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7 July 1995

This report was prepared for the Department des Affaires Economiques at the OECD as part of their programme on "Product Market Competition". I am obliged to John Van Reenen and Chris Walters for help in assembling and analysing the data used in this report. The usual disclaimer applies however.

INNOVATION AND COMPETITIVE ADVANTAGE

This paper examines the effects of the production of major innovations and patents on various measures of corporate performance. The analysis draws on panel data for 440 UK firms over the period 1972-1982. The observed direct effects of innovations on performance are relatively small. The paper also shows that little evidence can be found on innovation spillovers, associated with the production of either innovations or patents elsewhere in each firm's two-digit industry, raising performance. The benefits from innovation are more likely to be indirect, namely for user industries. However, innovative firms seem to be less susceptible to cyclical pressures than non-innovative firms. Firms in a competitive environment also seem more likely to engage in innovative activities than other firms.

* * * *

Cette étude examine les effets des activités d'innovation sur des différentes mesures de performance des firmes. L'analyse s'appuie sur un panel de 440 firms du Royaume-Uni et concerne la période 1972-82. Les effets observés des innovations sur les indicateurs de performance sont relativement faibles. En outre, les résultats de l'étude ne permettent pas de conclure que les innovations produisent des effets sur les performances des autres firms à l'intérieur de la même industrie (au niveau de la classification à deux chiffres de la nomenclature). Les bénéfices de l'innovation sont plutôt indirects, notamment pour les industries utilisatrices. Cependent, les firmes innovatrices semblent moins susceptibles d'être affectées par les fluctuations conjoncturelles que les firms qui n'innovent pas. Un environnement compétitif semble aussi favoriser l'activité innovatrice des firmes.

I. INTRODUCTION

There is no doubt that the development of competitive advantage is an important business policy issue for virtually all firms in most economies. What is more, the pressing nature of the problem has put it on the agenda of many public policy makers, despite the difficulty which most of them have had in identifying areas where their actions might make a real difference. Part of the problem facing policy makers is that there are many different ways for firms to develop competitive advantage, and it is not always clear when different strategies will be most appropriate. These problems are compounded by the fact that competitive advantage is not easy to measure, since different measures of performance give different rankings of firms. Finally, there is a real dearth of solid empirical evidence on the determinants of competitive advantage, and it is, therefore, difficult to be sure which kind of policy is likely to have the most beneficial effect on those to whom it is aimed.

The goal of this report is to empirically explore the relationship between competitive advantage and one of its possible determinants, namely the production of patents and innovations embodying new products and processes. The questions that we shall focus on include the following:

* what are the effects of the production of major innovations or patents on corporate profitability and growth?
* how does innovative activity affect profits and growth?
* are export oriented firms more innovative than other firms, and do they benefit more from the patents and innovations which they produce than domestically oriented firms?
* does current performance feedback to affect the production of patents or innovations?
* do technology spillovers from other firms have much effect on corporate performance?

In short, we hope to make some inferences about the importance of innovation production as a source of competitive advantage. These, in turn, will allow us to make some indirect inferences about the incentives firms have to innovate, and the likely value of public policies designed to stimulate the production of new products and processes.

The plan of the report is as follows. In Section II, we describe our data, and then, in Section III, we outline the results of the experiments we have conducted with the data. The work carried out for this report is an extension of a broader set of projects exploring the causes and consequences of innovative activity in the UK using large panels of data on individual firms. We will, therefore, try to tie in some of the specific results obtained in this particular project with those obtained elsewhere on similar data. Our conclusions are in Section IV.

II. THE DATA

We begin our exploration of the data in this section by looking at the sample, and identifying some of the basic statistical properties of the major variables of interest.

(i) the sample

Our basic data is drawn from a sample of 440 UK firms observed over the period 1972-1982 (see the Data Appendix for a fuller discussion). The sample was drawn from the DATASTREAM file of firms, which provides basic balance sheet information for a population of more than 2000 large (usually quoted) UK firms per annum. The criteria for inclusion in our sample were that: adequate financial data was available for each firm, the firm was quoted and it survived for at least five years during the sample period. The industry representation of our sample is restricted to manufacturing. This is not particularly restrictive, since almost all of the innovations and patents in the data sets that we have used were produced by firms primarily engaged in manufacturing.

The major difficulty with all studies of this kind is the potential problem of selection bias, since any sample which observes firms over a number of periods is necessarily concerned with surviving firms. The difficulty with data that is drawn exclusively from surviving firms is that the determinants of survival may not be exogenous to the process under consideration. If, for example, one were interested in the effect of innovation on corporate profitability, the fact that only profitable and (in some sense) innovative firms survive the competitive process means that the measured effect of innovation on the profits of surviving firms may conflate the effect of innovation on survival prospects with the effect that innovation has on profitability conditional on survival. In this case, the returns to producing innovations will be understated, since low profit non-innovating firms who do not survive are not included in the data[1]. To alleviate this problem somewhat, we have elected to work with an unbalanced panel, meaning that not all firms were present in our data in all of the years covered[2]. As a check on whether selection bias has affected our results, we replicated most of the work reported below on the panel of balanced firms, and did not observe any major changes.

The choice of time period for this study was determined mainly by data availability. The DATASTREAM data first becomes usable for our purposes in 1972, and the innovation data collected by SPRU ends in 1983. Since there is a noticeable fall off in the number of innovations produced in 1983 which might be at least partially attributable to the ending of the SPRU major innovations project, we choose to omit the last year of the data. The period contains at least one event of interest, namely the major recession of 1980-1981.

The DATASTREAM data provides information on profitability, sales, exports, stockmarket returns and other features of corporate activity which is routinely recorded on financial balance sheets. We have imported information from two further sources to augment this data. First, we have included data on about 4300 major innovations produced in the UK over the period 1945-1983. These innovations were deemed by a panel of experts to be technological breakthroughs, and have been commercially successful. This data was compiled at, and kindly provided by, SPRU at the University of Sussex, and John Van Reenen oversaw its transfer to our database. Second, we have added data on the patenting activity of the firms in our sample. This is data which records the patents taken out in the US by UK based firms. It was provided by SPRU and compiled by Chris Walters at London Business School.

(ii) simple correlations

Table I shows the pattern of partial correlations computed over all firms and years between the variables of interest in this report. The table divides these variables into three groups.

The first group of five variables includes the number of innovations and patents produced by each firm, plus three measures of the innovative activity in the two digit industry which each firm operates in: the number of innovations produced by other firms in the industry, the number of patents produced by other firms in the industry, and the R&D intensity of the industry. Three features of this block of correlations stand out. First, firms that innovate also tend to patent, but the relationship is not all that strong (the partial correlation is .4244). Indeed, one of the more interesting features of the innovations data is the fact that firms do not always patent all or part of their major innovations, and, needless to say, not all patents lead to major innovations. The second interesting feature of this block of correlations is the fact that the innovative performance of individual firms is only very weakly related to the level of innovative activity in the industry which they operate in. The simple fact is that very innovative industries contain more than a few firms which do not innovate, and even the most technologically stagnant industries sometimes host innovative firms. The third interesting feature of these correlations is the relatively weak relationship between the innovative output, patent output and the R&D input of the different industries represented in our sample. Amongst other things, this casts some doubt on whether the usual linear model of the innovation process (R&D leads to patents and then to new products and processes introduced onto the market) is a useful way to think about the relationship between these three measures of innovative activity.

The second block of correlations measures the association between the four dependent variables which we will be using to measure corporate performance. The observation of interest here is the fact that the four seem to be only weakly related to each other. ROR is a standard measure of accounting profitability, and it is positively but not very strongly related to Tobins-Q (a measure which is sometimes used as an alternative to accounting profitability in performance studies[3]). It is also not very strongly related to corporate growth, measured either in terms of sales or in the growth of market value. The weakness of the correlations amongst these different measures of performance suggests that each captures different aspects of corporate performance. We shall return to this point later.

The third block of correlations captures interactions between the major independent variables of interest which we shall be using. The first three (firm size, market share and capital intensity) are measured at the level of the firm, while the last three (concentration, union density and import density) are industry level measures. The only correlation of any appreciable size that is recorded on the table is the unsurprisingly high correlation between firm size and market share.

(iii) the persistence of corporate performance

The most striking feature of the different measures of corporate performance which have been used in studies of the determinants of competitive advantage is that they are not always statistically congruent with each other. In particular, measures of performance like accounting profitability typically vary far more between firms (or industries) at any given time than they do within firms (or industries) over time. By contrast, measures like the rate of growth of any one particular firm (or of any one particular industry) is typically very much more variable over time than it is between different firms (or industries) at any one particular time. This is also a feature of our data.

Figure 1 shows the cross section correlation in our four measures of corporate performance (ROR, Q, ΔlnS and ΔlnMV) over time; that is, the correlation between cross sections over increasingly long periods of time. To be meaningful, these cross section correlations must involve the same firms, and we have, therefore, restricted attention to firms who survive at least as long as each time interval. This means that the number of firms used in computing successive correlations is different (Figure 2 replicates Figure 1 on a balanced panel). Both measures of profitability are highly correlated over time. Profits between 1972 and 1973 are correlated with coefficient of over .90, and this correlation drops to just under .60 over the eleven years of our data. That is, knowing who the most profitable firms were in 1972 in the sample would go quite some way towards providing a prediction of who the most profitable firms were in 1982. Ranking firms by Tobin's Q shows even more stability over time: the correlation between firms ranked by Tobin's Q between 1972 and 1973 is larger than .95, and it drops to just over .80 eleven years later. By contrast, the correlation between firms ranked by the growth of their sales turnover between 1972 and 1973 is virtually zero, while that between firms ranked by the growth in their market value is just larger than -.17.

The implication of these calculations is that the usual practice of arguing that current period growth rates are good proxies of the level of profits in the long run is unpersuasive. Superior corporate performance, as measured by profitability, is very persistent over time, and current levels of accounting profits (or stock market valuations) are good predictors of (at least) near future levels of accounting profits (stock market valuations). However, corporate growth rates are very nearly random (meaning that firm size roughly follows a random walk), and superior performance, as measured by an unusually rapid growth in sales or market value in any one year, is unlikely to be repeated in the following year. Current period growth rates are not very useful for predicting their own future, much less for predicting future profitability[4].

(iv) innovative activity

The independent variables of most interest in this report are the number of major innovations produced by each firm, and the number of patents which they are granted in the US. Neither of these are entirely satisfactory measures of "innovativeness", not least because individual innovations and patents are difficult to compare technologically and they can have wildly different market values. Both measures are, however, superior to measures of innovativeness based on R&D spending. At best, R&D is a measure of inputs into the innovation process, but undertaking R&D is neither a necessary nor a sufficient precondition for producing either a patent or a major innovation. Innovation counts are at least direct (if imperfect) measures of innovative output, and, since it is the consequences (and not the causes) of innovation which are of interest here, they are the natural measure to focus on. Patents are less clearly identifiable as a measure of innovative output, not least because they seem to be highly correlated with input measures like R&D and are typically taken out well before the knowledge which they describe is embodied in a particular product or process. Our own view is that patents are most usefully thought of as intermediate input measures, reflecting increments of technological knowledge. These inputs are combined with information about users needs, design and manufacturability and so on to produce outputs like major innovations[5].

The most obvious feature of the data on the innovative output (i.e. major innovations or patents) of firms is that relatively few firms ever innovate or patent, while a very small number produce quite a few innovations or patents. One way to see this is to examine Table II, which shows that the average number of innovations produced per firm per year in our sample is 0.09; the average number of patents per firm per year is 1.6. Another, more revealing insight emerges from Figure 3, which plots the distribution of innovations and patents produced by the firms in our sample over the period 1972 - 1982. Even a cursory examination of the data reveals that most firms innovate or patent on an infrequent basis. 74% of the firms in our data did not introduce a major innovation over the period 1962-1982, while 54% did not patent over the period 1969-1982.

Given the infrequency with which it occurs, it is not hard to believe that the process of producing a major innovation (or, less plausibly, a patent) may involve a subtle but nevertheless pervasive transformation in the abilities of a firm. It has often been argued that innovative activity has two effects on the performance of a firm. First and most obviously, the **product** of the innovation process (whether it be a new product or a new process) is likely to affect the innovators costs or demand, and, therefore, its market position and profitability. Second and much more subtly, the **process** of innovating may affect a firms general competitive abilities, sharpening its ability to perceive environmental threats and opportunities, and then to respond flexibly to them. This second effect is likely to be much more difficult to observe than the first, since such a transformation is likely to alter many of the observable characteristics of the firm, and transform the whole process by which it earns profits and generates growth[6].

The third and fourth columns of Table III display differences between the characteristics of firms who innovated at least once during the sample period and those who did not innovate at all. Unsurprisingly, innovators patent more frequently than non-innovators, and they tend to operate in industries with a higher propensity to patent and a somewhat higher level of R&D investment relative to sales. These rather unsurprising differences aside, however, innovators do not seem to inhabit industries which are obviously more or less competitive than non-innovators. Innovative firms appear to be marginally more profitable than non-innovators, and they seem to grow somewhat faster. None of these performance differences are, however, very marked, suggesting that if an innovation gives firms a genuine competitive edge, it may only be evident in certain circumstances and at certain times. The clearest difference between innovators and non-innovators, however, is that the former are much larger than the latter and, as a consequence, they seem to enjoy a much larger market share.

