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Competition and Innovation

by P.A. Geroski \*

Internal paper



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## I. INTRODUCTION

This study is designed to assess the likely effects of reducing intra-Community barriers to trade on innovation rates in European industry. It exploits a relatively unique data base on major innovations in the UK, data which is not, unfortunately, available for the other countries of the Community. Although this may limit the generality of the results somewhat, many of the most interesting properties of this data have also been detected in studies on US data. It is not unreasonable, therefore, to treat the results discussed below as creating a presumption which is applicable throughout the Community in the absence of explicit evidence to the contrary.

## II. THE POLICY ISSUES AND EXPERIMENTAL DESIGN OF THE STUDY

The evidence suggests that there exist a number of obstacles which inhibit trade within the Community, and there are good reasons to think that removing them (or, at least, ameliorating their effects) may bring substantial gains to all member states. Several policy initiatives have been advanced to tackle these problems in various ways, and there is little doubt that they are likely to improve the allocative efficiency of the internal Community market to some greater or lesser extent. They seem likely to achieve this effect in one or both of two interdependent ways. First, many of the initiatives currently under active discussion will increase the size of the market that firms operate in. For example, both reductions in tariffs and/or non-tariff barriers to trade and new initiatives designed to open transportation services up to more competition will have the effect of reducing transportation costs (considered broadly), and so increase the market area open to a firm producing in any given location. Second, many of the proposed policy initiatives will have an effect on the degree of competition in markets. Thus, moves to strengthen competition policy and to open up public procurement practices are likely to increase the competitiveness of markets, particularly those inhabited by large dominant firms and/or protected "national champions".

Not only is efficiency likely to increase if either type of policy takes effect, but, more importantly, the two types of policy are likely to be mutually reinforcing. Reductions in tariffs and/or transport costs not only increase the effective market area of any particular firm but, by doing so for all firms, they increase the number of effective competitors that any particular firm is likely to

face both in newly opened market areas as well as in formerly closed home bases. Similarly, increases in competition which lower prices and stimulate cost reducing or new product innovations are likely to widen existing markets. Such an effect might, perhaps, be expected from a loosening of constraints on defense related public procurement if it leads to a much higher level of technological spillages into the civilian sector, and so to a higher level of new product generation in consumer goods. More prosaically, airline deregulation in the US has made clear the tremendous widening of markets that can be induced by eliminating restrictions on competition.

Thus, the primary effects of reducing intra-community trade barriers will be an increase in market size and in the degree of competition in the newly enlarged market. These changes, in turn, are likely to affect the efficiency of firms and the performance of markets in several important ways. In tracing these effects, it is necessary to distinguish static efficiency, the effectiveness of exploiting given levels of technology, from dynamic efficiency, the effectiveness of efforts to push back technological constraints.

The likely effect of increasing market size and the degree of competition on static efficiency is straightforward, and the only controversy that exists concerns its order of magnitude. As market size increases, whatever limitations that demand may have formerly put upon the realization of scale economies are removed, and firms will be able to move further down their average cost curves. Perhaps somewhat more substantively, increases in the degree of competition in markets are likely to encourage firms to reduce levels of X-inefficiency, a movement from current cost curves towards the true long run average cost curve. These two effects - movements along a



declining cost curve and movements between cost curves - clearly reinforce each other, and lead to an unambiguous prediction that costs are likely to fall as market size and the degree of competition increase.

The effects of market size and competition on dynamic efficiency, however, are much less clear. Certainly it seems plausible to believe that increases in market size will increase innovativeness, particularly if there are any economies of scale or fixed costs in the research and development process. However, the effect of competition on innovativeness is rather controversial. In particular, Schumpeterian arguments suggest that at least some degree of monopoly power is conducive to innovativeness, and that large firms are likely to be the most fecund in this respect. If these Schumpeterian assertions are correct, then it is no longer clear that removing obstacles to intra-Community trade will improve dynamic efficiency. Indeed, it is possible that the static efficiency gains arising from such a policy will be more than outweighed by losses arising from a reduction in dynamic efficiency. In short, it appears that a rather crucial step in the argument for opening up internal Community markets is the link between the degree of competition and innovation.

The crux of the matter is clearly Schumpeterian assertions about firm size, monopoly, and the innovativeness of firms. There are, in principle, two types of effect that monopoly power can have on innovative activity: a direct effect, or, the effect that monopoly power has on the response to any given level of expected post-innovation returns; and an indirect effect, or, the effect that monopoly power has on expected post-innovation returns and thence on

innovative activity. It is widely believed that the indirect effect of monopoly power on innovation is positive (i.e. that monopoly boosts expected post-innovation returns and so increases innovativeness), but that the direct effect may be negative (i.e. that monopolists respond more slowly than competitive firms to a given level of expected post-innovation returns). If the direct effect is relatively small or if it is positive, then it is hard to dispute Schumpeterian assertions that monopoly power is conducive to innovation. If, on the other hand, the indirect effect is relatively small and the direct effect is negative, then it follows that monopoly inhibits innovativeness and that competition stimulates it. This, of course, would imply that the dynamic efficiency consequences of removing intra-Community barriers to trade will augment and not offset the static efficiency gains that may emerge from such a policy.

Although it seems to be impossible to determine the size much less the sign of the total (direct plus indirect) effect of competition on innovation a priori, it is nevertheless worth exploring the a priori arguments in more depth. Given that indirect effects are likely to be positive (i.e. increasing monopoly or reducing competition increases innovativeness), it turns out to be the case that whether the total effect is positive or negative depends on whether an undoubtedly superior ability enjoyed by large firms with market power is more than offset by the weakening of incentives that market power gives rise to. Appreciating the force of the argument requires an understanding of the several factors which give rise to direct and indirect effects, and we shall consider them in reverse order.

The indirect effect of monopoly on innovation hinges on the effect that current monopoly has on expected post-innovation returns (and, of course, the effect that the latter has on innovative activity). The most straightforward and plausible argument in support of the proposition that the indirect effect is positive is that firms which currently enjoy a substantial degree of market power will be well placed to erect barriers to future entry. This, of course, limits the degree to which rivals can imitate an innovation when it is first introduced, and thus raises the percentage of the total gains to innovating which the initial innovator can appropriate for itself. Hence, because a monopolist is likely to be in a position to appropriate more of the expected gains arising from any given innovation than a more competitive firm can, the monopolist is more likely to innovate.

The second reason to expect a positive indirect effect is much more subtle. Positions of monopoly are, at base, founded on innovations of some sort, and thus the activity of those firms which currently enjoy market power depends upon exploiting their own previous innovations. More competitive rivals and new entrants are likely to be, at best, imitators, and to enjoy only restricted access to the original innovation. Thus, if the results of current innovative activity complement those innovations which have already been made by a firm with market power, then it will gain more from introducing the new innovation than will competitive rivals or new entrants.<sup>(1)</sup> It follows that if one observes a sequence of complementary innovations, then the whole sequence is likely to have been introduced by only one firm, and, in particular, by the firm which introduced the first innovation in the sequence. Since that

act is likely to give rise to at least some monopoly power, then, as a practical matter, one is likely to observe more innovations by monopolists than by competitive firms (*ceteris paribus*).

The direct effect of monopoly on innovation (that is, the effect of market power on the response to a given level of post-innovation returns) depends upon several offsetting factors. The most controversial element of the argument pits the positive direct effects of various "material advantages" that monopolists may enjoy against several "behavioural disadvantages" that may weaken their performance.<sup>(2)</sup> Numerous types of material advantage have been suggested in the literature. Economies of scale in research or economies of scope within a portfolio of related research programmes may exist, complementarities between research and marketing may yield important comparative advantages to large firms with well established distribution networks or with advertising skills, and so on. Indeed, many of these advantages spring from the high profits that market power is likely to yield. Access to internal funds weakens a firm's reliance on external credit markets, and this may enable it to operate more flexibly, to take a longer term view, and, perhaps, to act less cautiously than relatively poorly informed financiers may deem prudent.

