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Competitive Pressure, Selection and Investments in Development and Fundamental Research.

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Abstract

This paper analyses the effects of competitive pressure on a firm's incentives to undertake both fundamental research and development. It presents a new framework incorporating the selection effect of product market competition, the Schumpeterian argument for monopoly power, the Nickell/Porter argument for competitive pressure and the infant industry argument for protection. The key insight is that the effects of competitive pressure on a firm's incentives to innovate depend on the firm's efficiency level relative to that of its opponents. Finally the effects of competitive pressure on industry wide fundamental research and development are analyzed. It turns out that there is a trade off between development and fundamental research: a rise in competitive pressure cannot raise both types of innovative activity at the industry level.

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1. Introduction.

This paper has three main points. First it offers a framework to think about product market competition that encompasses both older ideas, such as the Schumpeterian argument for monopoly power and the infant industry argument for protection, and the recent theoretical literature on managers' incentives to improve efficiency. Second, it shows that the effects of competitive pressure on a firm's incentives to innovate depend on the firm's position in the industry efficiency distribution. Finally, it points to a trade off between industry wide fundamental research and development. A rise in competitive pressure cannot raise both types of innovative activity at the industry level.

Whereas the previous literature on innovation and competition has simply assumed that more competition reduces profit levels (for instance Hart (1983), Scharfstein (1988) and Aghion and Howitt (1992)) or looked at one or two examples to illustrate the effects of competition (for instance Hermalin (1992), Martin (1993) and Aghion et al. (1997)), this paper's purpose is to examine in more detail the effects of competition on firms' profit functions. This leads to a framework which shows that the Schumpeterian argument and the idea advocated by for example Porter (1990) that competition fosters innovation are not incompatible. They can be interpreted as relating to different types of innovations. Also the different results in the recent theoretical literature starting with Hart (1983) can be traced back to different (implicit) assumptions about how competition affects the profit function.

Three ingredients are used to create the framework here. First, I consider explicitly the case where firms differ in their efficiency levels. Assuming that firms are symmetric obscures important aspects of competition, for instance the idea that competition sorts efficient from inefficient firms. Second, not only is the effect of competition on profit levels considered but also the effect on the steepness of the profit function's slope with respect to a firm's own cost level. The steeper this slope, the more incentive a firm has to reduce costs. The last ingredient is a number of examples to illustrate what "more competitive pressure" can mean.

Most of the empirical and theoretical literature has tried to uncover the effect of competition on a firm's innovative behavior without conditioning on firm specific variables. The framework here suggests why this is bound to yield muddled results. The effects of competitive pressure on a firm's incentives to innovate depend on the firm's efficiency level relative to that of its opponents. In other words, a rise in competitive pressure may raise some firms' incentives to innovate, but it can at the same time reduce other firms' incentives. Conditions are derived under which a rise in competitive pressure increases low cost firms' incentives to reduce costs, while decreasing high cost firms' incentives to reduce costs. Then a rise in competitive pressure leads to polarization of efficiency levels in the industry. Such firm specific effects have not been fully recognized in both the empirical and theoretical literature on how competition affects firms' incentives to raise efficiency.

Finally, the theoretical literature has largely focussed on the effect of competition on a single firm. Here I analyze the effects of competitive pressure on industry wide development and fundamental research, too. There is a trade off between development and fundamental research on the industry level. A rise in competitive pressure can increase one form of innovative behavior but not both.

The relation between the theoretical literature and my work is discussed in section 4 below. In terms of the empirical literature, this work is *not* in the vein of Cohen and Levin (1989) who survey studies on innovation and market structure. The reason is that with asymmetric firms there is no simple relation between product market competition and market structure. A firm may be a monopolist due to high barriers to entry and face no competition, or it may be a monopolist because it is the most efficient firm in the industry and competition is so intense that less efficient firms cannot survive. In both cases the market structure is the same, yet competitive pressure differs starkly. Work by Nickell (1996) and Blundell et al. (1995) is more in line with the analysis here as they measure competitive pressure directly using variables like import penetration or rents. However neither of these two papers conditions on firm specific variables when determining the effect of competition on firms' research efforts. The concept of competition used by Hay and Liu (1997) is very close to this paper's idea of competitive pressure. They say that a market is more competitive if cost differences between firms lead to more pronounced differences in market shares. In my paper competitive pressure is said to be higher if cost differences lead to more pronounced differences in firms' profits.

The next section introduces competitive pressure, gives examples and shows the general framework. Section 3 analyses the effects of competitive pressure on a single firm's incentives to innovate. Section 4 shows how the recent theoretical literature fits into the general framework. Section 5 considers the effects of competitive pressure on industry wide development and fundamental research and shows the polarization result. Section 6 concludes the paper.

2. Competitive pressure.

A problem with the concept "competition" is that most economists have an idea what it means, but there is no standard way of defining it. Needless to say, any attempt to define competition will do no justice to the rich variety of interpretations held by economists. However, in order to analyze the relation between competition and innovation, it is useful to be precise about what competition means. Therefore I define a concept called "competitive pressure" which captures some (but probably not all) of the ideas associated with competition. As mentioned above, I have two justifications for my definition of competitive pressure. First, I give a number of examples where intuitive parameterizations of competition satisfy my definition. Of course, examples can never prove that my definition of competitive pressure is the "right one" (if there could be one right definition of competitive pressure, which I doubt), but still it is encouraging to see a number of examples which are in line with the definition. The second justification for the definition of competitive pressure used here, is that it captures the ideas of Schumpeter, Nickell and Porter and the infant industry argument on the relation between innovation and competition.

As shown below, besides clarifying some issues on the effects of competition on the profit function, the definition yields new results on the effects of competitive pressure on industry wide innovative activity.

In this paper, the essential feature of product market competition is taken to be that competitive pressure accentuates differences between firms. If firm 1 is more efficient than firm 2, this efficiency gap becomes more of an advantage for firm 1 relative to firm 2 as competitive pressure is increased. This conceptual view on competitive pressure leads to two contributions to the literature on competition. First, I will deal explicitly with the asymmetric case where firms differ in efficiency levels. Second, three different sources of pressure are identified that can interact.

First, I think every economist would agree that a rise in competition reduces industry wide profits. Usually one looks at the case where firms are symmetric and then a rise in competition reduces each firm's profits. Think for instance of the textbook example where n symmetric firms compete in Cournot fashion. Then a rise in n reduces each firm's profits and industry wide profits. However if one allows firms to differ in their efficiency levels, a rise in pressure affects firms differently depending on their efficiency level.

The following simple example illustrates these ideas. Consider an industry with two firms, where firm 1 is more efficient than firm 2, $c_1 < c_2$. Denote firm 1's profits by $\pi(c_1,c_2;\theta)$, where θ is a measure of competitive pressure. Now write 1's profits as $\pi(c_1,c_2;\theta) = \pi(c_2,c_2;\theta) + [\pi(c_1,c_2;\theta) - \pi(c_2,c_2;\theta)]$, that is the profits when both firms are symmetric plus a term measuring firm 1's cost advantage. A rise in pressure reduces the profits in the symmetric case $\pi(c_2,c_2;\theta)$ as mentioned above. However, a rise in competitive pressure may make it more profitable for firm 1 to have lower costs than 2. That is, by accentuating the cost difference, a rise in pressure increases $[\pi(c_1,c_2;\theta) - \pi(c_2,c_2;\theta)]$. As shown below, if c_1 is far smaller than c_2 the latter effect may dominate the former. In this case, a rise in competitive pressure raises firm 1's profits. Conversely, for firm 2 both effects work to decrease its profits since the rise in pressure makes its cost disadvantage more pronounced, thereby marginalising 2's share in the industry.