The fifth and sixth columns of Table III display differences between patenting and non-patenting firms. Unsurprisingly, patenters innovate more often than non-patenters, and they seem to operate in industries which are more technologically vibrant, as measured by industry innovative output, patenting propensity and R&D spending relative to sales. Patenters do not, however, inhabit industries which seem particularly competitive, as measured by standard indices of competitive activity (such as industry concentration, import intensity and union density). Patenters are not obviously more profitable than non-patenters (and their stockmarket valuation seems to be low relative to that of non-patenters), but they do grow marginally faster than non-patenters and they are larger (and enjoy larger market shares).

Table II (a) provides a range of further characteristics of innovating and non-innovating firms, patenting and non-patenting firms and more or less export intensive firms. This table is comparable to Table 3 in Barlet *et al.*, 1995, and points a similar picture of innovating firms: they are larger, invest more, have lower labour costs, export more and have higher margins.

(v) export oriented firms

One of the concerns of this report is the relationship between innovative activity and export performance. Our data is not rich enough to produce reliable annual data on the export performance of the firms in our sample. It is, however, possible to observe the export activities of the firms in our sample one or two years before 1972, and we shall use this information to distinguish between firms according to their export or domestic orientation.

Figure 3 also shows the distribution of export intensity across the firms in our sample. As with innovative activity, export activity is relatively skewed, but not nearly as skewed as innovative activity. 26% of the sample had no overseas sales, 28% exported less than 5% of their output, 44% exported less than 10%, while 38% exported more than 50% of their output. Unlike the two measures of innovative activity, our measure of export intensity does not obviously sort the firms in our sample into two groups: exporters and non-exporters. As a consequence, we have divided our sample into four equal groups of firms ranked by their export intensity. Table III shows the differences in characteristics between the firms in these four groups. Export intensive firms are obviously more innovative than domestically oriented firms, and they patent more as well. This may reflect the existence of size or scale effects in the application of new products or processes, or it may reflect a greater openness and learning ability on the part of firms whose strategies and operations are oriented towards global activities. This second conjecture is reinforced by the further observation that domestically active firms tend to operate in industries which produce less innovations, less patents and invest less in R&D, meaning that they are less likely to be exposed to new technological activities in their home market. The apparent competitive structure of the industries which domestically oriented firms operate in differs from that of export oriented firms only insofar as export oriented firms operate in industries which are more likely to attract imports. Export oriented firms are not obviously more profitable than domestically oriented firms, and they do not appear to grow faster. They are also not larger or more capital intensive than domestically oriented firms.

These results are broadly consistent with those obtained elsewhere. Wakelin, 1995, examined a sample of 500 UK firms over the period 1988-1992. She observed that 49% of innovative firms exported, while only 38% of the non-innovators exported. However, the average export intensity of innovating firms was more than 50% higher than that of non-innovators. Innovating firms were no more capital intensive than others, but they paid a higher level of average remuneration and were nearly three times larger than non-innovators. Barlet *et al.*, 1995, examined the relationship between export performance and innovation for a sample of 9377 French manufacturing firms over the period 1986-1990. As with the UK studies, they found export involvement to be positively related to innovation, and they observed that innovators were more open to trade than others. However, their results suggest that only product innovations (and not process innovations) have an effect on decisions to export.

(vi) a summary

Even a cursory look at the data suggests that the production of innovations and patents is likely to have only a modest effect on corporate performance, however it is measured. Performance differences between innovators and non-innovators are not large on average over the sample period, and, indeed, the major difference between the two types of firm is that innovators are larger than non-innovators (this may either be a cause or a consequence of superior innovative performance). The apparently relatively modest returns to the production of innovations may go some way towards explaining a further interesting feature of the data, namely the fact that innovative activity is an episodic and infrequent event in the ongoing operations of those firms who do innovate or patent. Most firms, however, never innovate or produce a patent, and this makes the fact that export oriented firms are more likely to innovate than domestically oriented firms interesting.

III. THE STATISTICAL RESULTS

Our goal in this section is to examine the effect that the production of innovations and patents has on corporate performance measured in several different ways. Amongst other things, we will examine whether the link between innovation and performance differs between innovative and non-innovative firms and between export and domestic oriented firms.

(i) the model and method

The basic experiment which we want to perform is conceptually straightforward: we want to discover the extent to which differences in performance between firms are associated with variations in the number of innovations and patents which they produce. To develop a structural model linking the production of innovations to performance, one might start with the decision to invest in R&D based on expected future returns, and then trace investments in R&D through an innovation production function to the production of patents and new innovations. New innovations and patents affect the cost or demand position of firms when they are introduced into the market, and this, in turn, yields a return (which may or may not be the same as was originally anticipated when investments in R&D were undertaken). Such a model would be interesting to estimate, and it would provide relatively precise information about how and when various exogenous variables of interest affect the production of innovations and their use to generate competitive advantage. Unfortunately, we have no data on R&D by firm, and this means that we will have to work with reduced form regressions linking measures of performance to the production of innovations. Although such regressions can sometimes be difficult to interpret and they are not always as efficient in their use of data as more highly structured statistical models, they are likely to be robust to a number of specification uncertainties. However, there are a number of problems which need to be addressed in even the simplest of these reduced form regressions.

The first and most familiar problem is that corporate performance is affected by numerous factors, not all of which operate independently. From the point of view of simple statistical modelling, this does not mean that one has to include all of these potential determinants of innovative activity an our regressions. It is, however, important to include at least those factors which may have an impact on performance and which are correlated with the degree of innovative activity. Following Schumpeter, many people believe that the degree of competition in a market is an important determinant of innovative activity, and this means that variables which reflect the competitive atmosphere in which a firm operates may need to be controlled for. To this end, we have included variables measuring the market share and capital intensity of each firm, as well as data on the level of concentration, union density and import intensity in the industry which each firm operates in. Further, innovative activity is, like corporate performance more generally, (roughly) pro-cyclical, and this means that it would be wise to include a cyclical indicator as well (in our case, this will be the rate of growth of GNP)[7]. Since profits and growth often evolve systematically over time (reflecting adjustment costs or the process of entry), we also include a lagged dependent variable in each regression[8]. Finally, we include a full set of fixed effects in each regression to capture unobserved and relatively permanent characteristics of the firm and its environment (like competitive ability, technological opportunity and conditions of appropriability).

The second problem with simple reduced form regressions is that the effects of innovation on corporate performance are unlikely to be instantaneous, and, further, the possibility of spillovers means that the performance of some firm i may depend on the innovative output of some rival j (and, of course, j may benefit from i's innovations). The first problem is usually addressed by including distributed lags in the variable of interest, but the main drawback with this rather standard procedure is that our panel of data covers a sufficiently short period to make one wonder whether the data will be able to reveal the full effects of each innovation on performance over time. This potential truncation bias may affect estimates of the individual co-efficients on the distributed lag, and can only be remedied by using a longer times series of data for each firm[9]. Dealing with problems raised by spillovers is slightly easier. Spillovers are conventionally measured by using the stock of innovations produced, patents granted or R&D spent by firms in industries "adjacent" to each firm. Although in principle, "adjacent" ought to refer to rival firms who operate in the same "technological space" as each firm, in practice most applications use Census based definitions of "adjacent". For our purposes, this means including the innovations produced, patents granted and R&D expenditures of all other firms who operate in the same 2-digit industry[10].

The third problem with simple reduced form regressions is that they may not actually be the right way to test interesting hypotheses about the effect of innovation on corporate performance. If what matters is the **product** of the innovation process, then simple correlations between innovations and corporate performance ought to suffice. If, however, it is the **process** of innovating which is primarily responsible for improving performance, then performance differences between innovating and non-innovating firms will not necessarily be exactly timed with the production of any particular innovation. Rather, innovating firms will generate profits differently from non-innovators, and the effects of innovation of performance will manifest themselves in a variety of ways and through a variety of other variables. This suggests that it might be more useful to distinguish innovating and non-innovating firms, running separate regressions for each. Much the same considerations apply to domestically and export oriented firms.

(ii) the determinants of profitability

The nine regressions displayed on Table III are alternative explorations of the link between innovative activity and accounting rates of return. The first column contains baseline estimates for the full sample of firms; the second and third columns report estimates of the baseline regression for the subsamples of innovating and non-innovating firms respectively; the fourth and fifth columns report regressions for the subsamples of patenting and non-patenting firms respectively; and the final four columns report regressions for subsamples of firms ranked from least to most export oriented.

Let us concentrate first on the regression applied to the full sample of firms. The lagged dependent variable is (unsurprisingly) very highly correlated with current accounting rates of return, reflecting the persistence of profitability noted earlier. The co-efficient on the lagged dependent variable suggests that the long run effects of changing any of the other exogenous variables will be about 1.67 times larger than the short run effects recorded in the table. Alternatively, one can read the co-efficient as suggesting that the effects of a transitory shock to profitability will persist for about five years (only about 1% of a shock in t will affect accounting profits in t+5). Market share is negatively (but not significantly) related to profits, and neither industry concentration or unionization are significantly associated with variations in profitability. Import penetration is the only measure of competitiveness which significantly affects accounting profitability, and it is (unsurprisingly) negative. Capital intensive firms appear to have lower margins, ceteris paribus, which is difficult to explain[11]. More interesting are the effects associated with demand shocks, and the regression shows that margins tend to rise during cyclic upswings. This effect seems to be both strong and relatively precisely estimated. The equation also contains a full set of fixed effects, and these cannot be simplified to a single constant, meaning that there appear to be relatively permanent differences between firms.

Our main interest here is in the effect of innovations, and while it is the case that the production of innovations is positively associated with profits, the effects are small and they are estimated with a good deal of imprecision. The estimates suggest that each innovation raises profit margins by about .0007 in the long run, a very modest contribution to profitability. However, it is larger than the effects associated with patenting activity and with all the spillover variables associated with the production of major innovations or patents which we experimented with. Collectively, patents and the spillover variables made no contribution to explaining profitability, and they were excluded from the regressions shown on Table III. The very small size and complete insignificance of the effects of patents on margins is almost certainly due to the low average (but high dispersion in) value of most patents[12], but it may also be a consequence of the fact that patents are often taken out well before the new product or process which they embody reaches the market. As a consequence, whatever effects patents have on margins may take quite some time to realize. The one variable associated with the innovation process which does appear to have a fairly precisely estimated (although still rather small) effect on profit margins is industry R&D intensity, which is positively and not quite significantly associated with profitability. This result is consistent with numerous studies which suggest that knowledge embodied in R&D expenditures (but that not patents or major innovations) spillover between firms.

The results on spillovers are not too surprising, and have been widely reported elsewhere. It appears to be the case that (predominantly US) studies using R&D data to measure knowledge stocks find evidence of spillovers, while (predominantly UK) studies using data on major innovations do not. Although there are several possible explanations for this difference, the most likely explanation is that the two measures of innovative activity measure quite different things. To the extent that R&D spending measures knowledge creation, it is likely to measure rather general, disembodied knowledge. However, by the time knowledge becomes embodied in a specific new product or process, it is likely to be rather use specific. Disembodied knowledge is much more likely to spillover between rival firms than is knowledge which has become very use specific, and this suggests that we ought to observe spillovers associated with R&D but not necessarily with innovations. That is exactly what we do observe.

These results are similar to those reported by Geroski *et al.*, 1993. They used a model like that used on Table III applied to a sample of 721 UK firms observed over the period 1972-1983, and observed positive but rather imprecisely estimated effects of innovation on profits. For their sample, each innovation raised margins by .0058 over the long run, increasing profits by about £500,000 in total. It is difficult to be sure why the smaller sample used in this report generates much lower estimates of the effects of innovations on profitability than the large sample used in Geroski *et al.*, 1993. However, the estimates reported in both studies were very imprecisely estimated, and this means that much of the difference between them may be due to sampling variation. Further, the imprecision of the estimates is consistent with the view that different innovations have rather different effects on profitability. This means that it is likely to be difficult to make precise statements about an "average" effect. The obvious conclusion to draw from both sets of studies is that the production of innovations has only a modest effect on profit margins.

The most interesting result reported by Geroski *et al.*, 1993, however, was that the profitability of innovative firms was determined by different factors than the profitability of non-innovative firms. These differences became evident when separate regressions were run for sub-samples including only innovating firms and only non-innovators. Perhaps the clearest differences which they observed was that innovative firms were more likely to benefit from spillovers, and were much less sensitive to cyclical forces (meaning that they were much more likely to be able to maintain margins through the recession than non-innovating firms). This was interpreted as suggesting that the **process** of innovating transformed the characteristics of firms who innovate, making them more flexible or adaptable and, thus, more able to withstand the pressures of a sudden adverse demand shock. Geroski *et al.* calculated that such indirect gains (primarily those associated with a diminished susceptibility to cyclical forces) from innovation were several times larger in total than the direct gains which arose from the **product** of the innovation process.

To explore this point further, we also separated our sample into subsamples of innovating and non-innovating firms. A comparison between the second and third columns of Table III shows a much larger and much stronger correlation between profit margins and cyclical factors for non-innovating firms than for innovators, meaning that non-innovators are more sensitive to cyclic shocks and their profitability rises and falls more sharply over the business cycle. Further, the profit margins of innovating firms seem to be more stable than non-innovators, at least in the sense that long run effects are more modest multiples of short run effects than is the case with non-innovators. These results are consistent with those obtained by Geroski *et al.* However, the unexpectedly negative correlation between market share and profits for innovating firms is puzzling, as is the persistently negative correlation between capital intensity and margins. Further, innovating firms do not seem more likely to benefit from spillovers. Patents produced either by innovating or non-innovating firms had no significant effect on margins, and the innovations produced by innovating firms also appeared to have little direct effect on margins. The only competitiveness variable which seems to have any effect on either innovators or non-innovators is import intensity, which is negatively and significantly correlated with profits in both sub-samples.