If they exist, all such material advantages undoubtedly give monopolists the ability to act more innovatively than more competitive firms. Whether monopolists exploit this potential and actual innovate more is another question altogether. The absence of competitive forces may enable managers to indulge in a preference for leisure or allow them to become sleepy. Levels of X-inefficiency may climb, and bureaucratic caution and inertia may come to dominate a

firm's activities, paralyzing its creativity and initiative, and atrophying its ability to respond flexibly to events. Thus, market power protects that possess it protects against competitive forces, but, if it is mainly the threat of competition which encourages firms to be innovative and efficient, then market power is likely to give rise to relatively slack behaviour, and so retard innovation rates.

Whether the material advantages of monopoly overcome the possible behavioural shortcomings of monopolists is an open question a priori. There are, however, at least two good reasons to suppose that the direct effect of monopoly on innovative activity will be negative unless the possibly superior ability of monopolists to innovate more than offsets any weaker incentives they may experience. First, a more competitive environment means, *inter alia*, that more firms are likely to be searching for possible innovations, and this clearly raises the probability of observing an innovation by some time  $t$  either because the more firms there are searching, the more likely it is that one of them will find something worthwhile, or because the more there are searching, the harder each will search.<sup>(3)</sup> Thus, the more competitive a market, the more likely it is that an innovation will be generated.

The second reason for suspecting that direct effects, on balance, may be negative is that monopolists may not only generate less innovations than firms in a competitive market, they may also be less quick in adopting innovations which are produced elsewhere. This possibility arises whenever introducing a new innovation displaces part of the activities of the old one upon which the current monopoly position is based (roughly whenever successive innovations

are substitutes). The gain to innovation in these circumstances is the level of expected post-innovation profits net of the profits on current activities which will be displaced by the innovation. Since these latter are likely to be enhanced by monopoly power, it follows that the incentive for a monopolist to adopt new technologies is lower than for a competitive firm not earning excess profits on current activities (*ceteris paribus*).<sup>(4)</sup>

Since the indirect effect of monopoly on innovation is likely to be positive, it follows that the persuasiveness Schumpeterian assertions ultimately hinges on the notion that the material advantages of monopolists at least roughly compensate for any behavioural disadvantages or other factors which might weaken the response of a monopolist to profitable innovative activities. By contrast, the anti-Schumpeterian position asserts that the behavioural disadvantages created by monopoly not only overwhelm other positive direct effects of market power on innovation, but also more than compensate for positive indirect effects. In this case monopolists are less likely to innovate than firms in more competitive markets (*ceteris paribus*), and Schumpeterian assertions must be resisted.

The policy implications of the relationship between competition and innovation are profound, and three are particularly relevant in the current context. First, many of the arguments which have led national governments to centre their public procurement and research activity in the hands of a small number of "national champions" are Schumpeterian in origin. The proponents of these arguments have stressed material advantages which, they have asserted, more than compensate for behavioural disadvantages and

other negative factors. If, however, the Schumpeterian argument is invalid then the attractiveness of this type of policy is much attenuated, and more competitive alternatives become important policy options. Second, Schumpeterian assertions have often been used as a caveat to proposals in favour of more vigorous anti-trust activity. What is asserted in such objections is a kind of dynamic economies vs monopoly power trade-off,<sup>(5)</sup> one that is non-existent if the Schumpeterian hypothesis is invalid. Both a loosening of procurement policies and a strengthening of competition policy are, of course, part of the broader range of policies discussed in the context of opening up internal Community markets. These are likely to affect both market size and the degree of competition, and the third policy implication of the relationship between competition and innovation is that, if the Schumpeterian hypothesis is correct, then these policies are liable to realize static efficiency gains only at the cost of at least some worsening of dynamic efficiency. If, however, the Schumpeterian hypothesis is invalid, then the static gains to opening up intra-Community markets will understate the total gains to such policies. The attraction of such policies then becomes difficult to resist.

Thus, an examination of the Schumpeterian hypothesis is a major step in the argument in favour of policy initiatives to break down barriers to trade within the Community. In fact, the data provide almost no support for the Schumpeterian position, and thus suggest that there is little reason to believe that a trade-off exists between monopoly power and dynamic efficiency. We shall examine this evidence in two stages. First, in Section III, we explore the relationship between firm size and innovation, and, second, in Section IV, that between the degree of competition and

innovation. Section IV also puts the results in a somewhat wider perspective by exploring the interactions between market size, the degree of competition, and innovativeness. Section V summarizes the report.



### III. FIRM SIZE AND INNOVATION

Although the Schumpeterian hypothesis is generally considered to be one which relates innovativeness to the degree of competition, it often also appears as a relationship between large firm size and innovation. The two types of arguments are by no means identical, but they are fairly similar at a broad level. The main case made for and against the hypothesized firm size - innovation relationship is generally a variant of the "material advantages" versus "behavioural disadvantages" argument discussed above in connection with direct effects. However, it is also possible to detect at least one indirect effect of firm size on innovation which may be important. Let us briefly consider each type of argument in turn before examining the evidence.

In the first place, size may have an effect on the efficiency with which research inputs process are transformed into the output of innovations. A possible advantage accruing from size is the ability to employ specialised equipment and personnel, and so extend the division of labour in research. In addition, researchers may be more productive when they have more colleagues to interact with, leading to an increased probability that unforeseen results will be recognised as important. Much the same effect may arise when several related research projects are run in tandem. On the other hand, large firms may experience problems in initiating or maintaining their research programme because of internal difficulties in coordinating their activities. This may arise because of the sheer number of successive layers of hierarchy in the firm through which ideas are required to pass. Further, to the extent that it is administration rather than research which tends to offer the most attractive prospects in terms of pay and status in large firms, then

the incentives facing talented employees may drive them away from research based activities. Thus, like monopolists, large firms potentially suffer from behavioural shortcomings which must be set against whatever material advantages they can command. The direct effect of firm size on innovation is, therefore, ambiguous.

There is, however, at least one indirect effect which may be positive, since firm size may have an effect on the magnitude of post-innovation returns. The point is simply that the total potential returns to an innovation may be higher the larger is the market to which it is applied, and the returns net of costs can be larger for large firms able to pre-empt most of the total market and spread their fixed costs over a greater sales volume. For example, the potential returns to a process innovation will vary directly with the level of output produced using the process. In perfectly functioning markets, this is not an important issue since innovations can be sold to other firms in the market, thus enabling the innovator to maximize the net gains from research and innovative activity. However, the market in innovations is liable to be an imperfect one, if only because it is frequently difficult for a seller to inform a potential buyer about the nature of the innovation without, at the same time, forfeiting his/her monopoly over the innovation (once a potential buyer knows what it is, there is no need to buy it). Hence, the major gains are likely to come from own use and, in this situation, a large firm may have more incentive to innovate than a small firm.

Most empirical work on this issue has tended to focus on relating the intensity of R & D input, measured either by expenditure or by the employment of research personnel, to firm size measured in

various ways. The evidence suggests that R&D intensity tends to rise more than proportionately with firm size initially, but, after some threshold of R&D intensity is reached, it remains constant or even declines. This threshold is likely to vary across industries, but there are indications that it may lie somewhere near the bottom range of Fortune's 500 industrials listing.<sup>(6)</sup> Although this would seem to suggest that large firms are more innovative, there are, however, at least two reasons for expressing doubt. First, smaller firms generally do not have formal R&D programs and thus their research inputs are not picked up in official R&D statistics. This does not imply that such firms do no research, but rather that official R&D statistics are biased towards measuring the research activities of very large firms. Secondly, there may be systematic differences in the efficiency with which firms undertake a given amount of research, leading to different innovative output rates from a given set of inputs.