Second, for my purposes here, three sources of competitive pressure on a firm can be identified. First, there is the number of the firm's opponents, second the efficiency level of the firm's opponents and third the way firms interact. In particular, the more opponents a firm faces and the more efficient these opponents are, the more competitive the firm's environment is. Further, for given number and efficiency levels of opponents, competitive pressure is determined by how aggressively firms interact. An example of this third source of pressure is whether firms are producing perfect substitutes or differentiated goods. The more differentiated the firms' goods are, the more monopoly power each firm has, and the less aggressive firms' interaction is. Consequently, with differentiated goods the effects of efficiency differences will be less pronounced than with homogenous goods.

This paper analyses the effects of competitive pressure on firms' decisions to enter an industry and on their choices of efficiency level. So changing the third source of competitive pressure, by affecting firms' entry and efficiency decisions, can change the number of firms in the industry and the efficiency levels of firms in the industry. That is, changing one source of pressure affects the other two sources of pressure. The analysis of the interaction of different sources of pressure is postponed until section 5. In this section and the next, attention is focussed on how one source of pressure affects one firm's decisions, isolating it from possible changes in opponents' actions.

Now some examples are considered of how one may interpret competitive pressure. In these examples, I denote pressure on firm i by θ_i, and an increase in θ_i is interpreted as a rise in competitive pressure on firm i. If a parameter increases pressure on all firms simultaneously, it is denoted by θ. In general the profits of firm i can be written as $\pi(c_i,c_{-i};\theta_i)$ where c_i is firm i's own constant marginal cost level and c_{-i} the vector of constant marginal cost levels of i's opponents. Throughout this paper it is assumed that firms only differ in their marginal cost levels. Since in this section and the next, the vector of other firms' costs c_{-i} is taken as given, it is suppressed for notational convenience and i's profits are written as $\pi(c_i;\theta_i)$.

2.1 Examples.

Example 1: Consider a market in country A with 2 firms facing demand of the form $p(X) = 1/X$ with $X = x_1 + x_2$ the sum of the output levels of firms 1 and 2. Firm 1 is resident in country A and has constant marginal costs equal to c_1. Firm 2 is not resident in country A, and the government of A can manipulate the price p_2 firm 2 charges in A by import taxes/subsidies. The firms compete in country A's market in Bertrand fashion. I think most economists would agree that the higher the import tax firm 2 has to pay, the lower the pressure on firm 1. Defining pressure on firm 1 as $\theta_1 = 1/p_2$, firm 1's profits can be written as $\pi(c_1;\theta_1) = \max\{0, 1-\theta_1 c_1\}$.

Example 2: Consider the same inverse demand curve as in the previous example, $p(X) = 1/X$. Now the two firms are both in the same country and compete in Cournot fashion. Firm i has constant marginal costs equal to c_i ($i = 1, 2$). Now I say that pressure on firm j is increased if it faces an opponent with lower costs. Therefore, pressure on firm j can be defined as $\theta_j = 1/c_i$ ($i \neq j$). With this interpretation of pressure, firm j's profits can be written as $\pi(c_j;\theta_j) = 1/(1+\theta_j c_j)^2$.

Example 3: Consider the inverse demand function $p(X) = 1 - X$, where $X = \sum_{j=1}^{n+1} x_j$ equals the sum of output levels of firms 1 to n+1. Firm i has constant marginal costs c_i and firm i's opponents have average marginal costs $m_{-i} = \sum_{j\neq i} c_j/n$. Then I say that pressure on firm i is increased if n increases while keeping m_{-i} constant. With $\theta_i = n$, firm i's Cournot profits can be written as $\pi(c_i;\theta_i) = \left(\frac{1-(\theta_i+1)c_i+\theta_i m_{-i}}{\theta_i+2}\right)^2$.

Example 4: Same set up as previous example, but now the number of opponents of firm i is fixed at n. Here the pressure on firm i is increased if it faces opponents with lower costs. Hence θ_i is defined here as $\theta_i = 1/m_{-i}$. Then it follows that $\pi(c_i;\theta_i) = \left(\frac{1-(n+1)c_i+n/\theta_i}{n+2}\right)^2$.

Example 5: The set up is the same as in the previous two examples. Now firm i's costs equal wc_i, that is labor is the factor of production and is paid a wage equal to w. Following Porter (1990: 642) a higher wage in the industry is interpreted as higher pressure on all firms to innovate. The idea is that a higher wage makes differences in efficiency more pronounced. Hence $\theta = w$, and firm i's profits can be written as $\pi(c_i;\theta)$

$= \left(\frac{1-(n+1)\theta c_i + n\theta m_{-i}}{n+2}\right)^2$. As shown below, it is possible that higher wages raise firms' incentives to reduce c_i. This gives an interesting perspective on a result found by Van Reenen (1996:195) that 'innovating firms are found to have higher wages'.

Example 6: Consider an Hotelling beach of length 1 with consumers distributed uniformly over the beach with density 1. Firm 1 is located on the far left of the beach and firm 2 on the far right. A consumer at position $x \in \langle 0,1 \rangle$ who buys a product from firm 1 incurs a linear travel cost tx, and if she buys from firm 2 she incurs t(1-x). Assume that each consumer buys one and only one product. Firm i has constant marginal costs c_i (i = 1, 2). Then demand for the products of firm i equals $q_i(p_i,p_j;t) = 1/2 + (p_j - p_i)/(2t)$. As travel costs decrease, consumers are more inclined to buy from the cheapest firm rather than the closest one. So as travel costs decrease, firms' monopoly power is reduced and pressure is higher. Measuring pressure as $\theta = 1/t$, the profits of firm i can be written as $\pi(c_i;\theta) = \frac{(3/\theta + c_j - c_i)^2}{18/\theta}$ with i, j = 1, 2 and $i \neq j$.

Example 7: Consider two firms, denoted 1 and 2, where firm i (= 1, 2) faces demand of the form $p_i(x_i,x_j) = 1 - x_i - \theta x_j$ with $i \neq j$ and $0 \leq \theta \leq 1$. Firm i has constant marginal costs c_i. I say that pressure on each firm is increased as goods become closer substitutes, that is as θ is increased. The Cournot Nash equilibrium profits of firm i can be written as

$$\pi(c_i,\theta) = \left(\frac{2(1-c_i) - \theta(1-c_j)}{4-\theta^2}\right)^2.$$

Example 8: Consider two firms, denoted 1 and 2, that face demand of the form $p_i(x_i,x_j) = \frac{1/x_i^{1-\theta}}{x_i^\theta + x_j^\theta}$ with $i \neq j$ and $0 < \theta < 1$. This demand function is derived from a CES utility function $u(x_1,x_2) = (x_1^\theta + x_2^\theta)^{1/\theta}$, where θ measures the degree of substitutability between the goods of firm 1 and 2. Firm i has constant marginal costs c_i. As in the previous example, I say that pressure is increased as goods become closer substitutes, that is θ rises. The Cournot Nash equilibrium profits of firm i can be written as $\pi(c_i;\theta) = \frac{1+(1-\theta)\left(\frac{c_i}{c_j}\right)^\theta}{\left(1+\left(\frac{c_i}{c_j}\right)^\theta\right)^2}$ with i, j = 1, 2 and i $\neq$ j.