Columns four and five on the table replicate this exercise by applying the model to subsamples of patenting and non-patenting firms respectively. These regressions display the same difference in dynamics observable with the subsamples of innovating and non-innovating firms: i.e. long run effects are much more quickly realized for patenting than for non-patenting firms. Further, patenting firms seem to be more able to benefit from spillovers than non-patenters (industry R&D intensity is both larger and much more precisely estimated for patenters than for non-patenters), but both types of firms seem equally (and significantly) susceptible to cyclical factors. Patenters did not gain much more in terms of margins from the innovations which they produced than non-patenters, and they gained little (if anything) from their patents. The profitability of both patenters and non-patenters seems to be affected by competitive market conditions only through the effects of import penetration, which negatively and significantly correlated with profits in both sub-samples.

The differences between innovating and non-innovating firms, and between patenting and non-patenting firms shown on Table III are statistically significant, and suggest that there is a considerable heterogeneity -- some of it systematic -- between firms which is not adequately captured by the fixed effects. The last four columns of the table show that at least some of the heterogeneity between firms is also linked to the degree of their export orientation. Reading across the four columns, it appears that the dynamics of profitability differ between domestic and export oriented firms, with the latter showing a relatively stable intertemporal pattern of variation not unlike that displayed by innovating and patenting firms. Export oriented firms also appear to benefit more from industry R&D than domestically oriented firms, although these differences are not very precisely estimated. Each innovation produced by a highly export oriented firm raises margins in the long run by .005, not quite as large as the effect of innovations produced on the margins of very domestically oriented firms (which are swollen by an unusually high estimated co-efficient on the t-2 innovations term). These differences are not, however, significant. Patents have no effects on margins of either domestically or export oriented firms, and neither do spillovers associated with the innovations or patents produced by other firms in the same two-digit industry. Export oriented firms are, however, relatively more sensitive to cyclical factors, unionization and import competition. Capital intensity is negatively correlated to profits for all types of firms, as is market share (whose effects are very imprecisely estimated).

It is often difficult to know exactly what accounting profitability measures, and it is now widely accepted that accounting rates of return can produce misleading measures of economic profits[13]. These problems have inclined some to think that stock market rates of return might be a more appropriate performance measure than accounting profitability, not least because stock market valuations are built up from current expectations of future profitability and so ought to reflect profitability in the long run. In this spirit, we replicated the regressions shown on Table III using Tobin's Q, and these results are shown on Table IV. The three most interesting differences between the two sets of exercises relate to innovations, spillovers and market share. First, the effects of innovation on Tobin's Q were larger and slightly more precisely estimated than on accounting profits, although they were not, in any real sense, large (patents, however, had no effect on Tobin's Q)[14]. Second, market share was positive and significantly related to Tobin's Q for all firms, innovating and non-innovating and patenting and non-patenting alike. Further, the effect of market share was larger and more significant for export oriented firms than for domestically oriented firms. Third and finally, spillover effects associated with the production of innovations elsewhere in the same two-digit industry as each firm had a positive and significant effect on Tobin's Q (although industry R&D intensity had a negative effect). Spillovers seemed to benefit non-innovators and non-patenters more than they benefited innovators and patenters, which is slightly difficult to understand.

Although the results reported on Table IV are consistent with the view that the production of innovations has a modest and very imprecisely estimated effect on corporate performance, Table IV contains a number of puzzles. Industry R&D intensity has a negative and generally significant effect on Tobin's Q, a result which is consistent with the oft made observation that the stock market undervalues investments in R&D. More puzzling still, industry concentration has a negative effect on Tobin's Q while unionization has a positive effect, both effects being significant in many of the equations. Finally, import intensity has a positive and significant effect on Tobin's Q for more export oriented firms. Tables III and IV are consistent in that both measures of corporate performance display strong and precisely estimated effects of demand shocks on performance, and on both tables it is evident that innovating firms are less affected by demand shocks than non-innovators. As with Table III, the fixed effects included on Table IV cannot be simplified to a single constant, suggesting the existence of permanent performance differences between firms.

On the whole, this is a relatively mixed bag of results, and it is hard to draw many strong conclusions from it. The clearest and most robust result which we uncovered is that firms display what appear to be almost permanent differences in performance, and the various exogenous variables have somewhat different effects on different types of firms. The clearest signal of this heterogeneity follows straightforwardly from the fact that the fixed effects in each regression can never be simplified to a set of random effects or to a single constant. What is more, these effects do not pull out all of the heterogeneity in the data, despite the high ratio of between to within variation in profitability. The three different methods of forming subsamples explored here all yielded significant differences in the co-efficients on the exogenous variables determining profitability, even if the pattern of differences is not entirely stable or easy to interpret.

This leads naturally to the second clear result which emerges from these regressions, namely that the production of innovations (but probably not the production of patents) affects corporate profitability in quite subtle ways. The direct effect of innovations (associated with what we have called the **product** of the innovation process) seems to be very small on average, and is very imprecisely estimated. However, innovating firms do differ from non-innovators (not least in being about 10% more profitable), and some of these differences are likely to be a consequence of the way that undertaking innovative activity transforms their internal capabilities. It seems to be the case that the differences in corporate capabilities generated by innovation are particularly easy to observe during recessions, since innovating firms are less susceptible to recessionary pressures. Interestingly, the production of patents does not seem to have quite the same effect on firm's internal capabilities as the production of major innovations does, not (perhaps) a very surprising result. It is also clearly the case that more export oriented firms differ from domestically oriented firms. They are more innovative and they patent more, but they are not obviously more profitable than domestically oriented firms.

The third clear result which emerges from all of this is that conventional structure-performance measures of competitiveness like concentration, unionization and import intensity have relatively modest effects on corporate performance. Of these three, only import intensity has a significant effect (in most regressions). Although this may come as something of a surprise for those schooled in industry level structure-performance regressions (which often reveal significant effects of concentration, unionization and import intensity on average industry profits), it should be no surprise. Differences in performance between firms in the same industry are often very large (and sometimes as large as differences in average profits between industries), and any exogenous variable which affects all firms (such as an industry level variable like concentration) is unlikely to have much effect on the differences between firms which are the dominant feature of the data. The correlations between performance and market share shown on Tables III and IV are more puzzling, but they seem to be bound up with the inclusion of fixed effects. Market shares are relatively stable over time, and this means that it is easy to confuse them with fixed effects. Our experience with regressions of this type is that omission of the fixed effects often has a big effect on the estimated coefficients of market share variables.

(ii) the determinants of corporate growth

It is easy to conclude from Tables III and IV that innovation has only a modest effect on corporate performance, at least when performance is measured by profitability. However, as we saw earlier, different measures of corporate performance have quite different statistical properties, and it seems plain that the various different performance measures commonly used by commentators embody different "bits" of information. For at least this reason alone, it seems worth replicating the exercise described in Tables III and IV using corporate growth rates as a measure of corporate performance. Table V shows nine alternative explorations of the link between innovative activity and corporate growth rates. As in Tables III and IV, the first column contains baseline estimates for the full sample of firms; the second and third columns report estimates of the baseline regression for the subsamples of innovating and non-innovating firms respectively; the fourth and fifth columns report regressions for the subsamples of patenting and non-patenting firms respectively; and the final four columns report regressions for subsamples of firms ranked from least to most export oriented.

It is apparent at a glance that the dominant systematic force driving corporate growth rates is fluctuations in the level of macro economic activity: the sales of most firms rise and fall with the rate of growth of GNP. This is hardly surprising. Further, sales growth is limited by import penetration, unaffected by concentration and unionization, and firms with larger market shares seem to have higher growth rates than lower ranked firms. The relationship between growth and market share is slightly hard to interpret, but it probably reflects the existence of a modest positive correlation between firm size and growth. It is, therefore, natural to interpret this correlation as reflecting the absence of any strong degree of reversion to the mean in corporate growth rates. Further, the very small but significant co-efficient on the lagged dependent variable suggests that the long run effects of most of the exogenous variables on growth is not much larger than their short run effects. This is, of course, a reflection of the lack of persistence of high or low growth over time (i.e. of the weak degree of within variation in growth rates), and means that firms who achieve high levels of growth in any particularly year are unlikely to be able to maintain them at high levels for any appreciable period of time. For this reason, the fixed effects play a much weaker role in the estimated regressions than they did in the profitability regressions discussed above. Finally, growth rates are much more variable than profit rates, and the percentage of the variance of growth rates which is explained by our regressions is appreciably lower than for profit margins.

Our main interest is, however, in the effects of innovative activity on growth rates. The production of innovations has a positive but extremely imprecisely estimated effect on growth rates: each innovation adds about .007 percentage points to growth rates in the long run. Spillovers associated with industry R&D are also positively associated with growth, and their effects are rather less imprecisely estimated than those associated with the production of major innovations. The number of patents produced by each firm has no effect on growth rates, and spillovers associated with the production of patents or innovations by other firms in the same two digit industry also do not appear to materially affect growth rates (these variables have been omitted from the table). The second and third columns of the table show that innovative firms differ in a number of respects from non-innovative firms, not least in their somewhat lower sensitivity to cyclical shocks. Patenting firms also differ from non-patenting firms in a number of respects (most notably in the sign of the correlation between their rate of growth and industry concentration), but both types of firm are equally cyclically sensitive. The last four columns of the table show the results of applying the basic regression to four equal sized subsamples of firms ranked from lowest to highest export intensity. It is clearly the case that growth rates of more export oriented firms are affected more strongly by the innovations which they produce (and they produce more innovations than domestically oriented firms), and they benefit more from R&D spillovers. Their growth rates are less affected by import penetration, more weakly correlated to market share and vary much less systematically than those of domestically oriented firms. Although the differences between export and domestically oriented firms shown on the table are significant, not all of them appear to be systematic or easy to interpret.

Broadly speaking, these results are not inconsistent with those reported elsewhere using similar data. Geroski and Machin, 1993, reported work on a sample of 539 UK firms observed over the period 1972-1983. They observed direct effects on growth rates associated with the production of particular innovations which were very small and rather imprecisely estimated: each innovation raised growth rates by about 1% - 1.4% over the long run[15]. However, they also observed that innovating firms were much less cyclically sensitive than their non-innovating rivals, meaning (once again) that it may be the **process** and not the **product** of the innovation process which matters most. Geroski *et al.*, 1995, also examined the growth rates of firms (this time using a balanced panel of 271 UK firms) and observed very small and quite imprecisely estimated effects associated with the production of innovations on corporate growth rates in a model which also included the growth of market value as an additional independent regressor. One way or the other, the message seems to be the same, namely that the production of major innovations or patents has a small effect on growth which is very difficult to discern with any accuracy.

Corporate growth rates are highly correlated with another measure of corporate performance that often attracts interest in discussions of competitiveness, namely productivity growth rates. Table V shows nine regressions explaining corporate productivity growth rates in a format similar to Tables III-V. Our interest is in the association between total factor productivity growth and innovative activity, and this means that we must include controls for labour and capital inputs (N_t and K_t respectively). The first column of Table VI shows that there is no stronger systematic relationship between the production of major innovations and total factor productivity growth. The production of patents and spillovers of knowledge from the production of major innovations or patents elsewhere in the same industry also had no effect on productivity growth, and these variables were dropped from the regressions shown on Table VI. Curiously, R&D spending is negatively and significantly associated with productivity growth, which is (unsurprisingly) lower in heavily unionized industries and in protected markets, and strongly pro-cyclical. Firms with large market shares also seem to enjoy higher rates of productivity growth. Scanning across columns (which display the same regression applied to eight sub-samples), it is clear that these results are fairly robust to heterogeneities between firms associated with innovation production, patent production and export intensity[16].

Although innovation and patent production seem to be only relatively weakly correlated with the high frequency fluctuations in sales and productivity growth rates that are the dominant feature of our short times series, it is clear from Tables I and II that innovating firms are larger than their rivals. At least in part, this seems to be a consequence of the fact that most of the innovations in our data were net job generators. In particular, Van Reenen, 1994, used data on 600 UK manufacturing firms between 1976 and 1982 to examine the impact of the production of innovations on employment. Large and statistically significant positive effects of innovations were discovered for up to three years after the production of the typical innovation, a result which was robust to second order dynamics, and corrections for capital, wages, industry factors and macroeconomic shocks. Correlations between innovation and employment growth were, however, weak. Process innovations had more effect on employment than product innovations (whose effects on employment were negative and significant). Innovating firms were somewhat more heavily unionized than non-innovators, and paid higher wages than non-innovators. They also had a higher variance in employment growth over time (but a lower variance in output growth), mainly because they grew faster in upswings and shrunk more slowly during recessions. Although patents also appeared to generate higher net job creation, their effect was not significant after controls for fixed effects were introduced. No evidence was uncovered suggesting that spillovers had effects on net job creation. Meghir *et al.*, 1995, extended this work using a more sophisticated model, and found no evidence that innovations induce capital deepening. However, they did observe that innovative firms had lower adjustment costs than non-innovators, a result consistent with the view that the process of innovating makes firms more flexible and adaptable.

