Knowledge Spillovers, Mergers and

Public Policy in Economic Clusters

by

George Norman[†§] and Lynne Pepall[‡]

Department of Economics
Tufts University
Medford
MA 02155

Abstract

This paper investigates the way market concentration affects research activity in an economic cluster. The firms in the cluster play a two stage Cournot game. In the first stage firms choose whether or not to engage in costly research that generates technological improvements that spill over perfectly to the other firms in the cluster. In the second stage, after the knowledge spillovers have occurred, firms compete in quantities. We solve for a symmetric mixed strategy equilibrium to the first stage of the game, and find that too low a degree of concentration destroys firms' incentives to undertake research. We then explore whether increasing concentration through merging can stimulate research activity in the cluster. Finally, we consider a public policy response to stimulate research and compare whether a direct public subsidy is preferable to a self-financing arrangement.

Keywords: agglomeration, research, perfect spillovers, mergers

JEL Codes: L10, O38

[†] Cummings Professor of Entrepreneurship and Business Economics, Tufts University.
[§] Corresponding author: Professor George Norman, Department of Economics, Tufts University, Medford, MA 02155, USA tel 617 627 3663, fax 617 627 3917, e-mail gnorman@emerald.tufts.edu.
[‡] Associate Professor of Economics, Tufts University.

1. Introduction

Knowledge spillovers commonly refer to productivity or product improvements in an industry that leave no paper trail. For example, knowledge spillovers could result from technical improvements such as changes in product design or capability, or upgrading production systems, or from developing new customers. These are improvements that cannot be patented, and therefore through spillovers can be implemented easily by other firms in the industry. Knowledge of these kinds of improvements spills over from one firm to another through various channels such as the movement of personnel, input suppliers, customers or informal meetings.

When firms are agglomerated in one geographic area these spillover channels are more readily accessible. As a result, clustering is viewed as a way to facilitate knowledge spillovers and improve the economic vitality of an industry. In the literature on economic geography and growth, knowledge spillovers are certainly regarded an important source of the positive externalities underlying and encouraging agglomeration. In the 1920's Marshall concluded that the reason so many firms making and machining steel were clustered around Sheffield was because there was something "in the air". More recently economists such as Krugman, Lucas and Porter argue that the chief economic advantage of being part of an economic cluster such as Hollywood, Silicon Valley or Madison Avenue is the informal knowledge that buzzes around such places. Audretsch (1998) further argues that the key to innovative activity lies in the knowledge spillovers in an economic cluster.

Irrespective of how easily knowledge spills over from one firm to another it is still the case that creating the knowledge in the first place is a costly activity. A firm's incentive to incur this cost is affected in two conflicting ways by how many other firms there are in the cluster. On the one had, there is an adverse effect because the firms can free ride on each other's costly effort. On the other hand, having many firms in the cluster can benefit or enrich research activity. The greater the numbers of firms engaged in the discovery of technological, product and/or process improvements, the richer is the pool of potential knowledge available to them all and hence the greater is the potential welfare gain to the industry.[1]

One way to resolve these incentive problems is to allow firms to cooperate in R&D in order to internalize the spillover effects, (see for example, De Bondt and Veugelers, 1991, Kesteloot and Veugelers, 1994). This form of cooperation implicitly assumes that research effort is contractible and enforceable. However, the type of research effort that gives rise to informal knowledge or "what's in the air" is more likely to be effort that is non-contractible and non-enforceable. How then does the knowledge "get into the air"? Does agglomeration always work to create these knowledge spillovers or are there industries or economic clusters that risk stagnation? If so, what can be done about it? These are the questions that motivate our paper.

We examine the conflicting effects of market concentration on R&D activity in the presence of *perfect* knowledge spillovers in a symmetric Cournot model. More precisely, we consider an economic cluster in which there is some endogenously determined number N of identical Cournot firms that play a two-stage game. In the first stage the firms choose whether or not to engage in costly research that generates technological improvements that spill over perfectly to other firms in the cluster. The improvements can have either a cost-reducing or demand-enhancing effect for the firms in the cluster. In the second stage, once the knowledge spillovers have occurred, the firms compete in quantities.[2]

---

[1] Some of these conflicting effects are documented in the extensive literature on R&D. See, for example, Dybvig and Spatt (1983), Spence (1984), Katz (1986), d'Aspremont and Jacquemin (1988), Kamien *et al.* (1992), Leahy and Neary (1997).

[2] The assumption of quantity competition among firms producing perfect substitutes may seem at odds with what we know about agglomeration or economic clusters. Clusters often contain firms producing complementary

If only some firms engage in costly research while others do not then, because of the spillovers, there would be a marked asymmetry in profitability among the firms, which, with free entry, would destroy the incentive to undertake the research. It is more sensible, therefore, to solve for a symmetric mixed strategy to determine which firms engage in costly research. This seems particularly appropriate for firms in an economic cluster. Such firms all benefit from watching each other and sharing technical information. At the same time, they will find it difficult if not impossible to keep technical information private. In this context it seems reasonable to treat each firm as contributing to the information pool with some probability q_i. All the firms benefit from this first stage research when they compete in the second stage quantity game.

A mixed strategy solution can be interpreted here as a loose form of cooperation among firms. Moreover, because this type of R&D effort is likely to be non-contractible or non-enforceable, a mixed strategy solution is a preferable way to understand how informal or implicit cooperation among firms can arise when there are spillovers. It stands in sharp contrast to the usual approach in the R&D literature of assuming a contractible cooperative agreement among firms to internalize spillover effects.

When we solve for the equilibrium probability that a firm engages in costly research we find, not surprisingly, that too low a degree of market concentration destroys the firm's incentives to generate knowledge spillovers. In other words, there is some critical concentration index below which there is no profit incentive for an individual firm to undertake research – q_i^* equals zero – leading to market stagnation.