Doubts about the relative efficiency with which large firms do research strike at the heart of Schumpeterian assertions about the benefits of large firm size. Direct evidence on this issue not only makes plain some of the hazards of using input data on R&D to measure innovative output rates, but also seems directly germane to the question of whether the direct effects of size are positive (large firm size increases innovativeness) or negative. Certainly the available evidence suggests that, in fact, smaller firms appear to be far more efficient than their larger rivals. For example, investigations of expenditure per patent and of comparable parallel product development efforts undertaken by firms of different sizes reveal that smaller firms incur lower costs, and produce far more output per unit of expenditure. Further, it is often observed that

small firms are quicker in bringing new products to the market. They often seem to engineer new products in up to 70 per cent of the time taken by large firms, develop prototypes twice as fast, establish production marginally faster, and start up sales in up to two thirds of the time taken by large firms. Finally, numerous studies suggest that large firms frequently produce rather minor innovations, relying heavily on small firms for ideas which they may improve and develop for commercial applications.<sup>(7)</sup>

If, as seems to be the case, there is a real danger in using information on R & D inputs to make inferences about the relationship between firm size (or, for that matter, market power) and innovativeness, then it is important to concentrate on work which uses direct measures of innovative output. Our major source of information derives from work done by researchers in S.P.R.U. at the University of Sussex, identifying 4378 major innovations introduced in the U.K. over the period 1945-83. By "major", one means that innovations in this data set have, in general, been deemed to be technically important and commercially successful. Although clearly but a sub-set of the total innovative activity in an economy, major innovations are at least the most important and, in our case, the most visible tip of the iceberg.

Table I shows the proportion of total innovations originating from different sized innovating and ownership units. Column (1) reveals that small and medium sized innovating units make a major contribution to total innovations. For example, 85.3% of all innovations emerged from units of less than 10,000 employees (that is, from firms well below the size of those in Fortune's top 500 list), 48.2% from those with less than 1000 employees and 23.4% from

units with under 200 employees. At best, one can observe a very weak U-shaped relationship between size and innovation, but even this does not hide the basic point that smaller firms are responsible for a share of total innovations which far exceeds their share of economic activity measured in terms of sales, employment or value added. In fact, Table I partially conceals a significant rise over time in the share of innovations introduced by units sized less than 1000 employees. This share has more or less steadily risen from 36.7% in 1945-49 to 39.9% (1950-54), 43.4% (1955-59), 40.4% (1960-64), 47% (1965-69), 50.7% (1970-74), 58% (1975-79), and to 59.9% in 1980-83, and has come largely at the expense of the share of firms in the 1000-9999 employees size range.

Although some of the theoretical arguments listed above are more applicable to the size of the innovating unit rather than the whole firm, it is the latter which is the main focus of our interest. Column (2) expresses the size of firms in terms of UK employment, and reveals that firms with less than 10,000 employees accounted for 56.1% of all innovations, firms with less than 1,000 employees for 33.2%, and firms with less than 200 employees for 17%. No matter how one looks at it, small and medium sized firms are clearly responsible for a significant proportion of innovations. What is not apparent from the table is that important changes appear to have taken place over time in the role played by both small and very large firms. In the last three years of the period, 43.2% of innovations emanated from firms with less than 1,000 employees, and 20.7% were accounted for by firms who employ over 50,000 workers. The share of firms less than 200 employees rose from 29.6% in 1945 to 43.2% in 1983, while firms of size 50,000 employees or more accounted for 17.7% in 1945 and 20.7% in 1983.

Table I:  
Percent of Total UK Innovations by Size of Unit, 1945-83

	(1)	(2)
	Innovating Unit	UK Ownership Unit
1-199 Employees	23.4%	17.0%
200-999 Employees	24.8%	16.2%
1,000-9,999 Employees	37.1%	22.9%
10,000-49,999 Employees	11.0%	23.0%
50,000+ Employees	3.7%	20.9%

Source: adapted from Pavitt et al, 1987.

Similar results have also emerged from two large scale U.S. studies. Feinman and Fuentevilla (1976) examined 500 important innovations which were first introduced in the U.S. during the period 1953-73. Of the 319 which originated from U.S. firms, 23.5% came from firms with less than 100 employees, 23.8% from firms employing between 100 and 1,000, 13.2% from firms with 1,001 - 5000 employees, 5% from firms employing 5001 - 10,000 and the remaining 34.5% from firms with more than 10,000 employees. Edwards and Gordon (1984) studied 8074 innovations introduced into the U.S. in 1982, and found that small firms (less than 500 employees) innovated at about 2.4 times the rate of large firms.

The only conclusion that one can draw from Table I is that if there are any important material advantages to doing research and development, they fail to make themselves plain in the output of the research and development process. Small firms are far more

innovative than their relative size would, at first sight, indicate. Of course, this apparently major role played by medium and small sized firms clearly varies by industry, and Table II shows this inter-industry variation for the data on UK innovations. Firms of size less than 1000 employees are important in the Machinery and Instruments industries where they account for more than 45% of all innovations. Firms of more than 10,000 employees, on the other hand, account for more than 75% of all innovations in Mining, Food, Chemicals and Electric Products. In fact, 64% of all small firm innovations are concentrated in Machines, Mechanic Engineering, and Instruments, while 45% of large firm innovations are in Chemicals, Electrical Engineering and Electronics (compared to 27% of all innovations). Thus, small firms not only made an important contribution to overall innovation rates, but often do so in the most innovative sectors.

In short, when one examines the relationship between innovativeness and firm size one finds no substantive reason to think that large firms are, in general, relatively innovative. While looking at crude counts of innovations is not a particularly compelling way to measure material advantages and behavioral disadvantages, they do at least give some useful insight into the net advantages of firm size. Perhaps the most important point to grasp from the evidence is that there apparently exist enormous differences in research efficiency between large and small firms. Because it is more than likely that official R&D statistics drastically understate the critical research inputs typically supplied by smaller firms, these differences in relative efficiency may be somewhat more apparent than real. Nonetheless, the fact of

Table II:

% of TOTAL INNOVATION PRODUCED BY FIRMS OF DIFFERENT SIZE

PRODUCING SECTOR	No. Innovations Produced	1-99	200-999	1,000- 9,999	10,000- 49,999	50,000+
Agriculture	12	8.3	0	66.7	25.0	0
Mining	126	0	2.4	0.8	12.7	84.1
Food	112	3.6	5.4	9.8	57.1	24.1
Chemicals	421	4.8	7.4	9.7	31.4	46.8
Metals	186	0.5	3.8	25.8	15.1	54.8
Machinery	573	26.2	27.1	33.7	12.4	0.7
Mechanical Engineering	558	14.0	12.0	18.5	38.4	17.2
Instruments	332	31.6	18.1	15.4	16.6	18.4
Electrical Engineering	346	3.2	2.3	4.0	15.3	75.1
Electronics	428	17.5	8.9	12.4	27.3	33.9
Shipbuilding & Offshore Engineering	67	13.4	14.9	46.3	23.9	1.5
Vehicles	212	9.4	8.5	28.8	27.4	25.9
Aerospace	85	2.4	7.1	17.6	29.4	43.5
Textiles, Leather & Clothing	144	20.1	11.8	32.6	6.9	28.5
Bricks, Pottery, Glass, Cement	157	14.0	7.6	18.5	48.4	11.5
Paper	54	16.7	20.4	13.0	38.9	11.1
Printing	29	6.9	34.5	55.2	3.4	0
Rubber & Plastics	91	15.4	27.5	1.1	15.4	40.7

Source: Adapted from Pavitt et al 1987.



matter is that there exists no real presumption that size is a major advantage, except possibly in a few sectors which are probably more the exception than the rule. Size may matter, but it is by no means the case that "big is beautiful".