Admittedly the examples above are chosen for their analytical tractability. One may argue that, say, the degree of substitutability of goods is a preference parameter and not a policy instrument to increase competition. I do not favor such a narrow interpretation. The parameterizations of pressure shown above have two main features. First, a rise in pressure reduces industry wide profits. Second, such a rise makes the effects of cost differences between firms more pronounced. And there are a number of policy instruments which have these same effects. For instance, think of reducing or abolishing a minimum price in a market. As a minimum price protects high cost firms from their low cost opponents, reducing the minimum price increases the effects on profits of cost differences. Another example is closed territory distribution for retailers. In this case an inefficient retailer is not pushed out of his territory by a more efficient neighbor. However if the government abolishes closed territory distribution, retailers feel their cost (dis)advantages more strongly. Finally, consider the case of firms from different countries competing in a global market. If trade barriers are reduced, their cost differences become more pronounced in terms of profits. These examples with their clear policy interpretations share the two main features of the examples above, but are not as tractable analytically. Therefore I prefer to work with the simpler examples, keeping a broader interpretation in mind.

Although competitive pressure θ_i is modeled in a variety of ways in the examples above, the profit functions $\pi(c_i;\theta_i)$ satisfy the same basic structure, as shown in the next subsection.

2.2 Framework.

The next definition restricts the parameter θ_i's effects on firm i's profit level, $\pi(c_i;\theta_i)$, and on the steepness of the slope of i's profits with respect to i's cost level, $|\partial\pi(c_i,\theta_i)/\partial c_i|$, to be consistent with an interpretation of θ_i as competitive pressure. The profit level of firm i determines i's incentive to enter. The higher profits are, the more incentive i has to introduce its new product. Assuming that i's product has to be invented before it can be introduced, i's profit level determines the incentive to do fundamental research in the sense of creating something new. The expression $|\partial\pi(c_i,\theta_i)/\partial c_i|$ is related to i's incentive to develop its product, in the sense of improving the productivity of its production process[1]. Identifying fundamental research with the introduction of a new product and development with reducing production costs of a product is in line with Aghion and Howitt (1996). The definition restricts how pressure affects these two incentives to do fundamental research and development. And below it is shown that these restrictions hold in the examples of the previous subsection.

The two essential features of the definition are that the effects of pressure are different for fundamental research and development. And second that the effects of pressure change with the firm's cost level. High cost firms are affected by pressure in a different way than low cost firms. The taxonomy is summarized in figure 1.

<u>Definition 2.1</u>

For given profit function $\pi(c_i;\theta_i)$, a parameter θ_i is said to measure *competitive pressure* on firm i if the following taxonomy holds.

Given constant marginal cost levels c_i, c_{-i} and pressure levels θ_i ($i = 1, ..., n$), there exist for each firm i the values $c_{li}, c_{mi}, c_{hi} \in \Re_+ \cup \{+\infty\}$, with c_{li}, c_{mi}, c_{hi} functions of c_{-i} and θ_i, satisfying

(i) $c_{li} \leq c_{mi} \leq c_{hi}$ such that

$c_i \in \langle 0, c_{li} \rangle$ implies $\dfrac{\partial \pi(c_i;\theta_i)}{\partial \theta_i} > 0$ and $\dfrac{\partial \left| \frac{\partial \pi(c_i;\theta_i)}{\partial c_i} \right|}{\partial \theta_i} < 0$ (firm i is called *exceptional*),

$c_i \in \langle c_{li}, c_{mi} \rangle$ implies $\dfrac{\partial \pi(c_i;\theta_i)}{\partial \theta_i} > 0$ and $\dfrac{\partial \left| \frac{\partial \pi(c_i;\theta_i)}{\partial c_i} \right|}{\partial \theta_i} > 0$ (firm i is called *excellent*),

$c_i \in \langle c_{mi}, c_{hi} \rangle$ implies $\dfrac{\partial \pi(c_i;\theta_i)}{\partial \theta_i} < 0$ and $\dfrac{\partial \left| \frac{\partial \pi(c_i;\theta_i)}{\partial c_i} \right|}{\partial \theta_i} > 0$ (firm i is called *good*),

$c_i \in \langle c_{hi}, +\infty \rangle$ implies $\dfrac{\partial \pi(c_i;\theta_i)}{\partial \theta_i} \leq 0$ and $\dfrac{\partial \left| \frac{\partial \pi(c_i;\theta_i)}{\partial c_i} \right|}{\partial \theta_i} \leq 0$ (firm i is called *weak*);

(ii) if competitive pressure on firms i and j is measured by the same variable (that is $\theta_i \equiv \theta_j$) then $c_i > c_j$ implies $c_{xj} \geq c_{xi}$ for x = l, m and h;

(iii) if competitive pressure on all n firms is measured by the same variable θ (that is $\theta_i \equiv \theta$ for each i), then there is at least one firm j in the industry with $c_j > c_{mj}$.

Figure 1 here.

Note that although this definition may look unfamiliar at first sight, the last line implies that the following well known result holds. If all firms are symmetric, a rise in competitive pressure on all firms reduces the profits of these firms. This can be seen as follows. If all firms have $c_i = c$, then for each firm j it will be the case that $c > c_{mj}$ and hence $\partial\pi(c,\theta)/\partial\theta \leq 0$ for each firm.

Together with the intuition given below, the following proposition is a major justification for this taxonomy. One can check for each of the examples in section 2.1 that the profit function is consistent with the taxonomy above.

<u>Proposition 2.2</u>

The variables θ_i in the examples of section 2.1 measure competitive pressure as defined above.

Before interpreting this result I will be precise about what it says. First, it does not say that for all examples above it is the case that $0 < c_{li} < c_{mi} < c_{hi}$, in other words that all four sets in the definition are non-empty. In fact in only one of the examples above all four sets are non-empty, namely in example 8 with θ close enough to one. However all examples fit into this structure in the sense that they satisfy the sequencing presented for increasing values of c_i.

Second, the definition above seems to be the strongest requirement that is still satisfied by the examples above. For instance the condition that $\partial\pi(c_i;\theta_i)/\partial\theta_i$ is convex in c_i is satisfied by some of the examples above but not by all.

Also note that the taxonomy is relative both to other firms in the industry and to the parameterization of pressure chosen. Hence firm i is in class $\langle 0,c_{li}\rangle$ only if it has exceptionally low costs relative to the other firms in the industry. And it is in the class $\langle c_{hi},+\infty\rangle$ only if its productivity performance is very weak as compared to the other firms in the industry. Further, a firm may be excellent with respect to one choice of pressure, say the number of firms in the industry, but weak with respect to pressure measured as the average of its opponents' cost levels.

Finally, the following natural ordering condition is imposed by (ii). If firm i is, say, good and firm j has lower costs than i then firm j cannot be weak with respect to the same measure of pressure. Similarly, if i is excellent and j has higher costs than i, then j cannot be exceptional, etc.

What is the interpretation of the definition? Below I discuss this in the framework of a simple game. Here I describe in words what the definition says. For the examples in section 2, an increase in pressure θ_i on firm i has different effects on firm i's profit level π and i's incentive to reduce costs $|\partial\pi/\partial c_i|$ depending on i's cost level c_i. In particular, there are three benchmark values for firm i, a low cost benchmark c_{li}, a middle cost benchmark c_{mi} and a high cost benchmark c_{hi}.

If firm i is *weak* in the sense that its cost level is rather high, $c_i > c_{hi}$, then increasing pressure on firm i reduces i's profit level and it reduces i's incentive to reduce its cost level. If firm i is *good*, in the sense that its cost level is not high and not particularly low, $c_i \in \langle c_{mi}, c_{hi}\rangle$, then an increase in pressure reduces i's profits but it increases i's incentive to improve its efficiency level. For an *excellent* firm i, that is $c_i \in \langle c_{li}, c_{mi}\rangle$, a rise in pressure increases its profit level and its incentive to reduce costs. Finally there are *exceptional* firms. These firms are exceptional in two senses. First, such firms have exceptionally low cost levels $c_i \in \langle 0, c_{li}\rangle$. Second, this class of firms is exceptional in the sense that there is only one example (example 8) in the previous section that features these firms. For an exceptional firm i, an increase in pressure increases its profit level but reduces its incentive to improve productivity.