---

products or services. However, the welfare gain of R&D with perfect spillovers and the effect of concentration on this gain are the same whether we assume price competition among firms producing perfects complements or quantity competition among firms producing perfect substitutes.

Coalition formation, for example through merger among firms, offers one potential mechanism to restore the incentive to modernize. A familiar property of the Cournot model, however, is the merger paradox. Mergers are unprofitable, and so will not occur, unless they involve sufficiently many firms in the market (Salant, Switzer and Reynolds, 1983). The reason why is simple enough to see. The firms that stay out of the merger are able to increase their market share in the post-merger game. This response undermines the profit incentive for firms to merge or form a coalition in the first place. However, when knowledge spillovers are an important part of the picture there is an additional twist. Now it is possible that merger could trigger the incentive to undertake costly research in the market, not only by the firms that merge *but also* by the remaining firms. The merged firms then benefit through knowledge spillovers from the research activities of the non-merged firms.

The idea that mergers give rise to synergies is a popular one. Traditionally economists have focused on whether mergers create cost synergies arising from economies of scale or scope in the firms that merge. In this paper the way that mergers generate cost synergies is different and novel. Mergers increase concentration in the economic cluster and in doing so trigger the incentive among firms to seek ways to modernize, make improvements and generally "get with it". The resulting productivity and product improvements lead to cost savings that benefit all the firms, not just those that merge. As a result, merger or coalition formation is a potential mechanism to safeguard the vitality and competitive edge of the economic cluster. Another implication of our analysis is that, provided R&D is sufficiently productive, in a sense that we establish below, mergers or alliances of few firms can be profitable, socially desirable *and* Pareto improving. This stands in contrast to Gaudet and Salant (1992) who find that "in the case of linear demand, in the absence of (savings in) fixed costs, all mergers in quantity competition are socially undesirable" (Gaudet and Salant, 1992, p. 152).

Despite the potential benefits that can flow from mergers, it must be recognized that merger is an uncertain mechanism, particularly in the kinds of markets we have in mind in which entry is likely to be relatively easy and concentration is low. In these circumstances, public policies to subsidize R&D costs would appear to be the only mechanism by which industrial stagnation can be avoided.

There are public policies whose goal is to make new technologies accessible and to provide management consulting services to small firms. In the U.S. the most common public program is the establishment of manufacturing technology centers (MTCs) for small manufacturing firms.[3] The business service centers serving small firms in the economic clusters in Emilia-Romagna, Italy, as well as the U.S. agricultural extension model, whose services have been viewed as a public good for technology transfer in the agricultural sector, have inspired this kind of public assistance to small firms.[4] Under current legislation federal funding for MTCs is of limited duration and there is some question whether the goal of a self-financing MTC is sustainable and/or desirable.[5] We show that the effectiveness of these types of policies and the desirability of alternative methods of funding cannot be judged without some consideration of their likely effects on market structure. Simply put, failure to account for the relationship between market forces and market structure is likely to lead to inappropriate public policy.

[3] For a survey of the existing technological programs that assist small firms including MTCs refer to Shapira (1993).
[4] See Feller (1993) regarding the agricultural extension model and Bianchi and Gualtieri (1990) for a study of the Emilia-Romagna model and its influence on European regional development policy.
[5] Since 1988 the funding of MTCs comes from the budget of the National Institute of Technology and Standards and was originally provided for a six-year period. Feller (1993) questions the goal of self-financing MTCs.

The remainder of the paper is structured as follows. In the next section we describe our model of how knowledge is created and spills over in an economic cluster. After solving for the mixed strategy equilibrium we then identify two critical levels of market concentration. The first is the level of concentration above which firms in the cluster undertake research with certainty while the second is the level of concentration below which no firms undertake research. In section 3 we consider whether there is a profit incentive among firms in the cluster to merge in order to restore the economic vitality of the cluster. Section 4 considers the role of public policy to stimulate research and the importance of designing appropriate mechanisms to fund the research. Our main conclusions are presented in the final section.

2. A Cournot Model of Knowledge Spillovers and Competition

We assume that the market contains N firms that produce an identical product and act as Cournot competitors. A free-entry process determines N. Inverse demand for the firms' product is assumed to be linear and given by:

(1) $P = A - Q$

where P is product price and Q is aggregate output; $Q = \sum_{i=1}^{N} q_i$. Production costs for each firm exhibit economies of scale and are given by:

(2) $C(q_i) = F + c.q_i$

where F are fixed costs. The firms play a two-stage research/quantity game. In the first stage the firms choose whether or not to engage in costly research activities and in the second stage they compete in quantities. We look for a subgame-perfect equilibrium to this game.

Consider first the benchmark case in which *no* firm chooses to undertake research. From standard analysis we know that each firm produces the Cournot-Nash equilibrium output $q_i^C = \dfrac{A-c}{N+1}$, the equilibrium product price is $P^C = \dfrac{A+Nc}{N+1}$, individual firm profits are

$\pi_i^C = \frac{(A-c)^2}{(N+1)^2} - F$ and consumer surplus is $CS^C = \frac{N^2(A-c)^2}{2(N+1)^2}$. It follows that $(A - c)^2$ is a measure of the potential surplus in the market.

We could instead assume that the N firms in the cluster produce perfect complements and compete in prices.[6] In this case Q denotes the number of packages of the N complementary goods demanded, while the price $P = \sum_{i=1}^{N} p_i$ is the aggregate of the prices set by the firms for their N goods. Standard analysis gives the Bertrand-Nash equilibrium price $p_i^B = \frac{A-c}{N+1}$ and each firm earns profit $\pi_i^B = \frac{(A-c)^2}{(N+1)^2} - F$. Once again the term $(A - c)^2$ is a measure of market surplus and it is the impact of R&D on this term that is important in what follows.