#### IV. THE DEGREE OF COMPETITION AND INNOVATION IN MARKETS

The Schumpeterian hypotheses about the determinants of innovation go well beyond propositions about firm size, and assert that an absence of rivalry in markets is also conducive to innovativeness. The argument is controversial because there are, in principle, two channels by which market structure affects the incentives to innovate, and the two can offset each other. Thus to examine the Schumpeterian hypothesis about the role of market power, one would like to try to separately measure both the direct and the indirect effects of monopoly on innovativeness. The former can be detected in experiments which let industry market structure vary, holding the level of post-innovation returns constant. Indirect effects are rather more complex, since they trace a causal channel from market structure to post-innovation returns, and thence to innovation. Measuring the size of indirect effects, then, requires examining the two partial correlations, and multiplying their effects together. The total, overall effect of monopoly on innovation is simply the sum of the direct and indirect effects.<sup>(8)</sup>

Thus, we are interested in exploring two particular partial correlations between market structure and innovation. However, such work must be embedded in a full model; to measure these various partial correlations accurately, one must take care to "hold all relevant things" constant. In the context of multiple regression, this means that one must hold constant those factors correlated with the independent variable of interest lest their effects on the dependent variable be confused with those of the independent variable. Practically speaking, this creates a trade-off between the inclusion of irrelevant variables (which can lower efficiency in estimation) and the omission

of relevant variables (which can create bias). In the current context, probably the most important factor that one must take account of is variations in "technological opportunity" across industries.

"Technological opportunity" refers to the fecundity of an industry's scientific and technological base, to those underlying, dynamic conditions of supply which affect the average productivity of research inputs in producing research output. In the literature, it has been measured in numerous ways. Scherer (1967), Lunn and Martin (1983) and Shrieves (1978) used subjectively chosen dummy variables for certain high technology industries (e.g. life sciences, electronics, aerospace, mechanical and electromechanical engineering, chemicals and so on); Waterson and Lopez (1983) used capital intensity and the rate of growth of net output per head as proxies; Hughes (1984) used data on R&D intensity in the U.S., France, Germany and Japan to indicating technological opportunity in the UK and, finally and perhaps most comprehensively, Levin et al (1985) used six proxies reflecting the sources of technical knowledge, industry maturity, and "closeness" to basic and applied science.

The importance of correcting for variations in technological opportunity across industries arises from the oft made conjecture that industries in which technological opportunity is rich and promising are also industries which are highly concentrated. There are several variants to this argument, not all of which are equally persuasive. One might, for example, think that technological opportunity is enriched by Government defense related research support. Since this is generally channelled to a small number of large firms in highly concentrated industries, it follows that high concentration and technological opportunity will go hand in hand. Alternately, technological opportunity might merely reflect the ease of appropriability, a factor

augmented (or, indeed, perhaps created) by strategic investments in barriers to entry made by leading firms in highly concentrated industries. Clearly, for these and other reasons, it seems likely to be the case that failing to correct for technological opportunity may bias the measured effect at least of industry concentration on innovation. The interesting consequence of introducing these various proxies for technological opportunity into regressions of market concentration on research input or output is that they generally cause the effect of industry concentration on innovativeness to diminish considerably, and estimates of this effect tend to become insignificantly different from zero. That is, omission of technological opportunity tends to overstate the effect of industry concentration on innovativeness, creating a distinctly pro-Schumpeterian bias in the results.<sup>(9)</sup>

Thus, two basic concerns must guide the construction of our empirical model of innovations. First, one must be able to measure both the direct and the indirect effects of market power on innovation, and, as argued above, this requires that we correct for variations in expected post-innovation rates of return. This we shall do by including a variable in the regression measuring post-innovation price-cost margins. Since a zero level of expected post-innovation returns is likely to discourage firms from doing any research whatever the degree of competition, we introduce the profitability variable in log form.<sup>(10)</sup> Second, one must correct for variations in technological opportunity across industries. The important point to grasp here is that while technological opportunity varies sector by sector, it is roughly constant over time. Hence, for each industry over time, it can be captured by a constant, but only by one that varies in value across sectors. Thus, to correct for variations in

technological opportunity, we shall include a full set of industry specific "fixed effects". Finally, to these two concerns we shall add a third. Previous studies of the Schumpeterian hypothesis have focused on the role of market concentration in affecting innovation, hinging the entire test of the Schumpeterian hypothesis on a single partial correlation. This seems to be unduly restrictive, and, in what follows, we shall use six measures of rivalry, looking for a consistent pattern of signs rather than a single positive or negative sign.

Using the data on innovations discussed above, we have conducted tests of the Schumpeterian hypothesis for the U.K., 1970-79. The basic model that we have used is:

$$(1) \quad I_i^* = \tau_i + \alpha_1 \log \pi_i + \alpha_2 M_i + \alpha_3 Z_i + \mu_i$$

where  $i=1, \dots, N$  indexes industries,  $\tau_i$  = an industry specific constant reflecting  $i$ 's "technological opportunity",  $\log \pi_i$  = the log of post-innovation price-cost margins in industry  $i$ ,  $M_i$  = the degree of monopoly,  $Z_i$  = other observable factors affecting innovations, and  $\mu_i$  is a residual.  $I_i^*$  may be positive or negative, and, indeed, if  $\pi_i \rightarrow 0$  then  $I_i^* \rightarrow -\infty$ . Observed innovations,  $I_i$ , are always non-negative and so the data must be described using a Tobit model,

$$(2) \quad \begin{cases} I_i = \tau_i + \alpha_1 \log \pi_i + \alpha_2 M_i + \alpha_3 Z_i + M_i & \text{if } I_i^* \geq 0, \\ I_i = 0 & \text{otherwise.} \end{cases}$$

If  $\alpha_1 > 0$ , then expected post-innovation returns stimulate innovation. Holding  $\log \pi_i$  constant enables one to observe the direct effect of monopoly on innovativeness,  $\alpha_2$ ; the indirect effect is  $\alpha_1$  times the effect that monopoly,  $M_i$ , has on  $\pi_i$  or, equivalently,  $\log \pi_i$ .

To estimate the  $N+4$  parameters in (2), one needs to use panel data (i.e. a times series of cross-sections). The advantage of panel data is that tracking a single cross-section unit,  $i$ , over time enables one to estimate  $\tau_i$ , and also enables one to bring more informatin to bear to the task of estimating all the parameters of (2) more efficiently. We have used two cross section samples of 73 M.L.H. (or, three digit) industries for 1970-74 and 1975-79 respectively.<sup>(11)</sup> The dependent variable is the number of innovations introduced in each of the two five year periods.

For the  $Z_i$ , we have used five variables: the growth of industry sales ( $GROW_i$ ), industry size measured as the log of industry capital stock ( $SIZE_i$ ), the average industry capital output ratio ( $KAP_i$ ), industry export intensity ( $EXPORT_i$ ), and industry unionization measured as the percentage of the workforce covered by collective agreements ( $UNION_i$ ). These variables are included to correct for omitted factors whose effects might otherwise mistakenly be attributed to market power, and were chosen for inclusion on the basis of previous appearance in the literature and a suspected correlation with the various measures of rivalry.