Why is this definition useful? Is it easy to identify to which class a firm belongs? Unfortunately not. As mentioned above, it is possible that a firm is good with respect to pressure measured as the number of its opponents, while it is weak with respect to pressure measured as the efficiency level of its opponents. So for each measure of pressure on firm i, one has to establish the signs of $\partial\pi/\partial\theta_i$ and $\partial|\partial\pi/\partial c|/\partial\theta_i$ to determine to which class firm i belongs with respect to that measure of pressure. Also the empirical determination of which firm belongs to which class is not without problems, but I'll come back to that in section 6.

Yet, from a conceptual point of view, it is instructive to note that competitive pressure does not always reduce each firm's profits, as is often assumed in the literature. Further, it is important to understand that competitive pressure affects firms differently depending on their efficiency level. Although a rise in competitive pressure may increase some firms' incentives to innovate, at the same time it can decrease other firms' incentives.

3. Partial effects of competitive pressure on a single firm.

In order to interpret this taxonomy, consider the following game which concentrates on the entry and investment decision of only one firm, say firm n. Firm n's profit function $\pi(c_n;\theta_n)$ is decreasing in its own cost level c_n. If firm n enters, it invests d(c) to reduce its constant marginal cost level to c. The function d(.) is called a development function. It is assumed that the development function d(.) satisfies $\partial d(c)/\partial c < 0$, $\partial^2 d(c)/\partial c^2 > 0$ and further $\partial^2 d(c)/\partial c^2 > \partial^2\pi(c;\theta_n)/\partial c^2$ for each c and θ_n. In words, investment increases with cost reductions at an increasing rate. If $\partial^2\pi/\partial c^2 > 0$, the function d(.) is more convex in c than n's profit function is, this ensures the second order conditions are satisfied below.

The way I look at this is that firm n gets an idea, which is the combination of a new product to produce together with a way to improve the productivity of the good's production process. The competitive pressure on firm n affects whether n will introduce its idea and how far to develop it.

As mentioned above, fundamental research is interpreted here as the research necessary to create something new, in particular to create a new product. Development is the research necessary to improve the production process of an existing product. The pay off to firm n from undertaking fundamental research in order to enter with its idea of a new product equals $V(\theta_n) = \max_{c \geq 0} \{\pi(c;\theta_n) - d(c)\}$. The higher $V(\theta_n)$, the more incentive a firm has to enter and hence the higher investments in fundamental research will be to create the new product. The value of c that maximizes $\{\pi(c;\theta_n) - d(c)\}$, denoted $c(\theta_n)$, is related to the development of the production process with which firm n's good is produced. How does a change in competitive pressure on firm n affect n's fundamental research and development?

Corollary 3.1

If firm n is a weak firm then $\partial V(\theta_n)/\partial \theta_n \leq 0$ and $\partial c(\theta_n)/\partial \theta_n \geq 0$,

if firm n is a good firm then $\partial V(\theta_n)/\partial \theta_n < 0$ and $\partial c(\theta_n)/\partial \theta_n < 0$,

if firm n is an excellent firm then $\partial V(\theta_n)/\partial \theta_n > 0$ and $\partial c(\theta_n)/\partial \theta_n < 0$,

if firm n is an exceptional firm then $\partial V(\theta_n)/\partial \theta_n > 0$ and $\partial c(\theta_n)/\partial \theta_n > 0$,

where these four classes of firms are introduced in definition 2.1.

Proof

The proof follows from the envelope theorem and the implicit function theorem.•

This result says that for weak and good firms, an increase in competitive pressure reduces the firm's incentive to do fundamental research as $\partial V(\theta_n)/\partial \theta_n \leq 0$. While for excellent and exceptional firms such a rise in pressure improves the incentive to do fundamental research. This is the selection effect described by Vickers (1995:13) as 'when firms' cost differ, competition can play an important role in selecting more efficient firms from less efficient ones'. By increasing competitive pressure, (weak and good) ideas with relatively high costs are discouraged to enter while (excellent and exceptional) ideas with relatively low costs are encouraged to enter.

In terms of the endogenous growth literature $\partial V(\theta_n)/\partial\theta_n \leq 0$, for weak and good firms, can be interpreted as the Schumpeterian argument for monopoly power. As pressure on a weak or good firm is increased, monopoly power and profit levels are reduced. This lowers the incentive to invent a new product. For instance, Aghion and Howitt (1992) identify the Schumpeterian argument in this way. However, for excellent and exceptional firms increasing pressure leads to a rise in profits. By putting more emphasis on cost disadvantages, rising pressure marginalizes the weak and good firms in the industry. This can lead to a rise in profits for the leaders in the industry, thereby stimulating their entry and fundamental research.

Why has the idea of more pressure stimulating fundamental research been overlooked up until now? In growth models like Aghion and Howitt (1992), there is only one active firm in the market. By definition 2.1 (iii) this monopolist is either good or weak. In that case a rise in competitive pressure, by reducing monopoly power, decreases profits and hence the incentive to invent a product. In my paper, inventing a product does not necessarily give a monopoly position and competitive pressure accentuates your cost advantage relative to your opponents. Hence if you are more efficient than your opponents, a rise in pressure can increase your profits and your incentive to enter.

For good and excellent firms increasing pressure leads to higher investments in development as $\partial c(\theta_n)/\partial\theta_n < 0$. This can be interpreted as the argument put forward by for instance Porter (1990) and Nickell (1996) that increasing competitive pressure forces firms to raise their productivity. By putting pressure on firms in their home market, the government forces firms to improve their products and production processes such that they will be more competitive in international trade. Porter's idea is that in this way governments can help their firms to become world leaders in their industry.

So the Nickell/Porter effect and the selection effect suggest that increasing competitive pressure improves the aggregate efficiency in an industry. The latter effect improves aggregate efficiency by removing inefficient firms from the market and the former by increasing the incentive to reduce costs for excellent and good firms. However for weak and exceptional firms competitive pressure works in the opposite direction.

For weak firms, increasing pressure reduces investments in development. This can be interpreted as a strengthening of the usual infant industry argument, which is used to claim protection for firms in starting industries. The argument then is that developing countries should initially protect their firms from competition from developed countries otherwise their firms may not start at all or may not survive. And indeed it is the case that $\partial V(\theta_n)/\partial\theta_n \leq 0$ for weak firms. However, putting pressure on weak firms also directly reduces their incentive to improve their productivity. So infant industries should be protected both in order to survive and to enhance their incentives for development.

The intuition[2] for this can be seen in a contest example. When a very talented agent plays a weak agent, increasing pressure translates in making the difference between them more pronounced. This will reduce the weak agent's effort as it has no longer even the slightest chance of winning. Similarly, if the talented player is far enough ahead of its weak opponent, such a rise in pressure may in fact reduce its effort as well. Since the rise in pressure marginalizes its weak opponent, the talented player has a sure win and can reduce its effort. And indeed for exceptional firms, a rise in pressure reduces its investment in development. This argument seems to be most persuasive if the number of contestants is small. Indeed, in the examples above, exceptional firms only feature in example 8, where there are two players.

The significance of the above result is twofold. First, the parameterization of pressure used here, yields a framework encompassing the Schumpeterian argument for monopoly power, the infant industry argument and the idea that increasing pressure on firms forces them to improve their productivity. Second, the result draws attention to the need to condition on firm specific variables in empirical research. In particular, the effect of pressure on a firm's incentives to invent new products and to develop these products depends on the firm's relative efficiency in the industry. For instance, the effect of a rise in import competition on a firm's productivity growth will depend on whether the firm is among the most efficient firms in the industry or instead among the weak firms in the industry.