Without loss of generality we normalize this measure of surplus by assuming that $(A - c)^2 = 1$. Suppose now that the firms can engage in research in the first stage. To do so, each firm that engages in research must incur a fixed cost r. The outcome of such research is assumed to be uncertain. Specifically, we assume that when a firm does research it receives a draw from a uniform distribution on some interval $[0, S]$, with this draw measuring the increase in market surplus that the firm's research generates. This increase in surplus can be assumed to arise either through process innovation that reduces production costs or through product innovation that increases the consumers' willingness to pay. In either case, if the firm's draw is s then its research increases our normalized measure of surplus to $1 + s$.

[6] Sonnenschein (1968) and Gaudet and Salant (1992) explore the equivalence between quantity competition among perfect substitutes and price competition among perfect complements.

Because spillovers are assumed to be perfect, the only draw that will be implemented is the maximum draw, which we denote $s(n)$, where n is the number of firms engaged in research. The expected value of this maximum is:

(3) $$s(n) = \frac{n}{n+1}S.$$

As we would expect the greater the number of firms that engage in research, the greater is the expected value of the maximum draw. In addition, and again as a result of perfect spillovers, the expected profit to each firm, ignoring research expenditures, is:

(4) $$E\pi_i(N,n) = \frac{1+s(n)}{(N+1)^2} - F\ .$$

Because *all* firms benefit from research there is a potential free rider problem in the first stage game. Furthermore, because all the firms are identical a pure strategy solution in which some firms do research and others do none is not a desirable solution concept. Instead we look for a mixed strategy solution in which each firm in the market undertakes research in the first stage with some probability q_i. Such a mixed strategy solution implies that the number of firms n that undertake research is a random variable. In turn, the expected gain in market surplus $s(n)$ is also a random variable, drawn from a binomial distribution.

What is a firm's profit incentive to undertake research in this type of market environment? Without loss of generality, we can consider the research decision of firm 1. Assume that firm 1 undertakes research with probability q while the remaining $N-1$ firms each undertake research with probability $\bar{q}$. The probability that exactly $N-j$ firms undertake research is $q(N-j) = q\binom{N-1}{j}\bar{q}^{N-1-j}(1-\bar{q})^j + (1-q)\binom{N-1}{j-1}\bar{q}^{N-j}(1-\bar{q})^{j-1}$ and the expected value of this research is, from (3), $q(N-j)\dfrac{N-j}{N-j+1}$. It follows that the expected profit to firm 1, ignoring fixed costs, is:

$$E(\pi_1(N,q,\bar{q},S,r)) = \frac{1}{(N+1)^2}\Bigg[1+S\Bigg[q.\bar{q}^{N-1}\frac{N}{N+1}+ \sum_{j=1}^{N-1}\left(\left(q\binom{N-1}{j}\bar{q}^{N-1-j}(1-\bar{q})^j+(1-q)\binom{N-1}{j-1}\bar{q}^{N-j}(1-\bar{q})^{j-1}\right)\left(\frac{N-j}{N-j+1}\right)\right)\Bigg]\Bigg] -q.r \tag{5}$$

In a symmetric Nash equilibrium, firm 1's mixed strategy is such that when the other $N-1$ firms do research with probability $\bar{q} = q^*$ then firm 1's best response is to choose $q_1 = q^*$. In other words, the equilibrium probability q^* of firm 1 engaging in research in the first stage must satisfy the first order condition $\left.\dfrac{\partial E(\pi_1(N,q,q^*,S,r))}{\partial q}\right|_{q=q^*}=0$. Differentiating (5) with respect to q gives:

$$\frac{\partial E(\pi_1(N,q,\bar{q},S,r))}{\partial q} = \frac{S}{(N+1)^2}\left[\bar{q}^{N-1}\frac{N}{N+1}+ \sum_{j=1}^{N-1}\left(\left(\binom{N-1}{j}\bar{q}^{N-1-j}(1-\bar{q})^j-\binom{N-1}{j-1}\bar{q}^{N-j}(1-\bar{q})^{j-1}\right)\left(\frac{N-j}{N-j+1}\right)\right)\right]-r.$$

This simplifies to:[7]

$$\frac{\partial E(\pi_1(N,q,\bar{q},S,r))}{\partial q} = \frac{1-(1-\bar{q})^N(1+N.\bar{q})}{N(1+N)^3\bar{q}^2}S-r\,. \tag{6}$$

It is convenient to define the parameter $\rho = r/S$, so that ρ is the ratio of the cost of research r to the maximum potential benefits of research S. By equating (6) to zero and solving

[7] These and other calculations have been performed using *Mathematica* and *Matlab*. Details can be obtained from the authors on request.

for $\bar{q}$ we can in principle solve for an interior solution to the Nash equilibrium probability, denoted $q^*(N, \rho)$, with which each firm in the market undertakes research.

Since the condition $\frac{1-(1-q)^N(1+N.q)}{N(1+N)^3 q^2} = \rho$ is a polynomial of degree $N - 1$ in q, an analytical solution for $q^*(N, \rho)$ can be provided only for $N = 2$, 3, 4 or 5. (These solutions are detailed in the Appendix for $N = 2$, 3 and 4.) For $N > 5$ we must rely upon numerical techniques or on an approximate solution to equation (6). Table 1 gives $q^*(N,\rho)$ for a range of values of N and ρ.