Finally, we were able to measure various dimensions of competition and rivalry in markets much more extensively than hitherto. The six measures that we have used are: industry concentration ( $CON_i$ ), the percentage change in industry concentration within the period ( $\Delta CON_i$ ), industry import intensity ( $IMPORT_i$ ), the gross share of sales by new entrants and by exitors ( $ENTRY_i$  and  $EXIT_i$ ), and the relative number of firms sized 99 employees or less ( $SFIRM_i$ ). If rivalry stimulates innovativeness, then one expects to see  $IMPORT$ ,  $ENTRY$ , and  $SFIRM$  positively correlated to innovativeness, and the other three

negatively correlated; the Schumpeterian hypothesis that market power is conducive to innovation predicts exactly the opposite pattern of signs. Thus, if the coefficients on CON, ΔCON and EXIT are negative while those on IMPORT, ENTRY and SFIRM are positive, we conclude that market power has a negative direct effect on innovation. If, on the other hand, one observed CON, ΔCON and EXIT to have positive correlations with innovativeness and IMPORT, ENTRY and SFIRM to have negative ones, then this suggests a positive direct effect and, almost surely, evidence in support of the Schumpeterian hypothesis. Any other pattern of signs is uninformative on the hypothesis of interest.

Table III shows the results of this test. The estimating equation is

$$(3) \quad I_i = \theta_0 + \theta_1 \ast \log w_i + \theta_2 \ast \text{CON}_i + \theta_3 \ast \text{GROW}_i + \theta_4 \ast \text{SIZE}_i \\ + \theta_5 \ast \Delta \text{CON}_i + \theta_6 \ast \text{KAP}_i + \theta_7 \ast \text{IMPORT}_i + \theta_8 \ast \text{ENTRY}_i \\ + \theta_9 \ast \text{EXPORT}_i + \theta_{10} \ast \text{SFIRM}_i + \theta_{11} \ast \text{EXIT}_i + \theta_{12} \ast \text{UNION} + \mu_i$$

The estimates reported in columns (i) and (ii) are OLS and Tobit estimates of (3), and provide evidence which is clearly inconsistent with the notion that there is a positive direct effect of actual monopoly on innovativeness.  $\theta_2$  is negative and significantly different from zero,  $\theta_8$  positive and nearly significant,  $\theta_{10}$  positive and clearly significant,  $\theta_{11}$  negative and significant and  $\theta_5$  negative and significant. Only  $\theta_7$  is clearly insignificant, and it is also the only variable whose coefficient breaks the essentially anti-Schumpeterian pattern displayed on Table III. It therefore seems to be the case that highly concentrated industries and those in the

TABLE III

Regression results for equation (3)

Independent Variables	(i)	(ii)	(iii)	(iv)
$\log \pi_i$	4.204 (.8917)	1.16 (.176)	1.70 (.295)	2.85 (.438)
$CON_i$	-50.87 (3.05)	-57.570 (2.274)	.824 (.960)	-77.10 (2.44)
$ENTRY_i$	31.864 (1.94)	18.51 (1.05)	-2.512 (.597)	85.07 (2.21)
$IMPORT_i$	-2.137 (.239)	-3.80 (.122)	-1.902 (-1.60)	11.08 (.545)
$SFIRM_i$	12.462 (2.131)	3.165 (1.09)	-1.22 (.886)	9.281 (1.028)
$EXIT_i$	-18.025 (2.207)	-26.171 (-1.38)	.775 (.225)	-56.29 (1.59)
$\Delta CON_i$	-7.688 (2.238)	-9.734 (2.02)	-.078 (.073)	-9.631 (1.22)
$SIZE_i$	.0709 (.016)	4.271 (.625)	1.22 (3.932)	-1.701 (.182)
$GROW_i$	2.296 (2.06)	3.44 (1.91)	.668 (1.44)	-.879 (.328)
$KAYO_i$	.906 (1.75)	.835 (1.25)	-.366 (3.17)	2.642 (1.38)
$EXPORT_i$	4.008 (.916)	6.987 (.883)	4.64 (3.27)	-.1515 (.019)
$UNION_i$	-7.77 (1.76)	-2.61 (.489)	.243 (.135)	-29.94 (3.34)
LogL	-392.58	-309.823	-64.2955	-278.283



Notes to Table III

All the equations include fixed effects; t-values (in absolute value) are given in brackets below estimated coefficients. The definition of the variables is:  $I_i$  = number of innovations;  $CON_i$  = 5 firm concentration ratio;  $GROW_i$  = % change in domestic production over the period;  $SIZE_i$  = log of industry capitalstock;  $DCON_i$  = % change in industry concentration;  $KAYO_i$  = capital-output ratio;  $IMPORT_i$  = imports as a % of sales;  $ENTRY_i$  = market share of entrants in year of entry;  $EXPORT_i$  = exports as a % of sales;  $SFIRM_i$  = No. firms <99 employees as a % of total number of firms;  $EXIT_i$  = market share of exiting firms in the year of exit;  $UNION_i$  = % workforce covered by collective agreements; and  $\log \pi_i$  = expected post-innovation price-cost margins. Column (i) presents an estimate of equation (3) using OLS. Columns (ii) and (iii) are Tobit and Probit estimates of the same equation, while column (iv) shows the regression in column (i) applied to the sample of industries for which  $I_i > 0$ , with an appropriate censored sample bias correction.

process of becoming more concentrated are less innovative than more competitive looking ones. There is also a noticeable tendency for this to be true in industries subject to high entry rates, low exit rates, and in industries which have a large small firm sector. The effect of import competition on innovativeness is negligible.

The sign pattern of the remaining six variables contains few surprises.  $\theta_{11}$ , the coefficient on  $\log \pi_1$ , has a positive effect on innovativeness, but one that is extremely difficult to estimate with precision. Industry size ( $\theta_4$ ), export intensity ( $\theta_9$ ), and unionization ( $\theta_{12}$ ), all appear to be relatively unrelated to innovativeness, while growth ( $\theta_3$ ) and capital intensity ( $\theta_6$ ) are positively associated with innovativeness (albeit weakly). As remarked above, these variables have, in the main, been included in order to avoid generating any bias in the estimates of  $\theta_2$ ,  $\theta_5$ ,  $\theta_7$ ,  $\theta_8$ ,  $\theta_{10}$  and  $\theta_{11}$ . However, it is worth noting that they do suggest that market size per se has no apparent effect on innovativeness, although, as expected, high growth rates seem to go hand in hand with more innovations.

The results on Table III are extremely robust to a wide range of respecifications. They are more or less invariant to quite substantial changes in the specification of (the log of) post-innovation returns. Use of rates of return on capital rather than price-cost margins, specifying returns in terms of levels and not logs, and use of a rational expectations proxy for expected post-innovation returns rather than actual, observed returns all had little effect. The results are also quite insensitive to changes in the vector of exogenous variables. Dropping any one or any subsample produced very little effect on the remaining estimated coefficient, although t-statistics often increased. Since it is reasonable to argue that

many of the six rivalry variables may be caused by innovations. tests on the exogeneity of those six variables - collectively, singly and in groups - were performed. In all cases, the null hypothesis that they are exogenous to the process generating innovations could not be rejected. The only variable for which these tests were at all close to rejecting that null was the level of industry concentration,  $CON_i$ . Two stage least squares estimates allowing CON to be endogenous produced an estimate of its coefficient which was somewhat more negative than those displayed on Table III, indicating that the estimates of this coefficient reported on Table III are biased upwards if they are biased at all. Finally, estimating the model (3) across the two cross-sections taken separately (and neglecting the fixed effects) yielded virtually identical results for each taken separately.