4. Product market competition in the recent theoretical literature.

This section shows how the recent theoretical literature on the effects of competition fits in the general framework presented here. The focus is on how these papers model the effect of competition on firms' profits.

All literature surveyed here assumes that firms are profit maximizers in choosing output or price levels, as I have done in section 2 to derive the examples' profit functions. However in the stage where firms invest to reduce cost levels (or X-inefficiency), these papers distinguish between managerial and entrepreneurial firms. Entrepreneurial firms invest to reduce costs in order to maximize pay offs, as I model it above.

Managerial firms are run by managers who have different objectives. Their objectives are determined by their disutility of effort to reduce costs, the threat to lose their job through bankruptcy and their salary schedule. In particular, managers dislike the effort necessary to improve efficiency, for instance through reorganizing the firm. Further, it is assumed that as profits decrease, bankruptcy becomes more likely in which case the managers lose their jobs. Thus managers put in effort to raise their salary and to avoid bankruptcy. Because the owners design salary contracts with an eye on their own profit pay off and because bankruptcy is directly related to profits as well, the effects of competitive pressure on profits found above are relevant for managerial firms too.

First, the models by Hart (1983) and Scharfstein (1988) feature managerial firms and two states of the world. The effect of a rise in competition is to reduce profits in one state of the world. It turns out that the effect of this reduction in profits on managers' effort to enhance efficiency depends on the precise specification of the managers' utility function. The effect that competition reduces profits is clearly compatible with the framework above. However in Hart's and Scharfstein's papers it is modeled under perfect competition while here the emphasis is on imperfect competition.

Aghion et al. (1997) have a model where a rise in competition reduces profits. In terms of the framework here, they assume that firms are either good or weak. For entrepreneurial firms the Schumpeterian argument applies and the reduction in profits makes these firms less innovative. For managerial firms, however, the fall in rents makes the threat of bankruptcy come sooner. This disciplines managers to invest more effort in reducing costs.

Vickers (1995b) shows that a rise in competition, through a rise in the number of firms in the market, affects firms' profits differently depending on their efficiency level. As shown above, this selection effect of competition is not confined to competitive pressure modeled as the number of firms. But Vickers shows that this effect qualifies the excess entry result found by Mankiw and Whinston (1986), where firms are symmetric and hence the selection effect plays no role. Vickers (1995a) analyses the idea that competition adds information such that the principal can set higher powered incentives for the agent. This information effect of competition is ignored in my paper.

Martin (1993: 446) finds that 'the greater the number of firms in the market -the greater the degree of competition- the smaller the payoff associated with a marginal increase in firm efficiency and the less it is in the interest of the owner of the firm to set a fee schedule that induces the manager to reduce marginal costs'. To show this, Martin uses example 3 in section 2 with symmetric firms. In that case, one can show that $c_i > c_{hi}$ for all firms i = 1, ..., n and therefore $\partial|\partial\pi/\partial c|/\partial n < 0$. In other words, due to his symmetry assumption, Martin implicitly supposes that all firms are weak.

Schmidt (1997) distinguishes two effects of competition. First, there is the threat of liquidation effect as $\partial\pi/\partial\theta < 0$. That is, Schmidt implicitly assumes that firms are either good or weak. As is Aghion et al. (1997), the threat of liquidation makes managers work harder to reduce costs. Second there is the value-of-a-cost-reduction effect which is written as $\partial\pi(c^L;\theta)/\partial\theta - \partial\pi(c^H;\theta)/\partial\theta$ where $c^H > c^L$. Writing it as $\partial\pi(c^L;\theta)/\partial\theta - \partial\pi(c^H;\theta)/\partial\theta = \int_{c^L}^{c^H} \frac{\partial\left|\frac{\partial\pi(c;\theta)}{\partial c}\right|}{\partial\theta} dc$ shows the similarity with the analysis above. Hermalin (1992) features the same effect and calls it the change-in-the-relative-value-of-actions effect. In Hermalin (1994) this effect appears again in the form of example 3 (in section 2 above) with $\theta = n$. None of these papers is able to sign this effect. Hermalin gives examples and parameter values where it is positive and other parameter values where it is negative.

Here the general framework can play a clarifying role, because it suggests sufficient conditions to sign this effect. If the firm is either excellent or good at c^H and

c^L than this value-of-a-cost-reduction effect is positive. If the firm is weak at c^L, the effect is negative.

In the same way the following assumption about competition in Aghion et al. (1995) can be justified. They have a duopoly model where a firm is either one step ahead of its opponent, level or one step behind, with profits $\pi(+1)$, $\pi(0)$ and $\pi(-1)$ respectively. They assume that $\partial[\pi(+1)-\pi(0)]/\partial\theta > 0$ and $\partial[\pi(0)-\pi(-1)]/\partial\theta < 0$. In words, a firm that is one step ahead is assumed to be good or excellent, while a firm that is one step behind is assumed to be weak.

Summarizing, the analysis above provides a unifying framework incorporating the recent theoretical work on competition. Further, it suggests conditions to sign the expression $\partial|\partial\pi/\partial c|/\partial\theta$ which appears in the literature, but could not be signed consistently before.

The next section looks at industry wide effects of a rise in pressure. The trade off found there between fundamental research and development is reminiscent of a result found by Aghion and Howitt (1996). In their model, a rise in competition stimulates fundamental research by reallocating resources away from development on old product lines to fundamental research which creates new product lines. The intuition is that developing old product lines becomes less profitable as competition increases. This is not inconsistent with the model below. However I focus on the opposite (Nickell/Porter) effect where a rise in competitive pressure sharpens firms' incentives to develop their products. The initial rise in competitive pressure together with the subsequent cost reductions makes it less attractive to introduce a new product. Hence fundamental research is reduced through the Schumpeter effect.

5. Industry wide effects of a rise in pressure.

Above the effects of pressure on one individual firm have been analyzed. But now consider the following problem. A social planner wants to increase industry wide innovative activity; will a rise in competitive pressure help? The answer is no, and two reasons are pointed out here. First, there is a trade off between the two forms of innovative activity distinguished here: development and fundamental research. Second, in industries where a relatively high proportion of firms is inefficient, a rise in competitive pressure may remove the inefficient firms from the market, thereby reducing overall pressure on the remaining firms.

The key to industry wide effects of competitive pressure is that different sources of pressure are interdependent. As mentioned in section 2, one can distinguish three sources of competitive pressure on a firm. First, there is the number of the firm's opponents in the industry, second the level of efficiency of its opponents and third the way firms interact.

Only two forms of interdependent sources of pressure are considered here. Below the interdependence between the way firms interact and the efficiency level of firms is considered. The next example illustrates the interdependence between the way firms interact and the number of firms in the industry.

Example: Consider two firms facing demand of the form $p_i(x_i,x_j) = 1 - x_i - \theta x_j$ with i, j = 1, 2, $i \neq j$ and $0 \leq \theta \leq 1$. Firm 1 has constant marginal costs equal to $c_1 = 0.75$. Firm 2 can invest to reduce its constant marginal cost level according to the development function d(0.5) = 0, d(0.4) = 0.0276 and d(0.3) = 0.064. In words, firm 2 has marginal costs equal to 0.5 if it does not invest at all and marginal costs equal to 0.3 if it invests 0.064. Both firms have fixed costs equal to zero. One can check that the equilibrium outcomes for different values of pressure θ are as follows.

level of competition	cost level firm 2	entry decision firm 1
$\theta = 0.5$	$c_2 = 0.4$	firm 1 enters
$\theta = 0.7$	$c_2 = 0.3$	firm 1 enters
$\theta = 1$	$c_2 = 0.5$	firm 1 does not enter

Increasing pressure from $\theta = 0.5$ to 0.7 triggers more investment by firm 2 to reduce its costs. This is the Nickell/Porter effect of competition on productivity. Increasing pressure further from $\theta = 0.7$ to 1, pushes the inefficient firm 1 out of the market through the selection effect. The reduction in pressure on firm 2, due to the exit of its opponent, outweighs (trivially) the increase in θ and firm 2 invests less in development than at $\theta = 0.7$ and even less than at $\theta = 0.5$.