One of the problems with our experimental design is that the relatively short times series which we are using does not allow much time for individual innovations to have an effect on corporate performance. One further experiment which we did casts some interesting light on this problem. We replicated the results shown on Table V using the rate of growth of market value as a dependent variable rather than the rate of growth of sales, and the results are shown on Table VII[17]. These regressions are particularly interesting, as they suggest that the production of innovations (but not patents) and spillovers associated with innovations, patents and R&D increase the growth of market value. In particular, each innovation increases market value by about .0062 in the long run. This is not inconsistent with what we observed earlier, but the estimates shown on Table VII are unusually precise. If, as seems not unreasonable, one interprets the increase in a firm's market value as an signal of a rise in its long run profitability, these results suggest that innovative activity increases the stream of profits realized by an innovation producing firm over time. It follows that the difference between Table III and Table VII can be interpreted as suggesting that the time period over which returns are earned from typical innovations is probably much longer than we have been able to allow for. The results on Table VII do not, however, suggest that these returns are particularly large.

In sum, these results are consistent with those reported earlier in suggesting that producing innovations or patents has only a modest effect on corporate performance. This observation applies also to productivity growth, but at least one study has reported positive effects of innovation on employment growth. As before, there seem to be indirect effects associated with the production of innovation arising mainly from the fact that innovation producing firms seem to be somewhat less cyclically sensitive than others. The most interesting thing about these growth regressions is the highly idiosyncratic nature of the growth process: corporate growth seems to occur in randomly timed, randomly sized spurts. While this makes periods of high (or low) growth episodic, these periods of superior growth performance do not seem to be closely timed with episodic bursts of innovative activity. In fact, it is probably a little unreasonable to think that well determined effects would be evident in the growth equations (or, for that matter, in regressions which examine variations in productivity growth rates). Corporate growth rates are enormously variable, and, indeed, they are almost random (meaning that firms size roughly follows a random walk). Given the apparently large number of quite idiosyncratic factors which seem to affect growth rates, it is hard to discern any systematic patterns associated with any particular exogenous variable (like firm size, for example), particularly with a variable like the production of patents or innovations which describes an event that happens only occasionally during the operations of firms. Further, while there are apparent differences in the process which generates growth in innovative and non-innovative firms, the growth rates of both types of firm are just too idiosyncratic to enable us to discern differences very clearly. This observation also applies to domestic and export oriented firms.

(iii) the determinants of innovative activity

It is in principle possible that our estimates of the effects of innovations and patents on corporate performance have been affected by simultaneity bias. To check this, we developed instruments for current period innovations and patents, and then re-estimated the equations applied to the full sample of firms reported on Tables III-VII. The main difficulty with this work was that none of the instruments was particularly satisfactory, since the equations for innovations and patents were poorly determined. The co-efficients on the innovations and patents instruments were within a standard error of those obtained using the actual number of innovations or patents produced, and the precision of our estimates was no higher than that reported on Tables III-VII.

Modelling the incidence of innovative activity using the data on counts of innovations and patents which we have been using here is rather difficult, and only a certain amount of progress has been made[18]. Aside from the inherent difficulty of predicting a variable as episodic as the production of major innovations, a number of econometric problems arise in working with count data to model dynamic phenomena. Nonetheless, two studies have made some progress in explaining variations in innovative activity between firms over time. Blundell *et al.*, 1993, examined the production of major innovations by a sample of 655 large UK firms over the period 1972-1982. They observed that more competitive industries tended to induce more innovative activity, but that within industries firms with larger market shares were more innovative than others. This result is consistent with the descriptive statistics which we discussed in Section II above, and it is important to recognize that both observations are the result of selection bias. Both the Blundell *et al.* sample and the one used here uses data on the major innovations produced by large firms, and, within the class of large firms who innovate, larger firms are more likely to innovate than smaller firms. However, the SPRU database is dominated by innovations produced by small firms, particularly those in engineering. Looking at the data as a whole, then, it is incorrect to assert that innovativeness and firm size go together[19].

A somewhat more elaborate model was developed by Geroski *et al.*, 1995b, who estimated a dynamic three equation model of innovations, patents and cash flow, and used it to simulate the effects of three kinds of public policy towards innovation: increasing R&D subsidies, cutting corporate taxes to increase company cash flow and stimulating the growth of aggregate GDP. They observed that patents appeared to "cause" innovations but not the reverse (a result consistent with the view that patents may be more usefully thought of as a measure of inputs into the innovation process than as an output). They also observed that innovations were more sensitive to demand than patents were (patents were more sensitive to variations in R&D spending than innovations). Their simulations suggested that none of the three types of policy considered were particularly effective in stimulating the production of either innovations or patents. Although Geroski *et al.*, 1995b, observed that patents and innovations increased cash flow and that cash flow stimulated the production of innovations (and, less clearly, patents), these effects took several periods to manifest themselves. It is, therefore, hard to use these results to suggest that simultaneity bias will, in practice, be an important issue.

These results raise the interesting issue of whether oligopolistic market structures facilitate or, at least, stimulate innovative activity. Although almost none of the work discussed above has uncovered a strong and precisely measured correlation between measures of market structure like industry concentration or import intensity and innovative activity, it is a clear feature of the data that large firms are more innovative than smaller ones. However, as noted above, this result is at least in part an artefact of sample selection. That is, the samples of large firms that we are working with excludes the innovative activity of small firms by construction. In the case of the SPRU data on innovations, this is fatal. Pavitt *et al.*, 1987, have shown that 17% of the innovations in the SPRU data base were produced by firms with 199 UK employees or less and 16.6% were produced by firms with 200-999 employees, while only 42% were produced by firms with 10,000 or more employees. It is almost indisputable that the production of a major innovation increases a firm size, and, it may also be that within any given size class, larger firms innovate more frequently than smaller firms. However, the fact that smaller firms innovate and that the production of an innovation increases the producer's market share means that innovative activity can be deconcentrating. In fact, the innovations contained in the SPRU data base do seem to be deconcentrating (see Geroski and Pomroy, 1990).

Despite this qualification, some might nevertheless assert that the positive association between firm size and innovation that is evident in the data is consistent with the Schumpeterian hypothesis that market power and innovation go hand in hand. The main problem with this view is that this association might be the result of some third factor which facilitates innovation and also stimulates firm growth. Large firms may be able to attract better managers or scientists (this may be why they are large), or they may have other abilities which facilitate innovation. At industry level, some industries have richer technological opportunities than others, and conditions of appropriability vary across sectors. Since both technological opportunity and favourable appropriability conditions stimulate innovation, if either of these features of market structure are more commonly found in oligopolistic industries, then this will induce a spurious positive correlation between innovation and market structure. In fact, this seems to be the case. Geroski, 1990, used six measures of market structure in regressions determining variations in the number of innovations produced in different industries, and found that industry concentration was positively associated with innovative activity when no correction was made for inter-industry variations in technological opportunities or in conditions of appropriability. However, when fixed effects were introduced to correct for these factors, the correlation between concentration and innovative activity turned negative. Very similar effects on the correlation between R&D intensity and firm size were observed by Cohen *et al.*, 1987, when they introduced measures of appropriability into their regressions.

The moral seems to be that conventional correlations between measures of market structure like market share and industry concentration on the one hand, and measures of innovativeness are hard to interpret as persuasive evidence consistent with the Schumpeterian hypothesis (see also Scherer, 1992, for some sceptical remarks in this vein). At the very least, one can feel reasonably confident in concluding that market structure is likely to have only second order effects on innovative activity, being much less important than factors like technological opportunity and conditions of appropriability.

IV. CONCLUSIONS

We conclude the report with a brief summary of the results, some reflections on the results and a few brief observations on the implications which they carry for public policy towards innovation.

(i) a summary

Our results are relatively easy to summarize. We have examined the effects of the production of major innovations and patents on various measures of corporate performance, including accounting profitability, stock market rates of return and corporate growth. In all cases, the direct effects of producing each additional innovation or patent on performance was both small and (in all but one case) very imprecisely estimated. We also found no strong evidence that spillovers associated with the production of either innovations or patents elsewhere in each firm's two digit industry raised performance. We examined the data for indirect effects on performance associated with innovation or patent production, as well as with export orientation. Although in all cases, significant differences emerged between different types of firms, not many systematic patterns emerged from the data. Innovative firms do, however, seem to be less susceptible to cyclic pressures than non-innovative firms. Finally, we observed that export oriented firms were more innovative than their more domestically oriented rivals, but this did not appear to open up a noticeable performance gap either in terms of profitability or growth.

(iii) some reflections on the results

Our examination of the effect of innovation production and patenting on these three measures of corporate performance seems to lead to the conclusion that the direct effects of innovation on corporate performance are modest. There are at least three reasons why it has been difficult to uncover a strong and systematic association between patent or innovation production and profitability or growth rates.

First, the effects of particular patents or innovations on growth may be very different in size, a complication which our experimental design is not easily able to accommodate. This problem may lead to very imprecise estimates of the effects of innovation and patent production on performance however measured in the full sample of 440 firms. We have tried to alleviate the problem by looking at sub-sample of firms (innovators and non-innovators, patenters and non-patenters, export oriented firms and domestically oriented firms), and while this exercise has revealed a substantial heterogeneity between firms, it has not noticeably sharpened up estimates of the effects of innovations. These additional regressions have, however, provided some grounds for thinking that many of the benefits of producing innovations are indirect, and arise because the process of innovations transforms firms competitive abilities.

The second reason why it may be difficult to discern strong effects running from the production of innovations to corporate performance is that our experimental design has not allowed enough time for these effects to register themselves. Major innovations are likely have long running (if rather subtle effects) on performance, and patents are dated from the time that they are taken out, not when they are embodied in a new product or process which generates net revenues. Either way, it is hard to avoid the suspicion that the four year lags which is all that our relatively short panel of data allows us is likely to lead to some understatement of the total returns to innovative activity. We have uncovered some indirect evidence which reinforces this concern, namely the rather stronger correlations which exist between the production of innovations and stock market rates of return (or the growth in the market value of the firm) than between innovations and either accounting profitability or growth in sales turnover. Since these stock market based measures of performance reflect current expectations of long run profitability, they at least have the virtue of tracing some of the longer run, future consequences of each innovation produced by the firms in our sample.

The third reason why it is difficult to discern strong and systematic effects of innovation on profitability and growth is that innovation users may gain a disproportionate share of the returns from innovative activity. Most of the innovations in our sample were not used by the firms who produced them, and many of the most footloose innovations in the data were produced by relatively small Engineering firms, presumably at the behest of major users elsewhere[20]. Case studies have uncovered a number of instances where users played a major role in initiating the production of an innovation[21], and it is not hard to believe that, in these circumstances, users have been able to appropriate most of the returns from the innovation process. It is impossible for us to identify the firms who used the innovations or patented in our data, but Geroski, 1991, was able to track flows of innovations between producing and using industries in the UK from 1976-1979. He observed that most of the productivity growth associated with the production of major innovations was recorded in using industries, not producing industries. It follows, then, that our results may accurately measure the effects that the production of innovations (and perhaps patents) have on the profits and growth of innovation producing firms, but, at the same time, understate the total effects which they have on corporate profits and growth in the economy as a whole.

One final set of observations is in order. Although the experiments reported in this project did not produce results as spectacular as might have been hoped for, there are lessons which can be usefully learned from the project. Two in particular seem to be important. First, there is an enormous amount of heterogeneity in the population of firms (even when one confines one's attention to the sub-population of large quoted firms), and it is very difficult to make much progress in explaining performance differences between firms in the face of all of this variation. Rankings based on accounting profitability and stock market valuations are much more persistent over time within firms than those based on growth, but, even still, our regressions involving profitability produced relatively unimpressive fits. Further work needs to be done to control for heterogeneity, particularly if one is going to try to trace the effects of a variable as episodic as innovations production on corporate performance. Second, it seems clear that further progress will require one to unlock the black box of the firm. The work discussed in this report contains a number of tantalizing clues about how the production of innovations or patents may transform the internal capabilities of firms, and we have conjectured that there may be an important link between the ability to produce new innovations and the ability to weather macroeconomic storms. There is a limit to what can be learned about the internal capabilities which might be transformed by the innovation process using the financial performance data (as we have done here). Further work may need to go inside firms, and look more carefully at what actually happens during the process of producing and then using innovations.

(iii) two policy issues

Although our results are somewhat negative, they do raise at least two policy issues of interest. First, if, as seems to be the case, innovating firms outperform non-innovating firms at least in part because the process of innovation transforms their internal capabilities, then it is likely that firms will invest too little in innovative activity. Although at least some firms try hard to make sensible ROR calculations about the effects of different innovation projects on future growth and profitability, their calculations are mainly confined to computing the direct effects on performance associated with each innovation or patent. It is difficult to measure changes in capabilities, and, indeed, it is often hard to be sure that certain types of capabilities are present unless they are needed. The measurement of these kinds of effects of innovation is likely to be very speculative, and most firms will not take them into account when assessing the likely consequences of investing in innovative capability. If, as seems likely, the indirect effects of innovation production exceed the direct effects, then these ROR calculations will seriously understate the return to innovation.

Second, if, as seems to be the case, many of the gains to innovation accrue to users, then it is likely to be the case that public policies which encourage the diffusion of innovations (rather than concentrating only on their production) are likely to bring large pay-offs. Needless to say, diffusion cannot be encouraged beyond the point where innovations producers no longer receive a decent return on their innovation or patent producing activities. However, if it is the process of innovating which matters more than the product, it would seem reasonable to believe that the trade-off between preserving incentives to innovate and encouraging the maximum diffusion of innovations may not be as strong as is generally believed. In particular, there is some reason to think that innovating firms are more able to benefit from spillovers than other firms and they may also be more able to weather macroeconomic storms. Either way, enhancing their internal abilities is likely to make them more effective users of innovations as well. Similar, polices which enable firms to make more use of the innovations and patents produced by other firms may also make then somewhat more likely to innovate or patent themselves.