Columns (ii)-(iv) on Table III show further experiments with the regression reported in (i). Since about 25%-30% of the industry 5-year periods reported no innovations, then (i) is, in principle, liable to be affected by a censored variable bias. A Tobit estimator is appropriate for situations such as this, and Tobit estimates of (i) are shown as (ii) on the Table. Clearly nothing of substance is affected by reestimating the model in this manner, although small biases are present. The Tobit model itself is, however, rather restrictive, for it assumes that the determinants of limit observations ( $I_i=0$ ) are identical to the determinants of the density of non-limit observations, ( $I_i$  given that  $I_i>0$ ). One can relax this assumption in a number of ways, but one of the simplest and most straightforward is the so-called "double hurdle" model.<sup>(12)</sup> This is a two equation model in which the first step is a Probit estimate determining whether or not innovations occur ( $I_i=0$  or  $I_i>0$ ), and the second step is an OLS estimate determining the number of innovations that occur given that at least

one is reported. The rationale behind the model is straightforward, and hinges on there being effects conveyed through the independent variables which affect the ability to innovate ( $I_i=0$  or  $I_i>0$ ) in a manner which differs from the intensity of innovation given that innovation occurs at all ( $I_i$  given  $I_i>0$ ). These equations are shown as (iii) and (iv) respectively on the Table. The Probit estimates suggest that the degree of competition has very little effect on the probability that an innovation will occur, but the estimates in (iv) show that competition increases - and monopoly power reduces - the number of innovations introduced given that at least one is introduced. Thus, it appears to be the case that monopolists are not so much less likely to innovate as they are less likely to do so more intensively than firms in more competitive sectors.

The estimates on Table III also cast some interesting light on the role played by "technological opportunity" in accounting for inter-industry variations in innovativeness. It is plausible to think that the conditions of technological opportunity are correlated with many of the twelve independent variables that we have used in the regressions on Table III. A regression of the estimated values of the fixed effects on the twelve independent variables produced an  $R^2$  slightly in excess of 50%. The results (not shown) suggest that industries with high technological opportunity are not only to be highly concentrated, but are also large, not very highly capital intensive, and rather more profitable than the rest. Given this, it is not very surprising to discover that failing to correct for variations in technological opportunity across industries (achieved by suppressing the fixed effects and forcing each industry to have the same intercept) leads to substantial bias. In particular, doing this makes concentration appear to be positively (but not significantly)

correlated to innovations, and to make both market size and expected post-innovation profits positively and significantly correlated to innovations. Large, profitable and highly concentrated markets appear to be more progressive, but this seems to be more or less entirely due to the fact that they have a richer "technological opportunity" than other sectors. Correcting for technological opportunity makes it plain that market size and profitability have little systematic effect on innovations, and that highly concentrated industries are significantly less progressive than the rest. Finally, a decomposition of the  $R^2$  statistics for (i) on Table III suggests that variations in technological opportunity taken alone account for at least 60% of the variation in innovations, while the twelve observables in (2) account, at best, for about 30%. Thus, technological opportunity appears to play a major role in explaining inter-industry variations in rates of innovation.

Thus far, we have established that the direct effects of monopoly power on innovation are negative; that is, that monopolists respond more slowly and less sensitively to a given level of expected post-innovation returns arising from any given innovation than more competitive firms. However, it is possible that these negative direct effects partially or, indeed, more than offset by positive indirect effects, leading to a positive total effect of monopoly on innovation. Thus, the next step is to calculate the indirect effects of monopoly on innovation.

To calculate the indirect effect of monopoly on innovation, one needs to know how post-innovation returns are affected by monopoly, and how they affect innovative activity in turn. Estimates of the latter

(i.e.  $\theta_1$ ) are shown on the first row of Table III, and are invariably positive but not significant. To estimate the effects of monopoly on post-innovation profits, one needs to estimate an equation of the form

$$(4) \quad \log \pi_i = \theta_0 + \theta_1 I_i + \theta_2 M_i + \theta_3 W_i + \epsilon_i,$$

where  $\log \pi_i$  = the log of actual price-cost margins, and the  $W_i$  are other exogenous variables. Using (4), the indirect effect of monopoly on innovation is  $\theta_2\theta_1$ . We have specified (4) to include all twelve independent variables in (3), and also have included several further variables to identify the two equation system, (3)-(4). Table IV shows the results of these calculations. The first column is an estimate of (4), and, using (ii) on Table III, is combined to give an estimate of the total effect of monopoly on innovation in column (ii). Thus, for example, the direct effect of ENTRY is (from (ii) on III) 18.51; the indirect effect is  $(1.16) \times (-.838) = -.972$ , and thus the total effect is = 17.54.

Table IV tells a very simple and straightforward story. Equation (i) shows that rivalry (i.e. low CON, high ENTRY, high IMPORT, high SFIRM, low EXIT, and high  $\Delta$ CON) reduces price-cost margins, ceteris paribus. Thus, for an innovation which yields a given total of potential profits, one expects to observe monopolists appropriating more of it than would be managed by firms in more competitive sectors. And, since this higher realized profit has a positive (if statistically weak) effect on innovativeness, it is clearly the case that the indirect effect of monopoly on innovation is positive. Since Table III suggests that the direct effects are negative, the size and sign of the

total effect of monopoly on inovativeness is uncertain. Putting together the estimates on Tables III and IV, it is clear that the trade-off which exists in principle does not amount to much in practice. In virtually every case, the sign of the total effect of a variable on innovation is the same as the sign of its direct effect computed by holding unexpected post-innovation returns constant. What is more, in most cases the sizes of the direct and effects are virtually the same. Thus, one concludes that the indirect feedback from market structure (and other variables) to innovation is weak and extremely uncertain in effect. The negative direct effects shown on Table III clearly suggest that monopolists are slower to respond to profitable innovative opportunities than are firms in more competitive markets; the very small indirect effects revealed on Table IV suggest that there is absolutely no systematic tendency for the higher post-innovation returns that monopolists appear to enjoy to compensate for their relative weaker response to such opportunities.

Thus, it seems plain that there is virtually no evidence whatsoever in the data which support the view that monopoly or market power is conducive to innovative activity. Opening up most markets to more competitive forces - lowering industry concentration, raising net entry rates, and sustaining a large and vibrant small firm sector - seems likely to have a positive and healthy effect on innovative activity.

One might reasonably ask, however, what the longer run effects of innovative activity is likely to be. In particular, will higher levels of innovative activity make markets even more competitive, or does innovation have a centralizing effect on the structure of markets? If it is the case that innovation is decentralizing and so increases

TABLE IV

Regression results for equation (4)

	(i)	(ii)
CON <sub>i</sub>	.323 (.270)	-58.919
ENTRY <sub>i</sub>	-.838 (2.56)	17.54
IMPORT <sub>i</sub>	-.0049 (.017)	-.412
SFIRM <sub>i</sub>	-.260 (1.87)	3.37
EXIT <sub>i</sub>	.445 (1.48)	-24.93
ΔCON <sub>i</sub>	-.102 (1.20)	-10.241
SIZE <sub>i</sub>	-.239 (1.71)	3.698
GROW <sub>i</sub>	-.056 (1.81)	3.333
KAYO <sub>i</sub>	-.017 (1.30)	.816
EXPORT <sub>i</sub>	.020 (1.39)	6.885
UION	.040 (.234)	-2.52

Equation (i) has the log of price-cost margins as its dependent variable and also includes fixed effects, risk, an instrument for innovations, concentration squared and size squared. Column (ii) is the total effects computed from (i) and (ii) on Table III. Indirect effects for CON were computed at sample mean values,  $\overline{CON} = .517$ .



competition in markets, then the basic relationship between competition and innovation that we have identified is mutually reinforcing.