The example shows how a rise in θ can indirectly, through the selection effect, reduce overall competitive pressure on a firm. A policy example is that a reduction in trade barriers (for instance through the expansion of an import quotum) may eliminate inefficient firms in the domestic industry, thereby reducing overall pressure on the surviving domestic firms.

The generalization of this result is straightforward. Overall pressure can be reduced through the selection effect if the efficiency distribution is skew with a high proportion of firms so inefficient that they would be removed by the selection effect.

One would expect the selection effect on overall competitive pressure to be small in industries with a large number of firms and a small proportion of least efficient firms. In that case, a rise in pressure θ will not be outweighed by a fall in the number of firms in the market. Then the relevant indirect effect comes through opponents' efficiency levels. This is the case I turn to now.

The following model is essentially the Dasgupta and Stiglitz (1980) model with two important additional features. First, firms are asymmetric in their ability to reduce production costs. Second, I analyze the effects of a change in competitive pressure instead of looking at the correlation between concentration and research intensity. Admittedly the model is rather simplistic in its portrayal of fundamental research and development. In particular, although it is often stressed that uncertainty is a major ingredient in research and development, it is absent in the model here. The disadvantage of this approach is that fundamental research boils down to entry into a market. However, the advantage is that one can concentrate on the interaction between the two types of innovation studied here, namely research driven by profit levels and research driven by the first derivative of profits with respect to a firm's own cost level. The generality with which this interaction is analyzed is new in the literature.

Assume the number of agents is large enough that they can be modeled as a continuum $\Re_+$. As above, an agent i has an idea of a new good to introduce into the market and a development function d(c,i) to lower the constant marginal costs c of producing the good. The development function is twice continuously differentiable in both arguments and satisfies $\partial d/\partial c < 0$, $\partial^2 d/\partial c^2 > 0$ and $\partial^2 d/\partial c^2 > \partial^2 \pi/\partial c^2$. Further assume that agents are arranged in such a way that low i agents have (weakly) better ideas than high i agents in the sense that $\partial d/\partial i \geq 0$ and $\partial^2 d/\partial c\partial i \leq 0$. In words, the development costs and marginal development costs are nondecreasing in i.

Consider the following deterministic two stage game. In the first stage each agent $i \geq 0$ decides whether or not to enter the market and, if he enters, how much to invest to develop his product. In the second stage, the number of firms in the market and their cost levels are common knowledge. The firms produce output and choose independently and simultaneously their strategic variable (output or price level). The second period Nash equilibrium pay offs to agent i with cost level c_i are written as $\pi(c_i,c_{-i},I;\theta)$ where c_{-i} denotes the vector of cost levels of i's opponents, I is the total number of firms in the market and θ measures competitive pressure in the second stage. The total number of firms in the market is introduced explicitly as an argument of the profit function in order to facilitate the isolation of the selection effect below. Assume that the profit function is twice continuously differentiable in all its arguments. Examples of second stage games with their pay off functions can be found in section 2.1. In this section attention is focussed on how θ affects the Nash equilibrium outcome in the first stage.

Definition 5.1 (Nash equilibrium in the first stage)

For a given second stage profit function $\pi(c_i,c_{-i},I;\theta)$ and level of competitive pressure θ, the first stage Nash equilibrium is described by:

- cost levels c_i of entering agents and
- the last agent, denoted I, to enter the market

satisfying

(i) $c_i \in \operatorname{argmax}_c \{ \pi(c,c_{-i},I;\theta) - d(c,i) \}$

(ii) $\pi(c_I,c_{-I},I;\theta) - d(c_I,I) = 0$ and for each $I' > I$ it is the case that $\pi(c_{I'},c_{-I'},I';\theta) - d(c_{I'},I') < 0$.

That is, each agent i chooses cost level c_i that maximizes profits minus development costs. The last agent I to enter earns zero pay offs and agents $I' > I$ cannot profitably enter. Since this implies that the subset $[0,I]$ of agents are in the market, I measures indeed the total number of firms in the market. The following lemma shows that the arrangement of agents in line with the quality of their ideas is preserved in their Nash equilibrium cost levels c_i and overall pay offs $V_i \equiv \pi(c_i,c_{-i},I;\theta) - d(c_i,i)$, where the arguments c_{-i}, I and θ of c_i and V_i are suppressed for notational convenience.

Lemma 5.2

Cost levels c_i are nondecreasing in $i \leq I$ and V_i is nonincreasing in $i \leq I$.

Proof

The first order condition for 5.1 (i) can be written as $\partial\pi_i/\partial c_i - \partial d/\partial c_i = 0$. Implicitly differentiating with respect to i yields $\left(\frac{\partial^2\pi_i}{\partial c_i^2} - \frac{\partial^2 d}{\partial c_i^2}\right)\frac{dc_i}{di} - \frac{\partial^2 d}{\partial c_i \partial i} = 0$. Note that because agents have mass zero, there is no effect of i on c_{-i}. The assumptions made above on the development function d(.) yield the result $dc_i/di \geq 0$. Second, using the envelope theorem one gets $dV_i/di = -\partial d/\partial i \leq 0$.•

The next assumption makes sure that a rise in pressure θ is not completely offset by a fall in the number of agents in the market as in the example above. Thus it is possible to concentrate on the interaction of pressure θ and firms' efficiency levels.

Assumption 5.3 (small tail of least efficient firms)

For each $i < I$ it is the case that $\pi(c_i,c_{-i},I;\theta) - d(c_i,i) > 0$.

In other words, a small change $d\theta$ in θ only affects the entry decision of agent I due to the following continuity argument. By assumption, the profit function $\pi(.)$ and the development function d(.) are continuous. Since for each agent $i \neq I$ profits are either strictly positive or strictly negative, a small change $d\theta$ in θ will not turn positive profits into losses or the other way around. Hence, such a small change in pressure θ affects no agent's entry decision except for agent I. Because a set consisting of one agent has measure zero, assumption 5.3 makes sure that the indirect effect of θ via I can be ignored. Note that assumption 5.3 is satisfied if each agent has a different idea in the sense that $\partial d(c,i)/\partial i > 0$ for each i and c.

The next result gives sufficient conditions for the Nickell/Porter idea that a rise in competitive pressure increases industry wide development. However it shows that a rise in industry wide development is incompatible with a rise in fundamental research, measured by the total number of new products I introduced into the market. Because definition 2.1 (iii) implies that there are always good or weak firms in an industry, a rise in competitive pressure cannot raise both types of innovative behavior. Fundamental research is only stimulated by a rise in θ if it reduces development activity for a substantial number of agents.

<u>Proposition 5.4</u>

(i) If all firms are excellent or good with respect to θ and c_{-i} and further assumption 5.3 holds then it is the case that $dc_i/d\theta < 0$ for each $i \in [0,I\rangle$.

(ii) If $dc_i/d\theta < 0$ for each $i \in [0,I\rangle$ then $dI/d\theta \leq 0$;

(iii) $dI/d\theta > 0$ only if $dc_i/d\theta > 0$ for a sufficiently large set of agents i.