DATA APPENDIX

The Sampling Frame

We began with two datasets, one an unbalanced panel of 649 firms with continuous "clean" technological and financial data (the *host* data), the other an unbalanced panel of 603 firms with overseas sales, domestic sales and exports data which were incorrectly dated (the *merged* data). The merged data was spliced with the host data by using both company identifiers and years. A dummy variable was assigned to each company-year according to whether it was only in the host data, only in the merged data, or in both datasets. Companies occurring only in the host or merged data were dropped after checking the mean value of their merged dummy over their sample years was an integer (to prevent odd observations occurring in both datasets being kept). Since the merged data was known to be incorrectly dated, companies with a discrepancy of 20% or more between host domestic sales data and merged domestic sales data were visually checked and those with anomalies not obviously due to dating errors dropped. Our final sample was an unbalanced panel of 440 firms from 1972 to 1982.

The Variables

INN - Defined as a count of the number of major innovations commercialised by a firm. This consists of over 4300 "major" innovations introduced in the UK between 1945 and 1983. The aggregate series displays discernable peaks and troughs at roughly five yearly intervals. The distribution of innovations is stable across time with most concentrated in the Mechanical Engineering, Electrical Engineering, Vehicles and Chemicals 2 digit SIC industries. See Townsend *et al.*, 1981, and Geroski, 1995, for further discussion. The data was kindly provided by SPRU.

PAT - Defined as a count of the number of patents granted to a firm by the United States Patents Office. This consists of the aggregate annual number of US Patents granted to over 7400 UK firms between 1969 and 1988, and relates to over 47,500 patents in total. US patents have been used in preference to UK patents in order to screen out the numerous low value patents taken out each year. The data was kindly provided by SPRU.

SPILL_I - Defined as net number of innovations used in a firm's principal 2 digit operating industry (net of its own innovations). Source: SPRU innovations database.

SPILL_P - Defined as the number of patents produced in a firm's principal 2 digit operating industry (net of its own patents). Source: SPRU patents database.

RDS - Defined as R&D expenditures as a proportion of sales in a firm's principal two digit operating industry. Source: Business Monitor, CSO, various years.

MS - Defined as market share of the firm in its principal Exstat Stock Exchange operating industry. Source: DataStream.

CONC - Defined as five firm sales concentration ratio in a firm's principal Exstat Stock Exchange operating industry. Source: Table P1002A, Census of Production, CSO, various years.

IMPS - Defined as principal Exstat Stock Exchange operating industry import density. Source: Business Monitor, CSO, various years.

UNION - Defined as union density in firm's principal 2 digit operating industry. Source: Bain, G. and Price, R., 1980, and the Labour Force Survey, CSO, 1980 - 1982.

CAP - Defined as a firm's capital intensity. Nominal replacement cost of a firm's capital as a proportion of its nominal sales. Source: DataStream.

AGG - Defined as aggregate growth. Growth in nominal GDP (measured using the Income method) for manufacturing industry. Source: Economic Trends, CSO, various years.

ROR - Defined as accounting rate of return. Nominal firm profits as a proportion of nominal firm sales. Source: DataStream.

Q - Defined as Tobin's (quasi) Q, or stock market rate of return. Nominal replacement cost of a firm's capital as a proportion of its nominal stock market value, at the end of December each year. This variable is known as quasi-Q because of its susceptibility to measurement error. Source: DataStream.

ΔlnS - Defined as nominal sales growth. Source: DataStream.

GMV - Defined as growth in a firm's market value. Source: DataStream.

Firm Size - Defined as the natural log of a firm's nominal sales. Source: DataStream.

NOTES

1. Although this argument suggests that our estimates might be regarded as lower bound estimates of the effects of innovation, there is at least one compensating bias which leads in the other direction. This is the fact that our data only includes successful innovations, a selection bias which means that our results are likely to overstate the returns to the total resources invested in innovation production.

2. The structure of the unbalanced panel is as follows: we had 312 firms present in 1972, 401 present in 1973, 419 present in 1974, 430 present in 1975, 432 present in 1976, 438 present in 1977, 440 present in 1978, 440 present in 1979, 437 present in 1980, 432 present in 1981 and 423 present in 1982.

3. See Lindenberg and Ross, 1981, for some early work that uses Tobin's Q as a measure of market power, and Scherer and Ross, 1990, Chapter 11 for a review of more recent work on this issue.

4. These observations are consistent with a large empirical literature on the Gibrat Hypothesis. Most of the work reported in this literature shows that corporate growth rates are very nearly random, although there is weak evidence that firm size and growth are negatively correlated (which induces a reversion to the mean). Geroski *et al.*, 1995, argue that current period growth rates depend on changes in current expectations about future profitability, and they uncovered positive and significant correlations between current period growth rates and changes in current period stockmarket values of firms. If agents are rational, changes in current expectations about the future will be random; i.e. growth rates will be random.

5. There has been a good deal of controversy about whether patents are measures of innovative input or of innovative output, dating at least from the work of Schmookler, 1966; see the perceptive discussion in Griliches, 1990.

6. The distinction between whether it is the **product** of the innovation **process** or the process of innovating which matters is related to an argument advanced by Cohen and Levinthal, 1989, namely that: "... *R&D not only generates new information, but also enhances the firm's ability to assimilate and exploit existing information...*". That is, firms invest in R&D to develop their "*absorptive capacity*", i.e. their "*ability to exploit outside knowledge of a more intermediate sort, such as basic research findings that provide the basis for subsequent applied research and development*". (pp. 569-79). One implication of this arguments is that industry spillovers may stimulate R&D. See also Mowery and Rosenberg, 1989, Cohen and Levinthal, 1990, Pavitt, 1991, and Malerba, 1992.

7. The effect of demand on innovative activity is somewhat controversial; see Mowery and Rosenbery, 1979, for a critical survey of some early empirical work on the subject. For work on the cyclical variation in the production of major innovations and patents in the UK over the post-War period, see Geroski and Walters, 1995.

8. See Mueller, 1986 and 1990, for pioneering work on the persistence of profitability over time. These dynamic models of profits are often thought of as reflecting the dynamics of profits over time associated entry; see also Geroski and Jacquemin, 1988. Autoregressive models of corporate growth are discussed in Geroski *et al.*, 1995.

9. This is likely to be a problem particularly with the data on major innovations, since if they really are "major", their effects should be profound and relatively long lasting. The use of a relatively short times series in these circumstances means that our regressions are likely to understate the effect of innovative activity on performance.

10. For discussions of how to measure spillovers, see Griliches, 1979; Geroski, 1994, surveys some of the recent work done on this problem. Jaffee, 1986, is perhaps the most noteworthy attempt to use a technology (rather than a Census) based definition of "adjacent"; Henderson *et al.*, 1992, use patent citations to trace spillovers.

11. Capital intensity is generally included in regressions like these to correct for the fact that margins are usually computed on the basis of labour and materials costs. This is not always a very satisfactory procedure, a point made with some vehemence by Fisher, 1987.

12. See, for example, the estimates by Pakes, 1986, and Shankerman and Pakes, 1986, which suggest that the average UK patent is worth between £1,000 and £2,000.

13. For recent discussions advocating the use of profits or value added measures to assess corporate performance, see Kay, 1993, and Nickell, 1995.

14. Work on the relationship between R&D expenditures, patents and market value has generally uncovered significant (but not very large) positive correlations; see the papers in Griliches, 1984, Pakes, 1985, Cockburn and Griliches, 1988, Griliches *et al.*, 1991, and others. Griliches, 1990, conjectures that: "*...the relative importance of fluctuations in market value of new patented innovations is about 1% of the total fluctuations in market value*" (p. 1687).

15. By contrast, Mansfield, 1962, observed effects of innovative activity on corporate growth of 4-13 percentage points over a period of 6-10 years post innovation, a somewhat longer data period than is available to us.

16. Geroski and Small, 1995, observed positive but very small and imprecisely estimated effects of patent and innovation production on company productivity growth rates for a sample of 216 UK firms observed over the period 1974 - 1990. They failed to find strong traces of spillovers on the productivity growth rates of particular firms associated with either patent or innovation production elsewhere in the same two digit industry. For some work on the relationship between R&D and productivity growth at the level of the firm, see Cuneo and Mairesse, 1984, and Griliches and Mairesse, 1984.

17. Although it is possible to interpret these regressions as a robustness exercise which explores the sensitivity of the results to alternative measures of growth, Geroski *et al*, 1995, argue that the rate of growth of market value is a proxy for changes in current expectations of future profitability, and, as a consequence, that it is an important determinant of the choices which are reflected in current period growth rates.

18. For surveys of recent work at industry level on the determinants of innovative activity, see Griliches, 1990, Cohen and Levin, 1989, and Chapter 17 in Scherer and Ross, 1990.

19. Pavitt *et al.*, 1987, discuss the relationship between firm size and innovativeness in the SPRU data on major innovations; see Acs and Audretsch, 1990, for work more generally on the relationship between firm size and innovation.

20. See Pavitt *et al.*, 1987, Robson *et al.*, 1988 and Geroski, 1995, the latter two of whom produce maps charting the flows of innovations between innovation producing and innovation using sectors.

21. See von Hippel, 1988, and others. Stoneman and Kwon, 1994, examined the diffusion of five process technologies across a sample of 105 innovating using firms in the UK over the period 1981-1986, and found that these users experienced increases in profitability of about 11% on average, a figure which is higher than that shown on Table III.

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Table I: Partial Correlations over all Firms and Years

Variable (Short Name)	Inn	Pat	NII	NIP	RDS	ROR	Q	Δln(S)	Δln(MV)	Size	MS	Cap	Conc	UD	MD
Innovations (Inn)	1.000														
Patents (Pat)	.4244	1.000													
Net Industry Innovations (NII)	.0465	-.0109	1.000												
Net Industry Patents (NIP)	.0297	.0342	.2948	1.000											
Industry R&D/Sales (RDS)	.0855	.0905	.1924	.2656	1.000										
Profit Margins (ROR)	.0454	.0603	.0145	.0071	.1709	1.000									
Quasi-Q Value (Q)	.0242	-.0089	.0764	.0726	.11	.2416	1.000								
Growth of Sales (Δln(S))	.0243	.0178	.0529	.044	.0431	.2625	.0978	1.000							
Growth of Market Value (Δln(MV))	.0239	-.0004	.0455	.0198	.0336	.1455	.1658	.0932	1.000						
Firm Size	.2679	.2812	-.0691	-.0056	.0129	-.1015	-.0639	.0603	.0086	1.000					
Market Share (MS)	.2929	.4659	-.1746	-.0939	.0753	.0168	-.0501	.0446	-.0053	.6315	1.000				
Capital Intensity (Cap)	-.0078	.0582	-.095	-.0823	.0374	.3325	-.1738	-.2331	.0018	.0078	.0686	1.000			
Industrial Concentration (Conc)	.0485	.0746	-.0865	.1535	.3038	.0843	.0418	.0548	-.0158	.1102	.1188	.1187	1.000		
Industry Union Density (UD)	.0494	-.0276	.4851	.0387	.131	.0461	.0209	-.0115	.0735	.019	-.0847	.032	.1794	1.000	
Industry Import Density (MD)	.0384	.0733	.3021	.3083	.3563	-.0518	.0588	-.0787	-.0222	-.0896	-.1484	-.086	.1197	.1683	1.000

Table II: Descriptive Statistics on Pooled Sub-Samples

Mean (Std. Dev.)	All Firms	Innovators	Non-Innovators	Patenters	Non-Patenters	Q_1 of Exporters	Q_2 of Exporters	Q_3 of Exporters	Q_4 of Exporters
Innovations	.0904 (.59)	.3538 (1.127)	0 (0)	.1847 (.856)	.0113 (.109)	.0205 (.15)	.0327 (.184)	.1537 (.567)	.2748 (1.202)
Patents	1.639 (11.828)	5.937 (22.821)	.1658 (.907)	3.595 (17.314)	0 (0)	.1403 (.573)	.4155 (1.452)	2.5869 (6.012)	5.6363 (26.416)
Net Industry Innovations	10.375 (15.08)	11.691 (15.17)	9.923 (15.021)	12.381 (15.68)	8.692 (14.343)	7.6442 (13.45)	7.838 (13.96)	12.856 (15.908)	15.119 (15.939)
Net Industry Patents	35.058 (55.97)	42.493 (56.29)	32.508 (55.64)	42.44 (59.303)	28.868 (52.24)	20.273 (39.08)	34.976 (59.1)	48.188 (63.917)	43.514 (58.622)
Industry R&D/Sales	1.2426 (1.986)	1.5558 (2.219)	1.1351 (1.888)	1.4083 (2.006)	1.1036 (1.959)	1.0218 (1.88)	.8621 (1.459)	1.6035 (2.197)	1.7182 (2.19)
Profit Margins	.1092 (.063)	.1127 (.064)	.108 (.062)	.1084 (.051)	.1099 (.071)	.1133 (.074)	.0956 (.044)	.1041 (.052)	.1174 (.058)
Quasi-Q Value	.8212 (1.591)	.8842 (2.029)	.7981 (1.396)	.7359 (.804)	.8973 (2.05)	.9671 (2.34)	.8664 (2.195)	.607 (.542)	.877 (1.04)
Growth of Sales	.1314 (.181)	.1407 (.185)	.1283 (.179)	.1392 (.165)	.1249 (.193)	.142 (.181)	.1284 (.159)	.1337 (.167)	.1294 (.191)
Growth of Market Value	.0869 (.509)	.0877 (.516)	.0866 (.506)	.0768 (.515)	.0959 (.503)	.107 (.496)	.0772 (.503)	.055 (.507)	.0934 (.527)
Firm Size (Log of Sales)	3.2569 (1.723)	4.5415 (1.887)	2.8163 (1.416)	4.1274 (1.722)	2.5271 (1.343)	3.573 (1.864)	3.5379 (1.452)	3.7697 (1.759)	3.5609 (1.733)
Market Share	.0317 (.079)	.0776 (.122)	.0159 (.048)	.0561 (.102)	.0113 (.0427)	.0477 (.108)	.0345 (.069)	.0404 (.079)	.0343 (.091)
Capital Intensity	.5428 (.378)	.5652 (.384)	.5351 (.376)	.526 (.102)	.5569 (.432)	.5597 (.481)	.4791 (.242)	.5182 (.225)	.5409 (.349)
Industrial Concentration	.411 (.174)	.4237 (.174)	.4067 (.173)	.4043 (.173)	.4166 (.174)	.4042 (.184)	.4123 (.16)	.4279 (.178)	.3972 (.17)
Industry Union Density	.6596 (.115)	.6837 (.102)	.6514 (.118)	.6806 (.105)	.642 (.12)	.634 (.13)	.6471 (.11)	.6781 (.101)	.7007 (.089)
Industry Import Density	.2469 (.139)	.2564 (.128)	.2436 (.143)	.2576 (.132)	.2378 (.145)	.2147 (.145)	.2219 (.113)	.2794 (.122)	.2937 (.118)

Notes: Q_n refers to the *n*th quartile of firms by base year export/sales ratio, where the ratio increases with *n*.