(Table 1 near here)

Substituting in equation (5) and simplifying gives expected profit to each firm:

(7) $$E\pi_i^*(N,S,r) = \frac{(1+S)q^*(N,\rho)(N+1) - S\left(1-(1-q^*(N,\rho))^{N+1}\right)}{(N+1)^3 q^*(N,\rho)} - r.q^*(N,\rho) - F .$$

From equation (6) we can show that $\partial q^*(N,\rho)/\partial N < 0;\ \partial q^*(N,\rho)/\partial r < 0; \partial q^*(N,\rho)/\partial S > 0$. The probability with which each firm undertakes research is a decreasing function of the cost of research r, a decreasing function of the number of firms in the cluster and an increasing function of the maximum potential returns to research S.

If $q^*(N, \rho) = 0$ we have the case in which *no* firm in the market engages in first stage research. This condition arises when $\left.\frac{\partial E(\pi_1(N,q^*,q^*,S,r))}{\partial q}\right|_{q^*=0} \leq 0$, or when:

(8) $$\frac{S}{2(N+1)^2} \leq r \Rightarrow N \geq \sqrt{\frac{S}{2r}} - 1 = \sqrt{\frac{1}{2\rho}} - 1.$$

This equation has a simple interpretation. If a firm's expected increase in profit from research, given that it is the only firm to undertake research, is less than the cost of research, then no firm has an incentive to undertake the research. It is here that we see the familiar downside of research spillovers. When a firm is the only one to undertake research, it can expect in the second stage to appropriate only a $1/(N + 1)^2$ share of the benefit. As a result, the greater is N the less is the benefit to a firm from its costly research. This leads to the equivalent interpretation of (8), that we are likely to see research stagnation in markets with low levels of concentration, or in which the ratio of the rewards to research to the costs of research, $S/r = 1/\rho$, is low.

By contrast, each firm undertakes research with certainty, i.e. $q^*(N, \rho) = 1$, if:

(9) $$N(1+N)^3 \leq 1/\rho .$$

There is a level of industry concentration above which the synergies from research dominate the temptation to free ride on the efforts of other firms. Alternatively, research activity can be stimulated provided that the research reward/cost ratio is sufficiently high.

These results can be summarized as follows:

Theorem 1: Define $\rho = r/S$, let $\underline{N}$ be the solution to $N(1 + N)^3 = 1/\rho$ and let $\overline{N} = \sqrt{1/2\rho} - 1$. The Nash equilibrium probability with which each firm engages in research is $q^*(N, \rho)$, where:

(i) $q^*(N, \rho) = 1$ for $N \leq \underline{N}$;

(ii) $q^*(N, \rho) = 0$ for $N \geq \overline{N}$;

(iii) $q^*(N, \rho)$ is the solution to $\dfrac{1-(1-q)^N(1+N.q)}{N(1+N)^3 q^2} = \rho$ for $\underline{N} < N < \overline{N}$.

Theorem 1 sheds new light on the concept of critical mass used by Porter (1988) to define an economic cluster.[8] In our analysis, the number of firms in the cluster must be less than $\overline{N}$ for the cluster to have the knowledge dynamism underlying competitive success.

Theorem 1 also suggests that when barriers to entry to the cluster are relatively low, entry could destroy the incentives to undertake research and generate knowledge spillovers. Suppose that the number of firms N in the cluster is determined by free-entry. Then if *no* firms undertake research the equilibrium number of firms is:

$$(10) \qquad N^0 = \sqrt{\frac{1}{F}} - 1.$$

It follows from (8) and (10) that if the sunk cost $F < 2\rho$ then the equilibrium number of firms is $N^0 > \overline{N}$. In such cases, entry barriers to the market are sufficiently low that free entry destroys the incentives of the entrants to undertake research. Simply put, when cost and entry conditions result in an industry becoming very fragmented, the appropriability problem characteristic of research spillovers undermines each firm's incentive to engage in modernization programs. Such industries stagnate and fail to modernize. It is tempting to suggest that the restaurant and cleaning industries are obvious examples.

3. Mergers and Economic Clusters

We have seen that excessive fragmentation in the market destroys the incentives to undertake the research that is key to the cluster's success. By contrast, an increase in market concentration can restore these incentives. Merger of firms in the cluster is an obvious way to increase market concentration but mergers will fail to occur endogenously unless two conditions are satisfied.

---

8 Porter (1998) defines clusters to be "critical masses – in one place – of unusual competitive success in particular

First, mergers will not arise unless we depart from our free-entry assumption and suppose that post-merger entry is effectively blockaded. The reason is simple to see. Merger of M firms initially reduces the market to $N - M + 1$ firms but then it is profitable for a further $M - 1$ firms to enter the market. The merging firms are, in effect, replaced, guaranteeing that the merger is unprofitable and so does not occur. Secondly, mergers may not be profitable even with blockaded entry because of a free-riding problem first noted in Stigler (1950) and later investigated in Salant, Switzer and Reynolds (1983) and Kamien and Zang (1990). Salant, Switzer and Reynolds show that in the type of linear, symmetric Cournot model we have specified, a merger of M firms in an initial N firm market is unprofitable unless $M > 0.8N$ i.e. unless at least 80% of the firms in the market join the merged entity. The reason is simple enough to see. The firms that stay outside the merger are able to benefit from the merger by increasing their market share and their profits since there is no way that the merged firm can effectively take advantage of its potentially increased size. This externality undermines the profitability of the merger unless sufficiently many firms merge.

In our Cournot model with knowledge spillovers there is an additional twist that has not been considered. Assuming that entry is blockaded, it is possible that a merger could trigger the incentive for firms in the economic cluster to engage in research. In other words, knowledge spillovers introduce a profit incentive for firms to merge that reduces the “80% barrier”. A merger of M firms increases industry concentration. Provided that the new number of firms in the market, $N - M + 1$, is less than $\overline{N}$ the merger induces research by the merged firms *and* by the firms that remain outside the merger. The merged firms then benefit through research spillovers from the non-merged firms.