<u>Proof</u>

(i) Using the implicit function theorem it follows from the first order condition for 5.1 (i) that $\frac{dc_i}{d\theta} = \frac{1}{-\left(\frac{\partial^2 \pi_i}{\partial c_i^2} - \frac{\partial^2 d}{\partial c_i^2}\right)}\left(-\frac{\partial\left|\frac{\partial \pi_i}{\partial c_i}\right|}{\partial\theta} + \int_0^I \frac{\partial^2 \pi_i}{\partial c_i \partial c_j}\frac{dc_j}{d\theta}dj + \frac{\partial^2 \pi_i}{\partial c_i \partial I}\frac{dI}{d\theta}\right)$. The term $dI/d\theta = 0$[3] because, by assumption 5.3, the set of agents whose entry decision is affected by a small change $d\theta$ of θ has measure 0. Further, by the assumptions on d(c,i), it is the case that

$-(\frac{\partial^2 \pi_i}{\partial c_i^2} - \frac{\partial^2 d}{\partial c_i^2}) > 0$. Consequently one finds that

$$\mathrm{sign}\left(\frac{dc_i}{d\theta}\right) = \mathrm{sign}\left(-\frac{\partial\left|\frac{\partial \pi_i}{\partial c_i}\right|}{\partial\theta} + \int_0^I \frac{\partial^2 \pi_i}{\partial c_i \partial c_j}\frac{dc_j}{d\theta}\,dj\right). \tag{1}$$

Since, by assumption all firms are good or excellent with respect to θ, it follows that $\partial|\partial\pi_i/\partial c_i|/\partial\theta > 0$. Further, since they are good or excellent with respect to pressure as measured by a fall in their opponents' costs, it is the case that $\partial^2\pi_i/\partial c_i\partial c_j > 0$. Consequently $dc_i/d\theta < 0$ for each $i \in [0,I\rangle$.

(ii) For a given last agent I to enter the market, one gets using the envelope theorem

$$\frac{dV_I}{d\theta} = \int_0^I \frac{\partial\pi_I}{\partial c_i}\frac{dc_i}{d\theta}\,di + \frac{\partial\pi_I}{\partial\theta}. \tag{2}$$

By definition 2.1 (ii) and (iii), there is always at least one firm that is either good or weak, and if the same pressure variables are used for all firms, this is the firm with the highest cost level. Since lemma 5.2 implies that firm I has the highest cost level, it is good or weak with respect to pressure measured by both θ and c_{-I}. Consequently $\partial\pi_I/\partial c_j > 0$ and $\partial\pi_I/\partial\theta < 0$. Therefore the condition $dc_i/d\theta < 0$ for each $i \in [0,I\rangle$ implies $dV_I/d\theta < 0$. That is firm I leaves the market and $dI/d\theta \le 0$. Finally, if assumption 5.3 does not hold, one gets $dI/d\theta < 0$.

(iii) Because $dI/d\theta > 0$ only if $dV_I/d\theta > 0$, by equation (2) it must be the case that $\int_0^I \frac{\partial\pi_I}{\partial c_i}\frac{dc_i}{d\theta}\,di > 0$ since $\partial\pi_I/\partial\theta < 0$ for the least efficient firm in the market. By the argument above $\partial\pi_I/\partial c_i > 0$, therefore $dV_I/d\theta > 0$ can only happen if $dc_i/d\theta > 0$ for a sufficiently large set of agents i. •

Note that by definition 2.1 (iii), it is possible that all firms in the industry are either excellent or good. For most parameterizations of pressure this will imply that the efficiency distribution in the industry has a small variance. If there are firms that are far more efficient than their opponents (or far less efficient), then there are bound to be weak firms in the industry as well. In that case a rise in pressure θ will not necessarily lead to a rise in industry wide development.

Proposition 5.4 gives conditions under which all firms increase their development efforts, but has no concept of aggregate development. Hence it has nothing to say about aggregate efficiency in cases where some but not all firms increase or decrease their development investments. It is instructive to consider the following special case with a simple aggregate efficiency index.

<u>Assumption 5.5</u>

For each firm i the profit function is of the form $\pi(c_i,C,I;\theta)$, where C is an aggregate cost index satisfying[4] $\partial C/\partial c_i > 0$ for each $i \leq I$.

For instance, the profit function in example 3 of section 2 can be written in this form with cost index $C = \int_0^I c_i \, di$. Below, a rise in competitive pressure is said to increase aggregate efficiency if and only if $dC/d\theta < 0$. Further, the aggregate cost index C acts as a pressure variable itself, where a fall in C is interpreted as higher pressure on a firm.

<u>Proposition 5.6</u>

Under assumption 5.5 it is the case that

(i) $dC/d\theta < 0$ implies $dI/d\theta \leq 0$;

(ii) $dI/d\theta > 0$ implies $dC/d\theta > 0$;

(iii) if assumption 5.3 holds and if there exist values I_*, I^* satisfying $0 < I_* \leq I^* < I$

such that firms $i < I_*$ are good or excellent with respect to θ and C and firms $i > I^*$ are weak with respect to θ and C, then

$$dC/d\theta < 0 \text{ implies } \frac{d|c_j - c_i|}{d\theta} > 0 \text{ for each } j > I^* \text{ and each } i < I_*.$$

<u>Proof</u>

(i) By the envelope theorem, one finds that for a given last agent I to enter the market it is the case that $\frac{dV_I}{d\theta} = \frac{\partial \pi_I}{\partial C}\frac{dC}{d\theta} + \frac{\partial \pi_I}{\partial \theta}$. As in the proof of proposition 5.4 (ii), firm I is good or weak with respect to pressure variables C and θ. That is $\partial\pi_I/\partial C > 0$ and $\partial\pi_I/\partial\theta < 0$. Hence $dC/d\theta < 0$ implies that I leaves the market and $dI/d\theta \leq 0$.

(ii) More firms enter the market only if their profits rise, that is $dI/d\theta > 0$ only if $dV_I/d\theta > 0$. Since, as in (i), $\partial\pi_I/\partial\theta < 0$ and $\partial\pi_I/\partial C > 0$, it follows that $dV_I/d\theta > 0$ only if $dC/d\theta > 0$.

(iii) Since assumption 5.3 holds, it follows from equation (1) that

$$\operatorname{sign}\left(\frac{dc_i}{d\theta}\right) = \operatorname{sign}\left(-\frac{\partial\left|\frac{\partial \pi_i}{\partial c_i}\right|}{\partial\theta} + \frac{\partial^2 \pi_i}{\partial c_i \partial C}\frac{dC}{d\theta}\right). \tag{1'}$$

It follows that $dC/d\theta < 0$ implies $dc_i/d\theta < 0$ for each $i < I_*$ and $dc_i/d\theta > 0$ for each $i > I^*$.

Therefore $\frac{d|c_j - c_i|}{d\theta} > 0$ for each $j > I^*$ and each $i < I_*$.•

Results (i) and (ii) of this proposition imply that the combination $dC/d\theta < 0$ and $dI/d\theta > 0$ is impossible. This shows the trade off between aggregate development measured by C and fundamental research measured by I. A rise in pressure θ cannot both reduce C and increase I. The intuition for this is as follows. By definition 2.1 (iii), the least efficient firm in the market is weak or good with respect to pressure variables C and θ. Hence, if a rise in θ reduces aggregate costs C then both sources of pressure are increased and the least efficient firm's profits are reduced. Consequently, firm I leaves the market. A rise in θ can only raise fundamental research if it reduces aggregate efficiency. That is, due to the rise in θ, the aggregate cost index C is increased to such an extent that the profits of firm I are raised. In other words, for firm I the rise in θ is outweighed by the fall in pressure due to the fall in aggregate efficiency.