Competition breeds innovative activity which, in turn, increases the degree of competition. If this is the case, then policies designed to increase the size of markets and increase competition will have a long run effect in excess of their short run effect. If, on the other hand, innovation is centralizing, then such policies will increase competition and innovativeness only in the short run. As the process gets under way, the increase in innovative activity will counteract the initial effects of the policy. Long run effects will be less than those observed in the short run and, indeed, may ultimately completely offset the initial policy actions. Thus, before finally concluding that competition stimulates innovativeness, one must check to see that short run effects do indeed persist.

To explore this question, one needs to know something about the feedback from innovation to market structure. The work on Table III uses six measures of market structure or its changes, but most interest focuses on industry concentration. Hence, we shall specialize the question somewhat, and ask whether innovative activity tends to concentrate or deconcentrate markets.<sup>(13)</sup> The simplest and most straightforward way to investigate this question is to use a dynamic model which distinguishes short from long run movements in market concentration, and allows for partial adjustment to changes in the latter. The model was estimated across the same 73 industries in the two five year time periods 1970-74 and 1975-79 as the regressions reported on Table III, and yielded the estimated equation

$$\begin{aligned}
 (5) \quad \Delta \text{CON}_t &= -1.083 \text{CON}_{t-1} + .0056 \text{KAYO}_t - .003 \text{SIZE}_t \\
 &\quad (23.28) \quad (3.67) \quad (2.51) \\
 &+ .0035 \Delta \text{KAYO}_t + .0149 \Delta \text{SIZE}_t - .0011 \hat{I}_t \\
 &\quad (1.08) \quad (.690) \quad (3.59)
 \end{aligned}$$

plus industry specific fixed effects ( $\bar{R}^2 = .71$ ), where  $\hat{I}_t$  is an instrument for  $I_t$ , and where now  $\Delta \text{CON}_t = \text{CON}_t - \text{CON}_{t-1}$ , and similarly with  $\Delta \text{KAYO}_t$  and  $\Delta \text{SIZE}_t$ . It is plain from (5) that innovations have a clear, statistically significant negative effect on market concentration, and thus that an increase in innovativeness will reduce long run levels of concentration. Further, the partial adjustment parameter implies that the effect of this change in long run concentration levels will be fully incorporated into actual, observed levels of market concentration largely within "the period" (i.e. within about five years). Like those reported on Tables III and IV, the results reported in (5) are extremely robust. Letting  $I_t$  be endogenous or lagging it had no substantive effect on the results, and, similarly, the inclusion or exclusion of  $\text{SIZE}_t$ ,  $\text{KAYO}_t$ ,  $\Delta \text{KAYO}_t$  and  $\Delta \text{SIZE}_t$  singly or in groups had no real effect.

Combined with the estimates of (3) reported above, (5) suggests that increases in competition and in innovative activity are mutually reinforcing. A competitive market produces more innovations than a more monopolistic one, and the result of this innovative activity is to make markets more competitive. Hence, over time one expects to observe a gradually increasing spiral of innovation and decreases in market concentration (all other factors held constant), decreases which will further boost innovation rates. Clearly a one-off increase in competition, say as the result of policy initiatives to reduce

intra-Community barriers to trade, will hasten this evolutionary process, and produce long run effects in excess of those observed in the short run.

One final set of remarks is in order. While it is clear that the degree of competition has an effect on innovative activity (and one that feeds back on itself) it is less than clear that market size per se has any impact on innovation. It appears to be true that markets which are rich in technological opportunity are also frequently rather large, but it is plain from Table III that once variations in technological opportunity across industries is held constant, then size per se plays very little role in affecting innovation rates. Whatever importance market size has is indirect, operating only to the extent that large markets are less concentrated, attract more entry, and so on. Regression (5) suggests that, at least with respect to movements in industry concentration, the effect of increased market size is minimal. Other studies in the literature have reported positive effects of size on entry rates and significant negative effects on concentration, but most studies seem to suggest that these effects are small.<sup>(14)</sup> One emerges with the clear feeling that initiatives to open up the internal Community market will have a positive effect on rates of innovation only to the extent that they increase competitiveness. Measures aimed solely at increasing market size without affecting the degree of competition are unlikely to produce a discernable impact on dynamic efficiency.

V. SUMMARY

The basic argument and results of this paper are as follows.

- (1) Recent policy measures proposed in the context of efforts to reduce intra-Community trade barriers are likely to affect both the size of and the degree of competition in markets;
- (2) increases in market size are likely to yield static efficiency gains if economies of scale exist, and increases in the degree of competition will reinforce this to the extent that they lead to a reduction in X-inefficiency.
- (3) In principle, increases in market size ought to stimulate innovativeness and raise the dynamic efficiency of markets;
- (4) however, increases in the degree of competition could lead to a reduction in innovativeness to the extent that large firm size and market power are necessary for innovation.
- (5) The data reveals that there are no obvious advantages to firm size or to market power in generating innovative activity in the short or in the long run.
- (6) It follows that moves to open up internal markets within the Community are unlikely to lead to any important trade-offs between the realization of static and dynamic efficiencies. The static gains to such policy proposals almost certainly understate the total gains to be realized from their implementation.

Notes

1. This argument follows Gilbert and Newberry, 1982. If the initial monopoly is based on an innovation then, if it introduces a second innovation, the monopolist can coordinate the pricing of the goods associated with the two innovations. If, by contrast, an entrant introduced the second innovation, then competition would prevail between the two goods. The returns the entrant would earn are, therefore, less than the returns that the monopolist would get if it introduced both goods, and this means that the monopolist would have a greater incentive to introduce it, pre-empting the entrant.
2. The terms are due to Rothwell (1985); the debate that follows in the text is discussed at greater length in Scherer (1980, pp.423-38).
3. This has been extensively discussed in game theoretic models of R&D; see, amongst others, Scherer 1967, Loury 1979, and Reinganum 1982; for good surveys, see Kamien & Schwartz, 1982, and Dasgupta, 1986.
4. This is the well known argument of Arrow, 1962; Fellner, 1951, also stressed that the foregone profits from the displaced line of activity can act as an opportunity cost slowing down the introduction of the new innovation.
5. On the standard, static efficiency vs. monopoly power trade-off which is caused by economies of scale, see Williamson (1968).
6. For good surveys, see Scherer (1980) or Kamien and Schwartz (1982); Fisher and Temin (1973) critically discuss how much can be inferred about the Schumpeterian hypothesis from regressions of firm size on R&D inputs.
7. In addition to Scherer (1980) and Kamien and Schwartz (1982), see also Ergas (1984). In a recent study in the UK, Schott (1977) discovered that many large firms aim for extremely modest technical advances whose value depreciates extremely rapidly.
8. Previous work in the literature has concentrated on simple partial correlations between market structure (as measured by concentration ratios) and measures of research inputs or innovative output, and have interpreted a positive correlation between the two as evidence consistent with the Schumpeterian hypothesis. Since this correlation does not measure either the direct or the indirect effect of monopoly on innovation, it is a little difficult to interpret. For surveys of this literature, see Kamien and Schwartz (1982) or Scherer (1980).
9. See, for example, Phillips (1966), Scherer (1967); Cohen et al (1987) find much the same effect in firm size and R&D regressions.
10. We also tried using rational expectations proxies of post-innovation returns rather than observed post-innovation returns, but no significant differences emerged from this. The rational expectations proxy for expected post-innovation profits used a two equation structural model of profits and innovations to derive a reduced form expression linking profits to all the

exogenous variables in the system. Assuming that agents possess rational expectations, one can then use the predictions from this reduced form equation to proxy expectations, since these predictions are exactly what a rational agent who knew the structure of the model would use (for further discussion of the econometric issues associated with rational expectations models, see Wallis (1980) and Wickens (1982)).