Table II(a): Means (Standard Deviations) of Key Variables by Sub-Samples

	Sample					Low			High
Variable	All	Innovators	Non-Innovators	Patenters	Non-Patenters	Q_1 X	Q_2 X	Q_3 X	Q_4 X
Employment (1000's)	5.9037 (13.452)	14.7333 (21.719)	2.6994 (6.089)	10.1481 (17.652)	2.1907 (6.104)	7.624 (16.883)	4.7094 (8.211)	9.4666 (15.756)	7.6655 (17.096)
Output/Capital	1.569 (1.321)	1.5198 (1.758)	1.5868 (1.122)	1.5248 (1.452)	1.6077 (1.195)	1.7844 (2.164)	1.5582 (.963)	1.3068 (.495)	1.4995 (.823)
Investment/ Capital	.0569 (.045)	.0587 (.043)	.0562 (.046)	.0549 (.034)	.0585 (.053)	.0645 (.062)	.0469 (.024)	.0544 (.035)	.0534 (.029)
Labour Costs/ Capital	.2057 (.098)	.1918 (.086)	.2107 (.102)	.197 (.086)	.2132 (.108)	.1862 (.099)	.2022 (.11)	.2121 (.079)	.2225 (.085)
Exports/Sales	.1993 (.137)	.2116 (.137)	.194 (.137)	.1954 (.126)	.2043 (.15)	.1018 (.062)	.0965 (.051)	.1559 (.065)	.3136 (.133)
Rate of Return	.1027 (.059)	.1085 (.059)	.1006 (.058)	.1023 (.05)	.1032 (.065)	.1101 (.068)	.0883 (.042)	.0988 (.053)	.1122 (.057)
Growth in Employment	-.0246 (.151)	-.0267 (.152)	-.0239 (.151)	-.0218 (.148)	-.0271 (.154)	.0012 (.147)	-.0296 (.146)	-.0425 (.147)	-.0345 (.141)
Growth in Output/Capital	.0549 (.166)	.0622 (.162)	.0522 (.167)	.0592 (.159)	.0511 (.172)	.0663 (.173)	.0464 (.158)	.0511 (.144)	.0671 (.193)
Growth in Investment/Capital	-.1031 (.451)	-.0968 (.455)	-.1053 (.449)	-.1158 (.435)	-.0918 (.465)	-.0785 (.468)	-.0928 (.392)	-.1243 (.438)	-.1056 (.464)
Growth in Labour Costs/Capital	.0134 (.161)	.0007 (.124)	.018 (.172)	.006 (.131)	.0199 (.184)	.0179 (.126)	.0302 (.247)	.0005 (.107)	-.0069 (.142)
Growth in Exports/Sales	.0406 (.272)	.0222 (.213)	.0487 (.294)	.0309 (.268)	.0534 (.277)	.1193 (.317)	.0602 (.252)	.0342 (.237)	.0195 (.308)
Growth in Rate of Return	-.0051 (.029)	-.0038 (.025)	-.0056 (.029)	-.0057 (.027)	-.0047 (.031)	-.0036 (.024)	-.0043 (.024)	-.0046 (.025)	-.0081 (.035)

Table III: The Determinants of Profitability

Indep	Sample					Low			High
Variable	All	Inn	No Inn	Pat	No Pat	Q_1 X	Q_2 X	Q_3 X	Q_4 X
ROR_{t-1}	.3983	.3012	.4184	.2519	.4763	.4566	.3399	.3913	.22
	(21.81)	(8.633)	(19.71)	(9.41)	(19.17)	(10.39)	(8.382)	(9.41)	(5.247)
INN_t	.0007	.0011		.0012	-.0005	-.0063	-.0002	-.0018	.0023
	(.53)	(.914)		(.942)	(.071)	(.913)	(.028)	(.77)	(1.113)
INN_{t-1}	-.0009	-.0007		-.0005	-.004	-.0009	-.0043	-.0026	.0007
	(.685)	(.621)		(.374)	(.517)	(.13)	(.748)	(1.17)	(.36)
INN_{t-2}	.0006	.0005		.0004	.0099	.0148	.0008	-.0012	.0008
	(.487)	(.398)		(.318)	(1.28)	(1.987)	(.143)	(.525)	(.424)
INN_{t-3}	.00002	-.0006		.0001	-.0004	.0017	-.0024	-.0003	.0004
	(.013)	(.458)		(.087)	(.051)	(.234)	(.493)	(.133)	(.175)
$R\&D_t/S_t$	.0012	.0007	.0015	.0021	.00005	-.0004	-.0001	.0025	.0018
	(1.558)	(.579)	(1.671)	(2.13)	(.042)	(.249)	(.072)	(1.75)	(1.005)
MS_t	-.0473	-.1179	.0539	-.0792	.0564	.0108	-.0109	-.0943	-.1126
	(1.395)	(3.219)	(.797)	(2.29)	(.677)	(.207)	(.147)	(1.8)	(1.138)
$CONC_t$	.0165	.0123	.0216	-.0027	.0278	.0023	.0491	-.0558	-.0055
	(1.251)	(.527)	(1.368)	(.152)	(1.452)	(.078)	(2.372)	(2.12)	(.126)
$UNION_t$	-.003	-.0176	.0038	.0052	-.0078	.0001	.0156	.0312	-.0923
	(.246)	(.813)	(.267)	(.317)	(.455)	(.005)	(.747)	(1.26)	(2.729)
$IMPS_t$	-.0452	-.053	-.0348	-.0295	-.0724	-.0286	-.0635	-.0335	-.0519
	(3.093)	(2.266)	(1.918)	(1.56)	(3.193)	(.928)	(2.379)	(1.32)	(1.23)
CAP_t	-.0243	-.056	-.0119	-.0411	-.0147	-.0229	.0076	-.0454	-.0546
	(6.835)	(9.194)	(2.777)	(8.38)	(2.906)	(2.745)	(.941)	(3.99)	(7.153)
AGG_t	.1134	.0219	.1487	.1165	.1103	.131	.1049	.0877	.186
	(8.412)	(.906)	(9.208)	(6.41)	(5.685)	(4.798)	(4.627)	(2.91)	(4.49)
R^2	.3117	.308	.3292	.2994	.3378	.3341	.3031	.3822	.3438
SSR	2.0667	.4356	1.5919	.7659	1.2536	.3077	.2117	.2829	.5211
$F[\alpha_i,\beta=\alpha,\beta]$ (p)	2.4372	3.013	2.321	3.154	2.0756	2.0548	2.4507	2.991	2.9761
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
FE/RE χ^2 (p)	641.66	216.1	449.96	346.9	298.55	105.7	117.28	139.9	129.02
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
F[exog] (p)	1.2219	1.0408	.9054	.4706	2.1954	.7219	1.3113	.6809	.7847
	(.261)	(.409)	(.511)	(.932)	(.025)	(.73)	(.208)	(.771)	(.667)

Notes: Dependent variable is ROR_t. Method of estimation is Ordinary Least Squares (OLS). All equations contain fixed effects. Absolute values of t statistics given in parentheses below estimated coefficients. Q_n X refers to the nth quartile of firms by base year export/sales ratio. SSR is the sum of squared residuals. $F[\alpha_i,\beta=\alpha,\beta]$ is an F test of the restrictions that the fixed effects can be simplified to a single constant.y FE/RE χ^2 is a Hausman test of fixed against random effects. F[exog] is an F test of the block exogeneity of current and up to three lagged values of Patents, Net Industry Patents and Net Industry Innovations.

Table IV: The Determinants of Quasi-Q

Indep	Sample					Low			High
Variable	All	Inn	No Inn	Pat	No Pat	Q_1 X	Q_2 X	Q_3 X	Q_4 X
Q_{t-1}	.5403	.5859	.5185	.5068	.552	.6305	.4583	.7545	.6193
	(29.34)	(19.584)	(22.498)	(22.39)	(21.344)	(15.32)	(9.044)	(18.798)	(15.912)
INN_t	.0032	.0052		.0288	-.5096	-.4593	.0866	.0108	.0308
	(.13)	(.219)		(1.985)	(3.174)	(2.394)	(.492)	(.486)	(1.153)
INN_{t-1}	-.001	-.0112		.0239	-.6016	-.585	-.0298	.0071	.0315
	(.042)	(.481)		(1.701)	(3.713)	(3.038)	(.164)	(.334)	(1.214)
INN_{t-2}	.0146	.017		.0243	-.2263	-.0823	-.0879	.0002	.0269
	(.619)	(.743)		(1.748)	(1.398)	(.400)	(.511)	(.012)	(1.048)
INN_{t-3}	.0061	.0107		.0132	-.1726	-.1105	-.1568	-.0168	.0229
	(.241)	(.435)		(.876)	(1.163)	(.568)	(1.012)	(.743)	(.801)
$SPILL\_I_t$	.0044		.0066	.0005	.0083		.0142		
	(1.953)		(2.458)	(.27)	(2.062)		(1.93)		
$SPILL\_I_{t-1}$	.0064		.0086	.0008	.0125		.0246		
	(2.492)		(2.752)	(.37)	(2.592)		(2.576)		
$SPILL\_I_{t-2}$	.0081		.0092	.0039	.0113		.0259		
	(3.136)		(3.012)	(1.967)	(2.347)		(2.829)		
$SPILL\_I_{t-3}$	.0156		.0179	.0079	.0225		.0349		
	(5.742)		(5.702)	(3.511)	(4.449)		(3.112)		
RDS_t	-.0577	-.0842	-.0575	-.0142	-.0945	-.1499	-.2718	-.0296	-.0137
	(4.18)	(3.508)	(3.519)	(1.203)	(3.85)	(3.416)	(4.024)	(2.115)	(.587)
MS_t	1.4227	1.3005	2.3111	1.4066	1.8555	.9364	1.9989	.913	2.1083
	(2.359)	(1.88)	(1.938)	(3.603)	(1.067)	(.654)	(.873)	(1.83)	(1.656)
$CONC_t$	-.6208	-.7799	-.5906	-.0801	-1.0279	-1.2095	-.2845	-1.154	.2194
	(2.597)	(1.743)	(2.099)	(.391)	(2.553)	(1.505)	(.434)	(4.537)	(.389)
$UNION_t$	.2757	1.5406	-.2345	.4846	.1078	1.0664	1.097	.4901	.0586
	(1.184)	(3.723)	(.862)	(2.324)	(.2844)	(1.632)	(1.575)	(2.096)	(.133)
$IMPS_t$	-.2571	-.3851	-.2242	.2641	-.6615	-1.4353	1.2614	.1299	1.1648
	(.97)	(.876)	(.686)	(1.204)	(1.399)	(1.727)	(1.504)	(.535)	(2.155)
AGG_t	.6739	1.0356	.5097	.5336	.8099	.4154	.9278	.9101	.427
	(2.824)	(2.467)	(1.813)	(2.559)	(2.044)	(.617)	(1.373)	(3.662)	(.854)
R^2	.2665	.3715	.234	.3207	.2799	.3469	.234	.4333	.3615
SSR	665.034	160.24	499.165	99.8273	546.713	236.68	211.408	26.7552	87.7433
$F[\alpha_i,\beta=\alpha,\beta]$ (p)	25.941	22.327	26.618	25.104	26.28	16.649	41.139	12.152	17.46
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
FE/RE χ^2 (p)	151.76	77.62	187.62	132.82	135.27	78.909	95.526	84.96	59.027
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
F[exog] (p)	.248	.7375	.9666	.3473	.7045	1.1877	.8967	.7109	1.1008
	(.981)	(.715)	(.46)	(.947)	(.589)	(.289)	(.519)	(.741)	(.357)

Notes: Dependent Variable is Q_t. Method of estimation is OLS. All equations contain fixed effects. Absolute values of *t* statistics given in parentheses below coefficients. Q_n X refers to the *n*th quartile of firms by base year export/sales ratio. SSR is the sum of squared residuals. $F[\alpha_i,\beta=\alpha,\beta]$ is an *F* test of the restrictions that the fixed effects can be simplified to a single constant. FE/RE χ^2 is a Hausman test of fixed against random effects. F[exog] is an *F* test of the block exogeneity of current and up to three lagged values of Patents and Net Industry Patents for the All, Pat, No Pat and Q_2 X samples; and of the block exogeneity of current and up to three lagged values of Patents, Net Industry Patents and Net Industry Innovations for the other samples.