Result (iii) shows that if a rise in competitive pressure enhances aggregate efficiency, it can lead to polarization in efficiency levels. That is, as a result of a rise in θ low cost firms reduce their cost levels further while high cost firms invest less in development. Such a rise in θ splits the industry in the sense that leading firms are pushed further forwads, while lagging firms are pushed back in terms of their efficiency developments. This polarization effect may be a first step towards understanding the weak empirical correlation between competitive pressure and firms' development efforts. In the words of Nickell (1996:741): 'there exists some empirical evidence ... but it is not overwhelming. Indeed, the broad-brush evidence from Eastern Europe and Japan is, if anything, more persuasive than any detailed econometric evidence'. The polarization effect suggests to condition on a firm's position in the industry efficiency distribution. This reiterates the main message of this paper that a rise in competitive pressure affects firms' R&D incentives differently depending on their cost level relative to that of the other firms in the market.

Should a social planner increase competitive pressure to increase industry wide innovative activity? First, he should make sure that firms' efficiency distribution does not feature a relatively high number of inefficient firms that would be induced to exit by the selection effect. In that case, a small rise in competitive pressure may reduce overall pressure on the remaining firms. Second, it is not possible to raise both development and fundamental research by a rise in pressure. It will depend on the welfare function whether a social planner should increase pressure or not. For instance, in a starting industry it may the case that the knowledge generated by agents' fundamental research is complementary and hence variety is better than perfection. In this case, competitive pressure should not be increased. On the other hand, in a mature industry where most ground has been covered already, agents' fundamental research may be substitutes. Then a rise in pressure, by speeding up the shakeout through the selection effect, will release resources in the least efficient firms that can be used more effectively elsewhere in the economy. Further the fall in prices due to higher competition and the cost reductions of efficient firms will be welcomed by consumers.

6. Discussion and conclusion.

This paper has presented a framework encompassing previous work on competitive pressure. Two new insights have emerged from this framework. First, the effect of competitive pressure on a firm's innovative activity depends on the firm's efficiency level relative to the other firms in the industry. In other words, competitive pressure does not affect all firms in the same way. A rise in competitive pressure may raise some firms' incentives to innovate while at the same time reducing other firms' incentives. Second, a rise in competitive pressure cannot raise both fundamental research and development at the industry wide level. That is, a rise in pressure cannot increase both aggregate efficiency and the number of new products introduced into the market.

Admittedly, from an empirical point of view it may not be straightforward to distinguish the four categories of firms presented above. What is the critical cost level that separates good from weak firms? Yet, the framework above does have some clear empirical implications. First, one can test whether the development activity of firms in, say, the top decile of the cost distribution is affected differently by competitive pressure than the development activity of the more efficient firms in the industry. Although this is a rough approximation of weak firms, if the hypothesis is rejected that both groups of firms are affected in the same way, this can be interpreted as evidence supporting the analysis here. Second, one can test the polarization result. Is it the case after a rise in competitive pressure, say due to increased import competition, that the spread in efficiency levels of domestic firms is increased? And if the increased import competition has enhanced the aggregate efficiency level of domestic firms, is it the case that the least efficient firms drop out of the market? Such findings would be in line with the results in the previous section.

With respect to the results on fundamental research to create new products, I mention the following two qualifications. First, in the analysis above no explicit representation of the product space is offered and products are simply assumed to be different. Then a fall in profits due to a rise in pressure makes it less attractive to introduce a new product and fundamental research falls. However, if firms invest to explicitly position their products this result can be overturned. Suppose fundamental research is needed to move a product away horizontally from the industry standard, and more research is needed in order to move it further away. Then a rise in pressure may make it profitable to move further away from the standard to create your own niche in the market and fundamental research increases. Second, the framework above does not capture markets where first mover advantages are important. In that case, firms choose Stackleberg output/price levels, while the profit functions above are derived from Nash output/price equilibria. The effects of competitive pressure on fundamental research in these two cases is left for future research.

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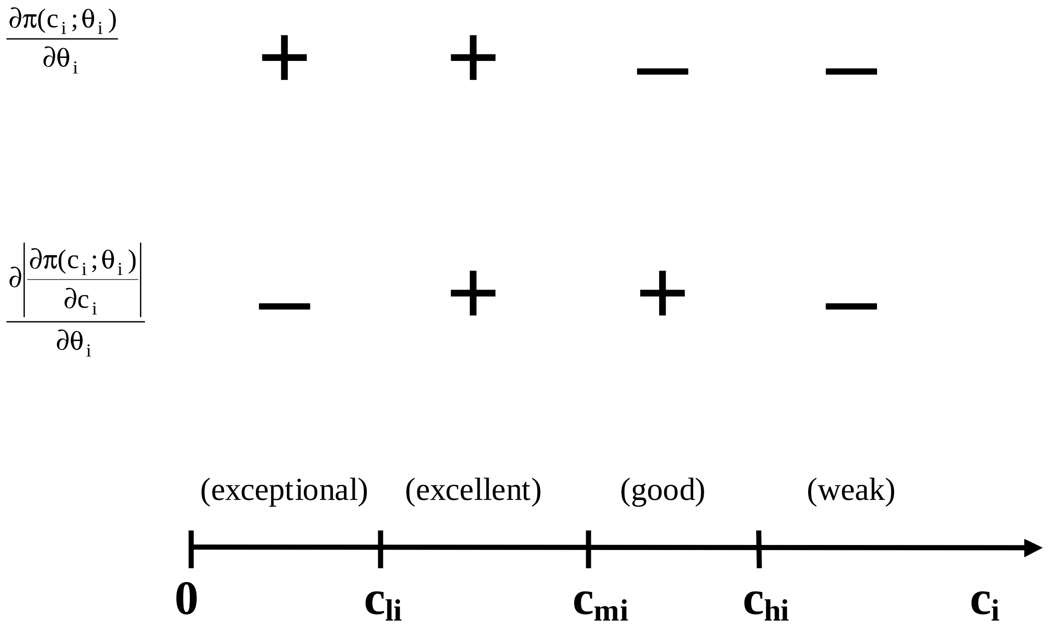
$\frac{\partial \pi(c_i;\theta_i)}{\partial \theta_i}$
+ + – –
$\frac{\partial \left| \frac{\partial \pi(c_i;\theta_i)}{\partial c_i} \right|}{\partial \theta_i}$
– + + –
(exceptional) (excellent) (good) (weak)
0 c_{li} c_{mi} c_{hi} c_i

Figure 1.

[1] Using the IO terminology, π is related to product innovation and $\partial\pi/\partial c$ to process innovation. I don't have strong preferences over which terminology is used. The important point is the distinction between innovations driven by profit levels and innovations driven by the steepness of a profit function.

[2] The possibility that $\partial c(\theta_n)/\partial\theta_n > 0$ is also identified by Schmidt (1997: 200) and Hermalin (1992: 353 and 1994: 527).

[3] To see this, let the indicator function e_i measure agent i's entry decision; with $e_i = 1$ if agent i enters and $e_i = 0$ if i does not enter. Then the number of firms in the market equals $I = \int_0^\infty e_i di$. If due to the change $d\theta$ in θ, only e_I changes (from 1 to 0) then $dI/d\theta = 0$.

[4] Note that for the results below no conditions are needed on how the number of firms I affects C. Presumably, one would like to assume that the aggregate cost index falls as inefficient firms leave the market, while it rises as the most efficient firms leave the market. Since only the effect of C on V_I is considered, such conditions are not needed below.