---

fields” and cites Silicon Valley and Hollywood as being the world’s best known clusters.

There are four parameters in our model that affect the analysis of the profitability of mergers: N, F, r and S. We can, however, simplify the investigation considerably by making the following assumptions in order to eliminate F and r. First, we assume that a free-entry process has determined the pre-merger number of firms in the market such that each firm just breaks even. Secondly, we assume that equation (8) is satisfied with equality i.e. each firm, at the margin, just chooses not to undertake research. These assumptions imply that $F = F(N) = 1/(N+1)^2$ and that $r = r(N,S) = S/2(N+1)^2$. When these two assumptions hold we can identify the minimum number of firms $\underline{M}(N, S)$ that have to merge for the merger to be profitable. The complicated nature of equations (5) – (7) requires that we employ numerical techniques.

Table 2 identifies $\underline{M}(N, S)$ for a range of values of N and S. We also report for comparison the lower limit $\underline{M}(N)$ on the number of firms that have to merge for the merger to be profitable in the absence of research spillovers. Table 3 identifies the post-merger equilibrium probability of research, $q^*(N_m, \rho)$, where $N_m = N - \underline{M}(N, S) + 1$ is the post-merger number of firms.[9] In other words, if the minimum number of firms $\underline{M}(N, S)$ merge, Table 3 describes what happens to the probability with which the remaining number of firms in the cluster undertake research. (Recall that the pre-merger probability is $q^*(N, \rho) = 0$.)

(Tables 2 and 3 near here)

Not surprisingly, mergers induce the firms in the market to undertake research, with the equilibrium probability $q^*(N_m, \rho)$ of doing research being an increasing function of post-merger market concentration. It is also not surprising that the proportion of firms $\underline{M}(N, S)/N$ that have to

[9] The associated values of F and r are given in the Appendix, Tables A.1 and A.2. Recall also that, given our assumptions, $\rho = F/2$.

merge for the merger to be profitable is decreasing in S, the potential returns to research, and that the proportion of firms that need to be involved in the merger for the merger to be profitable is generally less than the 80% limit.

What is, on first sight, rather more surprising is that the proportion of firms, $\underline{M}(N, S)/N$, required to make a profitable merger is *decreasing* in N, the initial number of firms in the market. Merger is more likely in clusters with many firms. By contrast, the proportion $\underline{M}(N)/N$ of firms required for a profitable merger when there are *no* research spillovers is an *increasing* function of N for $N \geq 5$.[10] In other words, the presence of research spillovers implies that the size barrier for a merger to be profitable is lower in less concentrated markets. These are precisely the markets that are at risk of stagnation and for which merger or coalition formation could be the answer.

This outcome reflects a balance between two sets of externalities. In the absence of research spillovers, mergers create significant external benefits for the outside firms, with the result that profitable mergers have to be *larger* in less concentrated markets. By contrast, when knowledge spillovers are present mergers induce insiders and outsiders to undertake research. This creates a reverse spillover from the outsiders to the merged firms that is stronger the larger the number of outsiders. These knowledge spillovers more than offset the external benefits of a merger, leading to the outcome we have noted.

An important question that we have not considered in discussing mergers in the presence of knowledge spillovers is whether profitable mergers are socially desirable. When no consideration is allowed for the impact of mergers on research activity, we have the strong conclusion that all mergers in quantity competition are socially undesirable (Gaudet and Salant,

[10] Ignoring the integer constraints there is a strictly decreasing relationship between N and $\underline{M}(N, S)$ for $N \geq 5$.

1992). This is not the case once we introduce knowledge spillovers between the merged and non-merged firms. Rather, we have the following:

Theorem 2: Assume a profitable merger of exactly $\underline{M}(N, S)$ firms. There is a value of S, denoted $\underline{S}$, such that for $S > \underline{S}$ all such profitable mergers increase total surplus.

The possibility that mergers can increase total surplus by inducing research that would otherwise not take place has implications for merger policy. These implications might be argued to be rather limited given that the primary focus of the anti-trust authorities tends to be on how consumers are affected by merger activity rather than on total surplus. However, the presence of research spillovers allows us to state an even stronger result.

Theorem 3: Assume a profitable merger of exactly $\underline{M}(N, S)$ firms. There is a value of S, denoted $\bar{S}$, such that for $S > \bar{S}$ a merger of $\underline{M}(N, \bar{S})$ firms is profitable for insiders and outsiders *and* increases consumer surplus.

What Theorem 3 tells us is that, if the maximum gains to research are great enough, a merger of $\underline{M}(N, \bar{S})$ firms is Pareto improving. The intuition is simple to see. When $S > \bar{S}$, the potential returns to research are sufficiently great that the tendency for the merger to increase prices is more than offset by the additional research to which the merger gives rise.[11]

Table 4 gives approximate values for $\underline{S}$ and $\bar{S}$ indicating that both $\underline{S}$ and $\bar{S}$ are decreasing in N. Mergers are more likely to be Pareto improving when the market is initially fragmented because of the strong research synergies to which the merger gives rise.

(Table 4 near here)

[11] This is reminiscent of the work of Farrell and Shapiro (1990), who indicate that a profitable merger in a Cournot market increases prices unless it generates “cost synergies”. A merger that induces research does, indeed, have cost synergies.

4. Public Policy and Research Activity

While the discussion of the previous section indicates that coalition formation may both induce research activity and lead to Pareto improving welfare gains, we have also seen that they will be effective only if post-coalition entry to the market does not occur. Suppose that this condition is not satisfied. The interesting question then is whether we can find a public policy approach that both stimulates research activity and can be justified on social welfare grounds.

