which is treated in reduced form.[4] Many well-known examples are special cases. The main contributions are as follows.

The reduced form framework helps to understand the economic intuition behind many examples. In particular, I identify four transmission channels by which competition affects investment. Specifically, I obtain the following observations concerning the determinants of the effects of competition on investment: (i) Increases in the *initial efficiency* of a firm relative to the competitor support a positive effect of competition on investment. (ii) Higher *positive spillovers* work towards a negative effect of competition on investment. (iii) Increases in the *initial level of competition* have an ambiguous effect on the relation between

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[1] See Gilbert (2006) and Schmutzler (2010) for recent surveys.

[2] See Gilbert (2006) for an elaboration of this point.

[3] We also allow for the case that both firms are identical.

[4] The setting rules out situations where the investments are not observable by competitors and therefore have no strategic effect in the product market. Vives (2008) considers this case.

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further competition and investment; expressed differently, U-shaped and inverse U-shaped relations between competition and innovation are possible.

Section 2 introduces the general model and defines competition in terms of its effects on equilibrium outputs and margins. It also presents examples of the general model and shows how competition affects investments in these examples. Section 3 derives properties of profits as functions of costs and the competition parameter. Section 4 discusses the comparative statics implications of these properties within the basic model. Section 5 discusses related literature very briefly.[5] Section 6 concludes.

2. The model

I shall consider a class of two-stage games. The assumptions are formulated as relations between equilibrium outputs and margins on the one hand and the degree of competition and the cost structure of the firms on the other. These assumptions are intuitively plausible, and they will be shown to apply in the examples below (see Section 2.2).

2.1. Game structure

2.1.1. Basics

Initially, firm $i \in \{1,2\}$ has constant marginal cost c_i^0. In period 1, given (c_1^0, c_2^0), firms $i = 1, 2$ choose investments y_i, with an increasing and convex cost function $K(y_i)$. In period 2, firm i has marginal costs $c_i = c_i^0 - y_i - \lambda y_j$, where $\lambda \in [0,1]$ is a spillover parameter and $j \neq i$. It will often be convenient to specify an arbitrary exogenous reference level $\bar{c} \in \mathbb{R}$ and to write $Y_i^0 = \bar{c} - c_i^0$ and $Y_i = \bar{c} - c_i$ for the firm's efficiency level before and after investment.[6] Clearly, $Y_i = Y_i^0 + y_i + \lambda y_j$.

A parameter $\theta \in \Theta \subset \mathbb{R}$ captures the intensity of competition; here $\Theta = [\underline{\theta}, \overline{\theta}]$ or $\{\underline{\theta}, \overline{\theta}\}$ for some $\underline{\theta} < \overline{\theta}$. The defining properties of θ will be introduced in Section 2.1.2.

The demand function for firm i is $q^i(p^i, p^j; \theta)$; it is weakly decreasing (increasing) in p^i (p^j). The product–market game is assumed to have a unique pure Nash equilibrium for each $\theta \in \Theta$ and $(Y_1, Y_2) \in \mathbf{Y} \equiv [\underline{Y}_1, \overline{Y}_1] \times [\underline{Y}_2, \overline{Y}_2]$, where $\overline{Y}_i \leq \bar{c}$ and $\underline{Y}_i \geq \bar{c} - c_i^0$ $(i = 1, 2)$.[7] The Nash equilibrium corresponds to prices $p^i(Y_i, Y_j; \theta)$ for $i = 1, 2; j \neq i$.[8] I assume that $p^i(Y_i, Y_j; \theta)$ is weakly decreasing in Y_i and Y_j, $j \neq i$. The following notation will be used:

1 Equilibrium margins $M^i(Y_i, Y_j; \theta) \equiv p^i(Y_i, Y_j; \theta) - \bar{c} + Y_i$
2 Equilibrium outputs $Q^i(Y_i, Y_j; \theta) \equiv q^i(p^i(Y_i, Y_j; \theta), p^j(Y_i, Y_j; \theta); \theta)$
3 Gross equilibrium profits $\Pi^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) \cdot Q^i(Y_i, Y_j; \theta)$

I will assume that M^i, Q^i and thus Π^i are twice continuously differentiable in Y_i and Y_j and, whenever $\Theta = [\underline{\theta}, \overline{\theta}]$, continuously differentiable in all variables wherever the respective function takes positive values. I use subscripts to denote partial derivatives of these functions. For instance, $M_i^i \equiv \frac{\partial M^i}{\partial Y_i}$, $M_j^i \equiv \frac{\partial M^i}{\partial Y_j}$, $M_\theta^i \equiv \frac{\partial M^i}{\partial \theta}$, $M_{ij}^i \equiv \frac{\partial^2 M^i}{\partial Y_i \partial Y_j}$, $M_{i\theta}^i \equiv \frac{\partial^2 M^i}{\partial Y_i \partial \theta}$ and $M_{j\theta}^i \equiv \frac{\partial^2 M^i}{\partial Y_j \partial \theta}$. Analogous notation applies to Q^i and Π^i.