Table V: The Determinants of Sales Growth

Indep	Sample					Low			High
Variable	All	Inn	No Inn	Pat	No Pat	Q_1 X	Q_2 X	Q_3 X	Q_4 X
ΔlnS_{t-1}	-.0979	-.122	-.092	-.1161	-.0885	-.1729	-.1021	-.1595	.017
	(5.429)	(3.37)	(4.429)	(4.298)	(3.65)	(4.113)	(2.695)	(3.859)	(.426)
INN_t	.0034	.002		.0029	-.0012	-.0272	.0039	-.0079	.0031
	(.432)	(.244)		(.368)	(.028)	(.612)	(.116)	(.626)	(.304)
INN_{t-1}	.004	.0018		.0056	-.0576	-.054	-.0415	.0105	.0037
	(.528)	(.235)		(.72)	(1.366)	(1.212)	(1.175)	(.864)	(.371)
INN_{t-2}	.0034	.0026		.0016	.0397	.0331	.0017	-.0065	.0037
	(.451)	(.332)		(.212)	(.941)	(.692)	(.05)	(.526)	(.354)
INN_{t-3}	-.0029	-.432		-.0047	.0504	.0388	.0436	-.0142	-.0056
	(.358)	(.518)		(.57)	(1.399)	(.863)	(1.447)	(1.093)	(.47)
RDS_t	.0051	-.011	.0113	.0084	.001	-.0234	-.0039	.0146	.0073
	(1.209)	(1.37)	(2.257)	(1.356)	(.171)	(2.296)	(.402)	(1.813)	(1.39)
MS_t	1.2009	.8495	2.0432	1.2765	1.3746	.8959	1.1703	1.3948	.0697
	(6.206)	(3.61)	(5.451)	(5.902)	(3.033)	(2.699)	(2.628)	(4.818)	(.439)
$CONC_t$	.0219	-.036	.0433	-.2139	.2185	.1175	.3346	-.1644	-.1445
	(.289)	(.238)	(.491)	(1.916)	(2.088)	(.629)	(2.61)	(1.125)	(1.92)
$UNION_t$	.0654	.0494	.0781	.2066	-.0508	.0532	.2884	.4274	-.0107
	(.95)	(.353)	(.992)	(1.988)	(.549)	(.352)	(2.237)	(3.159)	(.092)
$IMPS_t$	-.2975	-.588	-.1429	-.3549	-.2408	-.3253	-.1429	-.3623	-.0321
	(3.579)	(3.95)	(1.426)	(2.996)	(1.969)	(1.686)	(.875)	(2.582)	(.329)
AGG_t	1.1041	.997	1.1802	1.1669	1.0722	1.0448	1.0837	1.3901	.7638
	(15.39)	(6.88)	(14.2)	(11.01)	(10.91)	(6.642)	(8.61)	(9.539)	(4.29)
R^2	.1371	.1287	.1491	.1473	.1403	.1356	.2248	.2824	.0422
SSR	68.317	18.32	49.47	30.525	37.221	12.689	8.0963	8.8142	22.388
$F[\alpha_i,\beta=\alpha,\beta](p)$	1.4452	1.422	1.4824	1.3549	1.5515	1.9508	1.7927	1.597	N/A
	(.000)	(.005)	(.000)	(.002)	(.000)	(.000)	(.000)	(.002)	
FE/RE χ^2 (p)	328.3	106.4	233.51	187.5	156.5	86.168	83.066	80.095	20.884
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.588)
F[exog] (p)	.7137	.8228	.5638	1.425	.9045	.6045	.8732	1.343	.4468
	(.739)	(.627)	(.872)	(.148)	(.512)	(.839)	(.574)	(.19)	(.944)

Notes: Dependent Variable is ΔlnS_t. Method of estimation is OLS, Generalized Least Squares for Q_4 X. All equations except Q_4 X contain fixed effects. Q_4 X contains a constant and a random effects error term. Absolute values of *t* statistics given in parentheses below coefficients. Q_n X refers to the *n*th quartile of firms by base year export/sales ratio. SSR is the sum of squared residuals. $F[\alpha_i,\beta=\alpha,\beta]$ is an *F* test of the restrictions that the fixed effects can be simplified to a single constant. FE/RE χ^2 is a Hausman test of fixed against random effects. F[exog] is an *F* test of the block exogeneity of current and up to three lagged values of Patents, Net Industry Patents and Net Industry Innovations. Diagnostics for Q_4 X are on transformed data and may not be directly comparable.

<u>Table VI: The Determinants of Productivity Growth</u>

Indep	Sample					Low			High
Variable	All	Inn	No Inn	Pat	No Pat	Q_1 X	Q_2 X	Q_3 X	Q_4 X
N_t	.5439 (25.28)	.5229 (14.54)	.5453 (20.8)	.4982 (16.84)	.5738 (18.66)	.6305 (14.4)	.4994 (8.71)	.4483 (9.583)	.6431 (10.7)
K_t	.0832 (5.401)	.0911 (3.613)	.0784 (4.15)	.1045 (5.053)	.0683 (3.049)	.0506 (1.69)	.1493 (3.423)	.1184 (3.538)	.0783 (1.68)
INN_t	.0068 (.834)	.0061 (.874)		.0058 (.786)	.0117 (.263)	-.004 (.1)	.0272 (.609)	-.0064 (.72)	.0211 (1.3)
INN_{t-1}	.007 (.837)	.0062 (.856)		.0079 (1.036)	-.0379 (.85)	.0029 (.083)	-.0164 (.405)	.0126 (1.341)	.0117 (.71)
INN_{t-2}	-.0019 (.248)	-.0037 (.54)		-.0004 (.057)	-.0182 (.498)	.0102 (.324)	.0269 (.647)	.0061 (.651)	-.0173 (1.13)
INN_{t-3}	.0029 (.391)	.0014 (.215)		-.0014 (.194)	.0714 (2.109)	.0058 (.197)	.0167 (.41)	-.0104 (1.127)	.0058 (.419)
RDS_t	-.0142 (2.93)	-.0192 (2.596)	-.012 (2.04)	-.0105 (1.594)	-.0179 (2.575)	-.019 (1.89)	-.0335 (1.971)	-.0072 (.792)	-.0099 (.86)
MS_t	2.6527 (10.83)	2.1119 (8.9)	4.669 (7.96)	2.4702 (10.32)	3.9531 (5.595)	2.142 (4.96)	3.4544 (4.321)	2.0471 (6.219)	3.4572 (5.16)
$CONC_t$	.0283 (.08)	.183 (1.434)	-.036 (.366)	.0006 (.006)	.0457 (.394)	.0141 (.077)	-.0849 (.45)	-.04551 (.293)	.0552 (.237)
$UNION_t$	-.1559 (5.093)	-.0932 (1.794)	-.176 (4.76)	-.1241 (3.091)	-.1719 (3.778)	-.139 (2.1)	-.1492 (1.828)	-.1025 (1.686)	-.2204 (2.79)
$IMPS_t$	.0025 (1.759)	.0036 (1.575)	.002 (1.29)	.0036 (1.891)	.0019 (.966)	.007 (2.62)	.0024 (.652)	.0017 (.614)	.0052 (1.12)
AGG_t	.1415 (2.125)	-.0182 (.166)	.214 (2.62)	.1369 (.557)	.1541 (1.601)	.1873 (1.43)	.0387 (.207)	.2052 (1.559)	-.0107 (.059)
R^2	.4252	.5323	.3995	.4814	.3941	.5034	.3908	.4912	.4203
SSR	26.909	5.132	21.459	9.759	16.908	4.508	5.763	3.269	6.268
$F[\alpha_i,\beta=\alpha,\beta]$ (p)	.913 (.862)	.868 (.799)	.957 (.669)	.882 (.84)	.974 (.583)	1.21 (.138)	1.162 (.205)	.834 (.817)	.484 (1.00)
F[exog] (p)	.191 (.901)	.604 (.617)	2.212 (.083)	.664 (.578)	N/A	1.118 (.342)	.227 (.878)	.176 (.913)	.443 (.723)

Notes: Dependent variable is Q_t. Method of estimation is Ordinary Least Squares. All equations contain a constant. Absolute value of t statistics given in parentheses below coefficients. Q_n X refers to the nth quartile of firms by base year export/sales ratio. SSR is the sum of squared residuals. $F[\alpha_i,\beta=\alpha,\beta]$ is an F test of the restrictions that fixed effects can be simplified to a single constant. F[exog] is an F test of the joint significance of current and up to three lagged values of Patents.

Table VII: The Determinants of the Growth of Market Value

Indep	Sample					Low			High
Vars	All	Inn	No Inn	Pat	No Pat	Q_1 X	Q_2 X	Q_3 X	Q_4 X
GMV_{t-1}	-.1008	-.136	-.1014	-.1177	-.0909	-.1682	-.1293	-.1096	-.1763
	(5.168)	(4.417)	(4.572)	(4.567)	(3.146)	(4.749)	(3.66)	(3.075)	(4.65)
INN_t	.029	.0331		.0261	.1169	-.1033	.1504	.0051	.0377
	(1.715)	(1.703)		(1.538)	(.997)	(.917)	(1.459)	(.141)	(1.467)
INN_{t-1}	-.0076	-.0003		-.0009	-.0839	.2354	-.1225	-.0338	.0093
	(.511)	(.014)		(.063)	(.82)	(2.045)	(1.214)	(.89)	(.364)
INN_{t-2}	-.0134	-.0181		-.0107	.0009	.1311	-.1379	-.0235	-.0073
	(.83)	(.886)		(.677)	(.007)	(1.136)	(1.374)	(.622)	(.27)
INN_{t-3}	-.0012	-.0033		-.0109	.1904	-.0273	-.0452	.0102	-.0047
	(.065)	(.151)		(.578)	(1.684)	(.243)	(.484)	(.277)	(.155)
$SPILL\_I_t$	.0012	-.0007		-.0014				-.0053	-.0009
	(.702)	(.229)		(.613)				(1.764)	(.257)
$SPILL\_I_{t-1}$	.0056	.0147		.0112				.0125	.0088
	(2.611)	(4.409)		(4.137)				(3.545)	(2.36)
$SPILL\_I_{t-2}$	-.0064	-.0121		-.0097				-.0117	-.0068
	(4.306)	(4.453)		(4.865)				(4.261)	(2.182)
$SPILL\_P_t$	.0002	.001	-.0001	.0004	.0002		-.0006	-001	.0017
	(.335)	(.868)	(.172)	(.446)	(.21)		(.429)	(.793)	(1.095)
$SPILL\_P_{t-1}$	.0048	.0044	.0051	.0056	.0035		.0047	.0085	.0031
	(6.918)	(3.579)	(5.77)	(5.591)	(3.576)		(3.163)	(6.752)	(2.059)
$SPILL\_P_{t-2}$	-.0045	-.0046	-.0045	-.005	-.0035		-.0033	-.0063	-.0044
	(7.009)	(4.366)	(5.82)	(5.72)	(3.696)		(2.548)	(5.797)	(3.198)
RDS_t	.0114	.0131	.0109	.0107	.0133	.0169	.0238	.0256	.0161
	(2.269)	(1.297)	(1.614)	(1.617)	(1.745)	(1.191)	(1.251)	(2.208)	(1.225)
MS_t	-.0929	-.1439	.0559	.054	-.0076	-.0649	-.1008	.1071	-.2219
	(.895)	(.713)	(.319)	(.393)	(.036)	(.271)	(.238)	(.312)	(.563)
$CONC_t$	-.0435	-.0308	-.0232	-.1096	-.0203	-.0847	.1434	-.5028	-.1591
	(.717)	(.225)	(.358)	(1.229)	(.263)	(.549)	(.872)	(2.891)	(.842)
$UNION_t$	.1965	.2773	.2168	.3152	.2086	.7166	.3815	.926	-.0776
	(2.037)	(1.166)	(2.427)	(2.039)	(2.019)	(3.537)	(1.685)	(2.923)	(.231)
$IMPS_t$	-.2692	-.4069	-.242	-.334	-.2037	-.3205	-.4082	-.3165	-.2897
	(3.798)	(2.206)	(2.905)	(2.693)	(2.409)	(1.742)	(1.554)	(1.465)	(1.183)
CAP_t	-.0319	-.0366	-.0339	-.0974	-.0188	.0075	-.1197	-.2526	-.1009
	(4.415)	(.663)	(1.222)	(2.277)	(.715)	(.144)	(1.203)	(2.199)	(1.442)
AGG_t	-.0433	-.6395	.3587	-.0588	.1332	.1564	-.5866	.2107	-.1747
	(.213)	(1.659)	(1.629)	(.199)	(.517)	(.401)	(1.42)	(.438)	(.339)
R^2	.0442	.0799	.0385	.0747	.0291	.0583	.0544	.1456	.0709
SSR	828.053	219.872	594.948	400.663	420.154	140.496	148.946	138.048	164.085
$F[\alpha_i,\beta = \alpha,\beta]$ (p)	.8083	N/A	.8199	.7674	.819	N/A	N/A	N/A	N/A
	(.998)		(.989)	(.992)	(.976)				
FE/RE χ^2 (p)	72.655	20.909	55.472	34.776	41.511	19.48	23.785	18.48	15.42
	(.000)	(.526)	(.000)	(.041)	(.001)	(.616)	(.359)	(.677)	(.844)
F[exog] (p)	1.7846	2.3301	1.7922	1.7985	1.1286	.8935	1.4915	1.086	1.3773
	(.129)	(.054)	(.084)	(.127)	(.336)	(.539)	(.166)	(.362)	(.24)

Notes: Dependent Variable is GMV_t. Method of estimation is GLS, OLS with White Standard errors for the All, No Inn, Pat and No Pat samples. All equations contain a constant. Absolute values of *t* statistics given in parentheses below coefficients. Q_n X refers to the *n*th quartile of firms by base year export/sales ratio. SSR is the sum of squared residuals. $F[\alpha_i,\beta=\alpha,\beta]$ is an *F* test of the restrictions that fixed effects can be simplified to a single constant. FE/RE χ^2 is a Hausman test of fixed against random effects. F[exog] is an *F* test of the block exogeneity of current and up to three lagged values of Patents for the All, Inn, Pat, Q_3 X and Q_4 X samples. F[exog] is an *F* test of the block exogeneity of current and up to three lagged values of Patents and current and up to two lagged value of Net Industry Innovations for the No Inn, No Pat and Q_2 X samples. This *F* statistic tests the block exogeneity of current and up to three lagged values of Patents and current and up to two lagged value of Net Industry Innovations and Net Industry Patents for the Q_1 X sample. Diagnostics for OLS estimates are on untransformed data and may not be directly comparable.