One example of such a public program is a Manufacturing Technology Center (MTC). An MTC coordinates the research activities of the industry and helps transfer the technology to the participating firms. This kind of public policy program in the U.S. was inspired by the agricultural extension model, whose services have been viewed as a public good for technology transfer in the agricultural sector. The business service centers of Emilia-Romagna in Italy serve a similar role and have been models for public assistance to small manufacturing firms elsewhere in Europe.

We contrast two possible policy approaches. First, the public authorities may attempt to stimulate research through direct subsidy with no attempt at recovery of the subsidy. Alternatively, the intention may be to make the research self-financing by requiring that all firms in the market subscribe to research costs, perhaps through a lump-sum tax of r.

Consider first direct subsidy. Then all firms in the market face research costs of zero and so undertake research with certainty. The expected profit of each firm is:

$$E\pi_i^s(N,S,F)=\frac{1+\dfrac{N}{N+1}S}{(N+1)^2}-F. \tag{11}$$

Given that entry is not blockaded, the post-subsidy equilibrium number of firms N^s is such that $E\pi_i^s(N^s, S, F) \geq 0 > E\pi_i^s(N^s+1, S, F)$. Comparison of (10) and (11) indicates that $N^s > N^0$. The subsidy, by stimulating research activity, encourages entry to the market.

Assume instead that research is self-financing, perhaps by requiring that each firm in the market underwrites research costs through a lump-sum tax of r. Once again, this results in the firms undertaking research with certainty since r becomes effectively a sunk cost of entry, with the result that the expected profit of each firm is now:

$$(12) \qquad E\pi_i^f(N, S, F, r) = \frac{1 + \frac{N}{N+1}S}{(N+1)^2} - r - F.$$

Denote the free-entry number of firms in this case as N^f. Assume also that, in the absence of the research subsidy, $r = r^0 = S/2(N^0+1)^2$. This implies that each firm just fails to undertake research at the free-entry equilibrium with no research stimulus. It then follows that:

$$(13) \qquad E\pi_i^f(N^0, S, F, r^0) = \frac{(N^0-1)S}{2(N^0+1)^2} > 0.$$

In this case, $N^f > N^0$ and self-financing of research leads to additional entry. This need not, however, always be the case. It is easy to see that:

$$(14) \qquad E\pi_i^f(N^0, S, F, r) = \frac{\left(N^0 S - (N^0+1)^3 r\right)}{(N^0+1)^3} < 0 \Rightarrow r > \frac{2N^0}{N^0+1} \cdot r^0.$$

In other words, for r “large enough”, the effect of compelling firms to subscribe to research costs might actually be such that $N^f < N^0$ with the result that self-financing of research leads to less entry.

The fact that attempts to stimulate research in the presence of knowledge spillovers may either increase or decrease entry to the market is not, of itself, sufficient to indicate whether this type of policy is socially desirable. What is necessary is to identify the impact of the policy on total surplus. If we maintain our free-entry assumption and assume that $r \geq r^0$, total surplus prior to the research policy is consumer surplus with N^0 firms:

$$(15) \qquad TS^f\left(N^0, S\right) = \frac{1}{2}\left(\frac{N^0}{N^0+1}\right)^2.$$

With the research policy, no matter how it is financed, total surplus is consumer surplus minus the costs of the research:

$$(16) \quad TS^f\left(N^m, S, r\right) = \frac{\left(N^m\right)^2}{2} \cdot \frac{\left(1+\frac{N^m}{N^m+1}S\right)}{\left(N^m+1\right)^2} - N^m r$$

where N^m is the free-entry equilibrium number of firms with the research policy, so that $N^m = N^s$ or N^f depending upon how the research is financed.

Consider first the situation in which research costs are $r = r^0$, so that each firm just chooses not to undertake research without the research policy. Then establishing the research policy induces entry no matter how it is financed. Moreover, we can show[12] that the impact on total surplus is such that:

$$(17) \qquad TS^f\left(N^s, S, r^0\right) > TS^f\left(N^f, S, r^0\right) > TS^f\left(N^0, S\right).$$

Theorem 4: Assume that $r = r^0$. Then establishing a research policy induces entry and increases social surplus no matter how it is financed. However, public subsidy of research is preferable to a self-financing arrangement.

[12] This was done by extensive grid search using *Mathematica*. Details can be obtained from the authors on request.

When research costs are this low, the additional entry that arises from public subsidy of research as compared to self-financing (and the no-policy equilibrium) more than justifies the additional research costs that are incurred.

Once we allow for research costs to be higher than r^0 we find a very different situation. For r close to r^0, Theorem 4 continues to hold, with the result that public subsidy of research is socially desirable. However, with more expensive research activity, the additional entry induced by public subsidy becomes increasingly costly, making this form of subsidy less desirable. Nevertheless, a self-financing research policy may still be socially desirable. In such cases, the benefits of research activity more than offset both their costs and the increased market concentration the self-financing arrangement induces. Finally, there will be a point at which research costs are sufficiently high that no form of public intervention can be justified.

This is illustrated in Figure 1. When research costs are r^1, total surplus with public funding of research is ***a***, self-financing of research gives total surplus of ***c*** and the no-research total surplus is ***e***. Now assume that research costs are r^2. This reduces the total surplus of the research policy from TS_r^1 to TS_r^2. There is no impact on the no-research equilibrium, or on the free-entry number of firms with public subsidy of research. However, the total surplus from public subsidy is decreased to ***b***. If the research policy is self-financed, the free-entry equilibrium number of firms is reduced from N_1^f to N_2^f and total surplus is reduced from ***c*** to ***d***. In the case illustrated, self-financing of research is socially desirable but public subsidy is not.