The following convention will be used:

Convention. *Whenever I refer to the functions M^i, Q^i and Π^i and their derivatives as being decreasing (increasing) in an argument, this property is required to be strict only on the set of $(Y_i, Y_j; \theta) \in [\underline{Y}_i, \overline{Y}_i] \times [\underline{Y}_j, \overline{Y}_j] \times \Theta$ such that $\theta > \underline{\theta}$ and $Q^i(Y_i, Y_j; \theta) > 0$ and $Q^j(Y_j, Y_i; \theta) > 0$.*

This convention takes care of the possibility that changes of a variable have no effect in some parameter regions because the firm is so inefficient that outputs, margins and profits are zero. It also allows for the possibility that, when competition is very weak, the efficiency of the competitor has no effect on own outputs, margins and profits.

The following assumptions will be made throughout the paper, and they hold in examples E1–E5 below.

(A1) $Q^i(Y_i, Y_j; \theta)$ is (i) increasing in Y_i, (ii) decreasing in Y_j, $j \neq i$.

A1(i) requires that the output increase implied by the own price reduction dominates the output reduction from the competitor price reduction; similarly for (ii). In line with the above convention, I do not require strict monotonicity everywhere for two reasons. First, when one firm has sufficiently low Y_i, its outputs may be zero and thus constant for non-degenerate sets of Y_i, Y_j; θ. Second, if $\theta = \underline{\theta}$ corresponds to the case that firms produce sufficiently unrelated products that firms do not compete, it is natural to assume that Q^i is independent of Y_j, at least when there are no spillovers.

(A2) $M^i(Y_i, Y_j; \theta)$ is (i) increasing in Y_i, (ii) decreasing in Y_j, $j \neq i$.

As $M^i(Y_i, Y_j; \theta) = p^i(Y_i, Y_j; \theta) - \bar{c} + Y_i$ and $M_i^i = \frac{\partial p^i}{\partial Y_i} + 1$, A2(i) requires that cost reductions are larger than induced price reductions; similarly for (ii).

The investment game reduces to a one-stage game with payoff functions

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

I assume that there exists a unique interior subgame perfect equilibrium $(y_1(Y_1^0, Y_2^0, \theta), y_2(Y_1^0, Y_2^0, \theta))$.[9] For simplicity, I write $y_i(\theta) \equiv y_i(Y_i^0, Y_j^0, \theta)$.

2.1.2. Defining competition

I now introduce intuitive assumptions on the relation between θ and equilibrium outputs and margins. These assumptions hold in examples E1–E5 below and in many other examples.[10]

(C1) $M^i(Y_i, Y_j; \theta)$ is decreasing in θ.

The property that competition reduces margins is standard.

(C2) Q_i^i is increasing in θ.

Thus the positive effect of lower costs on output is higher when competition is intense, reflecting the increasing relevance of business-stealing. For the next property, the following definition is useful:

Definition 1.

(i) Firm i with efficiency level Y_i^m is *marginal* given $(Y_j; \theta)$ if $Q^i(Y_i, Y_j; \theta) = M^i(Y_i, Y_j; \theta) = 0$ for all $Y_i \leq Y_i^m$ and $Q^i(Y_i, Y_j; \theta) > 0$ and $M^i(Y_i, Y_j; \theta) > 0$ for all $Y_i > Y_i^m$. Firm i is *potentially marginal* given $(Y_j; \theta)$ if there exists a $Y_i^m \in [\underline{Y}_i, \overline{Y}_i]$ such that firm i is marginal given $(Y_j; \theta)$ if it has efficiency level Y_i^m.

(ii) Firm i is *dominant* given $(Y_i; \theta)$ if $Y_j \leq Y_j^m$ for $j \neq i$. Firm i is *potentially dominant* given $(Y_j; \theta)$ if there exists a $Y_i^d \in [\underline{Y}_i, \overline{Y}_i]$ such that firm i is dominant given $(Y_j; \theta)$.

[5] See Schmutzler (2010) for a more detailed treatment of related literature.
[6] The 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.
[7] The restrictions reflect the requirement that $0 \leq c_i \leq c_i^0$.
[8] For price competition, $p_i(Y_i, Y_j; \theta)$ is the equilibrium price; for quantity competition, it denotes the market clearing price for equilibrium outputs.
[9] Often, equilibria where only one firm invests coexist with the symmetric equilibria. Also, in some parameter regions all pure-strategy equilibria are asymmetric. I ignore such equilibria in the following.
[10] Appendix 2 gives the margins and outputs for E1–E5.