11. The innovations data base only provides 80 possible MLH industry classifications, and 7 further industries were eliminated because of holes in our capital stock series. Five year intervals were chosen to minimize the effect of any inaccuracies in recording the precise date of innovation.
12. For a good discussion of limited dependent variable models, see Maddala (1983); Blundell and Meghir (1987) discuss the "double hurdle" model.
13. We have done some simple reduced form regressions which indicate that increases in innovation increase entry and exit at a diminishing rate, and reduce imports, small firm activity and percentage changes in market concentration at a diminishing rate. None of these effects appear to be strong or significant.
14. See Geroski and Masson (1987) and Curry and George (1983), respectively, for surveys of these studies.

Data Appendix

$I_i$  = number of major commercially successful innovations used in industry  $i$ . this data is based on a major study by SPRU, University of Sussex, of 4378 major innovations in the U.K., 1945-83; for details see Townsend, 1981, and Robson and Townsend, 1984. The data was obtained from the ESRC Data Archive at Essex.

$\pi_i$  = price-cost margins, defined as net output less the wage bill less net capital expenditure divided by gross output. Data was obtained from the Census.

DCON and  $CON_i$  = percentage change and level of the 5-firm concentration ratio, from the Census of Production.

ENTRY $_i$  and EXIT $_i$  = market share of all new (exiting) firms. The data was drawn from a special compilation made by ENTRY and EXIT for the 1980-74 period were measured by 1974 values of the variables since data for 1970-73 was not available.

IMPORT $_i$  and EXPORT $_i$  = import and export intensity, obtained from the DTI via the MICRODATA data based compiled at the OECD. this data is virtually the same as is available in the Business Monitor.

SFIRM $_i$  = relative number of firms  $\leq 99$  employees, from the Census. One or two missing observations were filled using Order averages.

SIZE $_i$  and KATO $_i$  = log of industry assets and capital stock output ratio, obtained from calculations made by D. Allard for the OFT.

UNION $_i$  = % of workers covered by a collective agreement, from the New Earnings Survey. One or two missing observations were filled using Order averages.

All other variables used were derived from these or directly obtained from the Census of Production; all market shares have been adjusted for imports and exports.

REFERENCES

- Arrow, K. (1962) "Economic Welfare and the Allocation of Resources for Inventions", in R.R.Nelson (ed.) The Rate and Direction of Inventive Activity, Princeton University Press, Princeton.
- Blundell, R. and C. Meghir (1987) "Bivariate Alternatives to the Tobit Model", forthcoming, Journal of Econometrics
- Cohen, W., R. Levin and D. Mowery (1987) "Firm Size and R&D: A Re-Examination", Journal of Industrial Economics, 35, 543-66.
- Curry, B. and K. George (1983) "Industrial Concentration: A Survey", Journal of Industrial Economics, 31, 203-56.
- Dasgupta, P. (1986) "The Theory of Technological Competition" in J.E. Stiglitz and G.F. Mathewson (eds.), New Developments in the Analysis of Market Structure, Macmillan, London.
- Edwards, K. and T. Gordon (1984) "Characterization of Innovations Introduced on the U.S. Market in 1982", Report for U.S. Small Business Administration by the Futures Group, Washington D.C.
- Ergas (1984) "Why do Some Countries Innovate More than Others?", CEPS, Brussels.
- Feinman, S. and W. Fuentevilla (1976) "Indicators of International Trends in Technical Innovation", Report to National Science Foundation by Gellman Research Associates.
- Fellner, W. (1951) "The Influence of Market Structure on Technological Progress", Quarterly Journal of Economics, 65, 556-77.
- Fisher, F.M. and P. Temin (1973) "Returns to Scale in Research and Development: What Does the Schumpeterian Hypothesis Imply?" Journal of Political Economy, 81, 56-70.
- Geroski, P.A. (1987) "Innovation, Technological Opportunity and Market Structure", mimeo, University of Southampton.
- Geroski, P. and R. Masson (1987), "Dynamic Market Models in Industrial Organization", International Journal of Industrial Organization, 5, 1-14.
- Geroski, P. and R. Pomroy (1987) "Innovation and the Evolution of Market Structure", mimeo, London Business School.
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- Gilbert, R. and D. Newberry (1982) "Pre-emptive Patenting and the Persistence of Monopoly", American Economic Review, 72, 514-526.
- Hughes, K. (1984) "Determinants of R&D Expenditure in UK Manufacturing Industry", forthcoming Journal of Industrial Economics
- Kamien, M. and N. Schwartz (1982) Market Structure and Innovation, Cambridge University Press, Cambridge.



- Levin, R., W. Cohen and D. Mowery (1985) "R&D Appropriability, Opportunity, and Market Structure: New Evidence on the Schumpeterian Hypothesis", American Economic Review, 75, 20-24.
- Loury, G. (1979) "Market Structure and Innovation", Quarterly Journal of Economics, 93, 395-410.
- Lunn, J. and S. Martin (1983) "Market Structure, Firm Structure and R&D", forthcoming, Quarterly Review of Economics and Business.
- Madalla, G. (1983), Limited Dependent and Qualitative Variables in Econometrics, Cambridge University Press, Cambridge.
- Pavitt, K., M. Robson and J. Townsend (1987) "The Size Distribution of Innovating Firms in the U.K.: 1945-1983", Journal of Industrial Economics, 35, 297-316.
- Phillips, A. (1966) "Patents, Potential Competition and Technical Progress", American Economic Review, 56, 301-10.
- Reinganum, J. "A Dynamic Game of R&D" Patent Protection and Competitive Behavior", Econometrica, 50, 671-88.
- Robson, M. and J. Townsend (1984) "Users Manual for E.S.R.C. Archive File on Innovations in Britain since 1945", mimeo, SPRU, University of Sussex.
- Rosenberg, N. (1974) "Science, Invention and Economic Growth", Economic Journal, 84, 90-108.
- Rothwell, R. (1985) "Innovation and the Smaller Firm", mimeo, SPRU, University of Sussex.
- Scherer, F.M. (1965) "Firm Size, Market Structure, Opportunity and the Output of Patented Inventions", American Economic Review, 55, 1097-1125.
- Scherer, F.M. (1967) "Market Structure and the Employment of Scientists and Engineers", American Economic Review, 57, 524-31.
- Scherer, F.M. (1967) "Research and Development Allocation Under Rivalry", Quarterly Journal of Economics, 81, 359-94.
- Scherer, F.M. (1980) Industrial Market Structure and Economic Performance, 2nd edition, Rand McNally, Chicago.
- Schott, K. (1976) "Investment in Private Industrial Research and Development in Britain", Journal of Industrial Economics, 25, 81-99.
- Schrieves, R. (1978) "Market Structure and Innovation: A New Perspective", Journal of Industrial Economics, 26, 329-47.
- Townsend, J., F. Henwood, G. Thomas, K. Pavitt and S. Wyatt (1981) "Innovations in Britain since 1945", Occasional Paper No.16, SPRU, University of Sussex.
- Wallis, K. (1980) "Econometric Implications of the Rational Expectations Hypothesis", Econometrica, 48, 49-73.

- Waterson, M. and A. Lopez (1983) "The Determinants of Research and Development Intensity in the U.K.", Applied Economics, 15, 379-91.
- Wickens, M. (1982) "The Efficient Estimation of Econometric Models with Rational Expectations", Review of Economic Studies, 49, 55-67.
- Williamson, O. (1968) "Economies as an Anti-Trust Defense", American Economic Review, 68, 18-34.

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