(Figure 1 near here)

Figure 1 implies the following relationship between research costs and the desirability of government policies to stimulate research:

(i) when research costs are relatively low (near to r^0), public subsidy is preferred;

(ii) at intermediate values of research costs, self-financing is preferred;

(iii) at high values of research costs neither type of research policy can be justified.

This is consistent with the kinds of situations in which government programs to stimulate research have been advocated. These are generally intended to stimulate research activity by small manufacturing firms that find it difficult, if not impossible, to protect their research findings. This is just the kind of environment in which research costs are likely to be relatively low and so in which public funding of research will be beneficial.

5. Conclusion

This paper builds upon an important theme in economic geography and growth: that knowledge spillovers are a key source of the positive externalities underlying agglomeration. Knowledge spillovers are product or productivity improvements that can easily be implemented by all firms and therefore lead to an increase in the market surplus of the entire cluster. Nevertheless, creating the knowledge in the first place is costly for a firm. Because of free riding effects there is an adverse impact on research activity from having too many firms in the cluster. On the other hand the greater the number of firms actively engaged in discovering new ways of doing things the richer is the potential pool of knowledge and knowledge spillovers. Finally because the effort leading to the discovery of knowledge is non-contractible there is little scope for formal cooperative agreements among firms in a cluster.

The tension between competition and cooperation in an economic cluster affects very much whether there is “something in the air”. We have in this paper modeled how this tension underlies the creation of knowledge spillovers in an economic cluster, and specifically, what is the effect of market concentration on the likelihood that a firm puts “something in the air.” If concentration is sufficiently low, the private profit incentive is too weak for firms to expend resources on research efforts. Increased concentration, perhaps through a merger of some of the firms, is necessary to stimulate research activity. We have identified the circumstances in which such a merger is profitable. In addition we have shown that there are circumstances in which mergers are not only profitable but are actually Pareto improving as a result of their impact on research activity.

Merger is, however, not a mechanism that can be relied upon to maintain the competitive edge of a cluster. The effectiveness of a merger is particularly limited when entry is relatively easy, a condition that is very likely to hold in markets with a low level of concentration, i.e., markets that are at risk of stagnating. The alternative is a non-market or public policy response to stimulate research but care must be exercised in the design of such public policy given the impact that it has on market structure.

We have shown that if the cost of doing research is relatively low, both public subsidy of research and self-financing arrangements, perhaps through lump-sum taxes on market participants, stimulate entry and increase social welfare. However, a policy of public subsidy of research is preferable. By contrast, when research is somewhat more costly, the costs of additional entry induced by public subsidy more than offset the benefits. In such cases, the preferable approach is to make the research policy self-financing, perhaps through lump-sum taxation of market participants. The potentially detrimental effects from increased market concentration that self-financing induces in these cases are more than offset by the benefits that flow from the firms' research activities.

Bibliography

d'Aspremont, C. and A. Jacquemin, (1988), "Cooperative and noncooperative R&D in duopoly with spillovers", *American Economic Review*, 78, 1133-1137.

Audretsch, D. (1998) "Agglomeration and the location of innovative activity", *CEPR Discussion Paper* Series No. 1974.

Bianchi, P. and G. Gualtieri, (1990), "Emilia-Romagna and its industrial districts: the evolution of model", in Leonardi, R. and R. Nanetti, *The Regions and European Integration*, London: Pinter Publishers.

De Bondt, R. and R. Veugelers (1991), "Strategic investment with spillovers", *European Journal of Political Economy*, 7, 345-366.

Dybvig, P. and C. Spatt, (1983), "Adoption externalities as public goods", *Journal of Public Economics*, 20, 231-247.

Farrell, J. and C. Shapiro, (1990), "Horizontal mergers: an equilibrium analysis", *American Economic Review* 80: 107-126.

Feller, I., (1993), "What agricultural extension has to offer as a model for manufacturing modernization", *Journal of Policy Analysis and Management*, 12, 574-583.

Gaudet, G. and S. Salant, (1992), "Towards a theory of horizontal mergers", in *The New Industrial Economics* edited by George Norman and Manfredi La Manna. Aldershot: Edward Elgar.

Kamien, M, Muller, E., and I. Zang, (1992), "Research joint ventures and R&D cartels", *American Economic Review*, 82, 1293-1306.

Kamien, M. and I. Zang, (1990), "The limits of monopolization through acquisition", *Quarterly Journal of Economics*, 465-499.

Katz, M., (1986), "An analysis of cooperative research and development", *The Rand Journal of Economics*, 17, 527-543.

Kesteloot, K. and R. Veugelers (1994) "Stable R&D cooperation with spillovers", *Journal of Economics and Management Strategy*, 4, 651-672.

Leahy, D. and P. Neary (1997) "Public policy towards R&D in oligopolistic industries", *American Economic Review*, 87, 642-662.

Porter, M., (1998), "Clusters and the new economics of competition", *Harvard Business Review*, 77-90.

Salant, S., Switzer, S. and R. Reynolds, (1983) Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot-Nash equilibrium”, *Quarterly Journal of Economics*, 185-199.

Shapira, P., (1993), “Public infrastructures supporting small firm modernization in the United States”, *Proceedings on Cooperation and Competitiveness*, International Conference, Lisbon.

Sonnenschein, H., (1968), “The dual of duopoly is complementary monopoly: or two of Cournot’s theories are one”, *Journal of Political Economy*, 316-318.

Spence, M., (1984), “Cost reduction, competition and industry performance”, *Econometrica*, 52, 101-121.

Stigler, G., (1950), “Monopoly and oligopoly by merger”, *American Economic Review, Papers and Proceedings*, 40, 23-24.