Figure 1: Correlations over all Firms - Unbalanced Panel

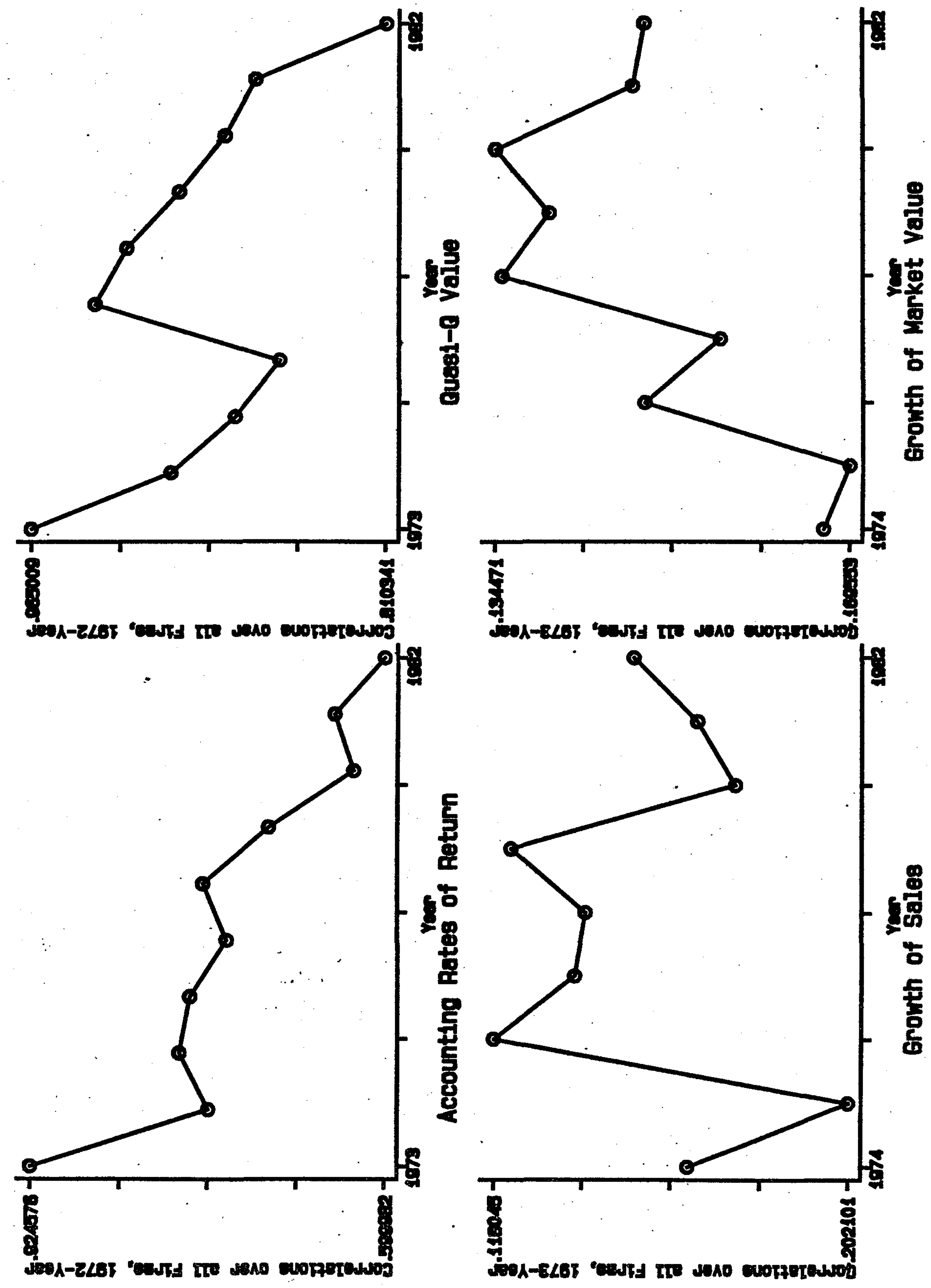


Figure 2: Correlations over all Firms - Balanced Panel

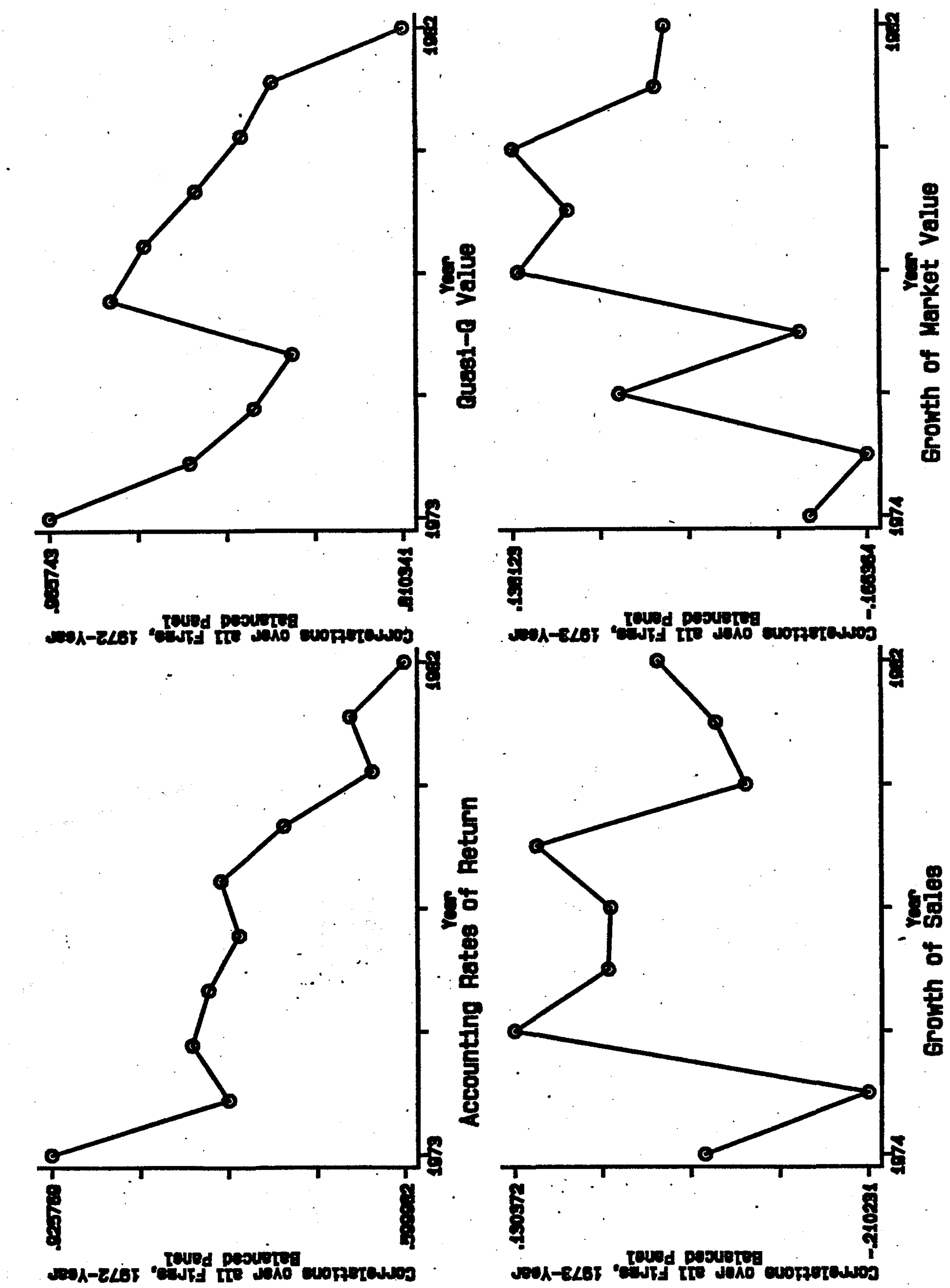
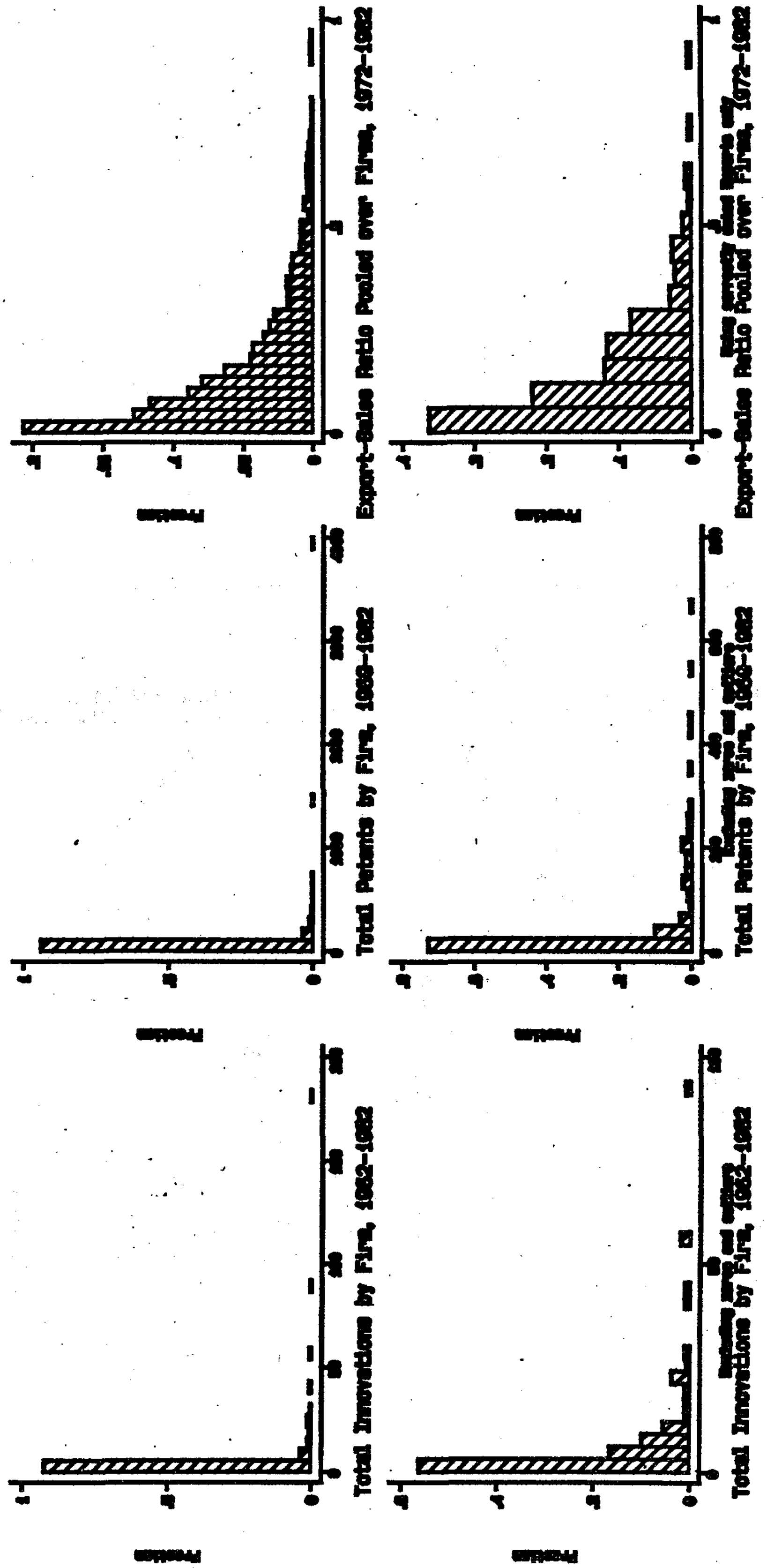


Figure 3: Histograms of Innovations, Patents and Export Intensity



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