Appendix:

When N = 2, 3, 4 or 5 we can, in principle, identify explicit solutions for the research probability $q^*(N, \rho)$, since these involve the solution of polynomials of up to degree 4. We present these solutions for N = 2 and 3 and sketch the solution for N = 4.

(i) $N = 2$:

Assume that firm 1 undertakes research with probability q_1 and firm 2 with probability q_2. Then the expected profit to firm 1, ignoring fixed costs, is:

(A.1)
$$E\pi_1(2,q_1,q_2,S,r) = q_1q_2\left(\frac{1+s(2)}{9}-r\right)+q_1(1-q_2)\left(\frac{1+s(1)}{9}-r\right)+ q_2(1-q_1)\frac{1+s(1)}{9}+\frac{1}{9}(1-q_1)(1-q_2).$$

This simplifies to:

(A.2)
$$E\pi_1(2,q_1,q_2,S,r) = \frac{1}{54}\left(q_1(3-2q_2)S+6+3q_2S\right)-q_1r.$$

From this we have:

(A.3)
$$\frac{\partial E\pi_1(2,q_1,q_2,S,r)}{\partial q_1} = \frac{1}{54}(3-2q_2)S-r.$$

It follows that the Nash equilibrium research probability is:

(A.4)
$$q^*(2,\rho) = \begin{cases} 1 & \text{for } \rho < 1/54 \\ 3/2-27\rho & \text{for } 1/54 \le \rho \le 1/18 \\ 0 & \text{for } 1/18 < \rho \end{cases}.$$

(ii) $N = 3$:

Assume that firm i undertakes research with probability q_i. Then the expected profit to firm 1 is:

(A.5)
$$\begin{aligned} E\pi_1(3,q_1,q_2,q_3,S,r) = {} & q_1q_2q_3\left(\frac{1+s(3)}{16}-r\right)+ \\ & \left(q_1(1-q_2)q_3+q_1q_2(1-q_3)\right)\left(\frac{1+s(2)}{16}-r\right)+(1-q_1)q_2q_3\frac{1+s(2)}{16}+ \\ & q_1(1-q_2)(1-q_3)\left(\frac{1+s(1)}{16}-r\right)+(1-q_1)\left(q_2(1-q_3)+(1-q_2)q_3\right)\frac{1+s(1)}{16} \\ & +\frac{1}{16}(1-q_1)(1-q_2)(1-q_3). \end{aligned}$$

Simplifying and differentiating with respect to q_1 gives:

(A.6) $$\frac{\partial Ep_1(3, q_1, q_2, q_3, S, r)}{\partial q_1} = \frac{1}{192}(6 - 4(q_2 + q_3) + 3q_2 q_3)S - r.$$

At a symmetric equilibrium we have $q_1 = q_2 = q_3 = q^*(3, \rho)$, with:

(A.7) $$q^*(3,\rho) = \begin{cases} 1 & \text{for } \rho < 1/192 \\ \left(4 - \sqrt{2(288\rho - 1)}\right)/3 & \text{for } 1/192 \leq \rho \leq 1/32 \\ 0 & \text{for} 1/32 < \rho \end{cases}.$$

(iii) $N = 4$:

Now assume the firm 1 undertakes research with probability q_1 and firms 2, 3 and 4 undertake research with probability $\overline{q}$. Then by exactly the same argument as above, the expected profit to firm 1 is, after simplification:

(A.8) $$E\pi_1(4, q_1, \overline{q}, S, r) = \frac{1}{500}\left(5\left(4 + 6\overline{q}S - 4\overline{q}^2 S + \overline{q}^3 S\right) + q_1\left(10 - 20\overline{q} + 15\overline{q}^2 - 4\overline{q}^3\right)S\right) - q_1 r \ .$$

It follows that the Nash equilibrium research probability $q^*(3,\rho)$ is the solution to the cubic:

(A.9) $$\left(10 - 20\overline{q} + 15\overline{q}^2 - 4\overline{q}^3\right) = 500\rho.$$

This is less than unity for $\rho \geq 1/500$ and greater than zero for $\rho \leq 1/50$.

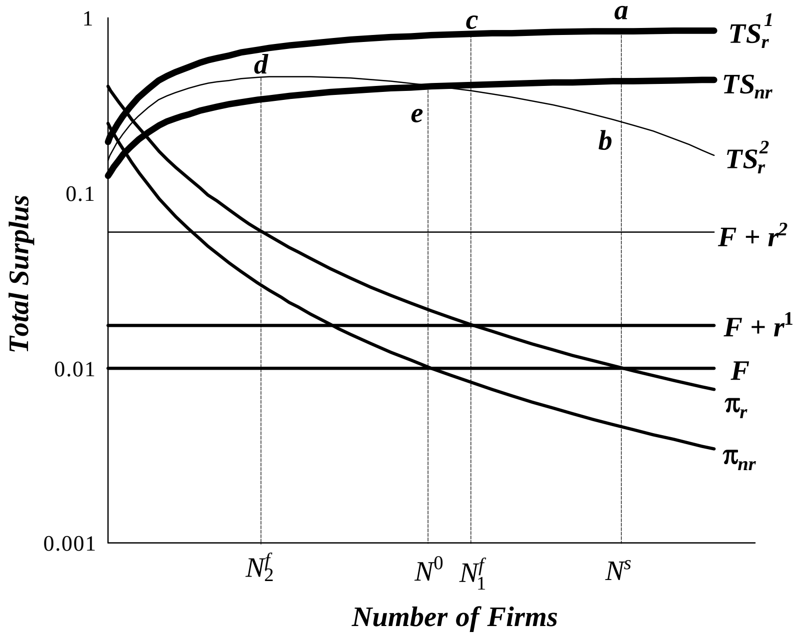

Figure 1: Research Policy and Total Surplus