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Innovation, Profitability and Growth Over the Business Cycle*

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Abstract. Recent debates about Industrial Policy are dominated by a concern to make firms "more innovative". In order to make progress in assessing the magnitude of the effects of innovation on corporate performance, one needs to know how such effects occur. We have contrasted two views of the effect of innovation – "the product view" and "the process view" – and have provided some evidence to suggest that both effects are evident in the data. Although it is clear that individual innovations themselves have a positive effect on profitability and growth, it is equally clear that the process of innovation seems to transform firms in some way that gives rise to what look like generic differences between innovators and non-innovators. As a consequence, the process by which profitability and growth are generated differs noticeably between the two types of firms. Perhaps the clearest of these differences is that innovating firms seem to be much less sensitive to cyclical shocks than non-innovating firms are.

Key words: Innovation, profitability, firm growth.

JEL codes: L10, O31.

1. Introduction

Debates about Industrial Policy in the UK are dominated by a concern to make UK firms "more innovative". Countless measures of research progressiveness seem to tell the sorry story of a once great industrial power slipping down the international innovation league tables, and each dozen economists who address this problem produce several dozen solutions. Although there is much work yet to be done in measuring social rates of return and assessing the relative efficacy of different policies designed to stimulate innovation, it seems clear that a comprehensive examination of these issues requires one to think carefully about how the performance of innovative firms might differ from that of non-innovative ones. In this paper we woul like to focus directly on this question, and ask "what effects would one expect to observe on UK corporate performance if UK firms became more innovative?".

As in many other situations, the answer turns out to be sensitive to the way one poses the question in the first place. There are (at least) two alternative views about how innovation might enhance the performance of a firm. The simplest and most obvious view is that product or process innovations alter an innovating firm's competitive position against rivals, or strengthen its bargaining power vis-a-vis buyers or suppliers. Each innovation is, therefore, likely to have an effect on performance which occurs immediately after its arrival, but this effect is likely to be transitory: profits and growth will be elevated above "normal" levels for only as long as the innovator can defend itself from rivals. A second and much more subtle view argues that the process of innovation transforms the firm itself, building up its internal capabilities in a variety of ways that create generic differences between innovating and non-innovating firms. This view sees innovation as itself being the consequence of some more fundamental change that transforms a firm's profit and growth performance in both the short and the long term. That is, innovation is an observable signal of a more primal event which has permanent effects on the performance of a firm, effects that do not necessarily manifest themselves only after an innovation occurs. In sum, these two views correspond to the notions that innovation affects corporate performance because *the product of* innovative effort can favourably affect a firm's market position, and because *the process of* innovation can transform a firm's internal capabilities.

Applied econometricians will instantly recognize that these two views of the effects of innovation involve quite different structures of measurement and testing. Adopting the first view leads one to construct models of corporate performance that include, inter alia, an innovation variable, and the parameter of interest is the size of the co-efficient on that variable. Adopting the second view, however, requires one to entertain the hypothesis that the effects of all of the determinants of corporate performance differ between innovating and non-innovating firms. This, in turn, means that one needs to estimate separate performance equations for each sub-set of firms, and test whether they differ from each other. In what follows, we shall concentrate on exploring the second view of the effect of innovation on corporate performance (not least because it nests the first), estimating corporate performance equations for innovative and for non-innovative firms. It turns out that there are discernable generic differences between the two types of firms which reveal themselves most clearly during recessions.

The plan of the paper is as follows. In Section 2 below, we shall outline the econometric models of corporate performance that we intend to use, and then develop a number of arguments supporting the view that innovation is an observable index of a more fundamental generic difference between different types of firm. In Section 3, we shall describe the data which we have used, and discuss the results of applying our models of corporate growth and profitability to that data. A brief summary and a few concluding observations are contained in Section 4.

2. Innovation and Corporate Performance

There are numerous ways to assess corporate performance, and most commentators agree that there is no simple, single measure which captures everything of importance. However, assessing performance using multiple indicators is often made difficult by the conflicting rankings each measure gives of the performance of different firms. For those interested in describing the behavior of firms, performance measures are of interest because of the incentives that they create for managers, and many commentators express differences in the managerial objective functions of different firms in terms of relative preferences between growth and profitability.[1] It follows that one might legitimately start by focusing on these two measures, and that is the course that we shall pursue here. There are, of course, countless different ways to measure profitability and growth, but many of these different measures of each have similar properties.[2] In what follows, we shall concentrate on profitability measured as a return on sales, and growth measured as the first difference in the log of sales.

Developing models of the effect of innovation (and other exogenous variables[3]) on corporate performance measured either as profits or as growth requires one to make two different sets of decisions. The first and most important is the decision about how innovation affects performance, and, as we have seen, there are (at least) two views worth considering in this context: that it is *the product of an innovation* which matters, and that it is *the process of innovation* which matters.[4] The second decision relates to the type of "experiment" which one needs to conduct in order to observe the effect that one is looking for. If one believes that it is *the product of innovation* which matters, then an accurate measurement of the effect of innovation on performance requires one to correct for other determinants of performance which might be correlated with innovation, to allow effects to accumulate over time, and so on. If, on the other hand, one believes that it is *the process of innovation* which matters, then one needs to decide how to identify the firms who have been transformed by this process, and distinguish them from firms who have not. Let us consider each type of decision in turn.

The two views of how innovation might affect performance lead to two quite different types of econometric model. Consider some firm i operating at time t. In an environment characterized by a number of exogenous variables x_{it} and z_{it}, it manages to achieve a profit outcome, π_{it}, and a rate of growth g_{it}. In addition, it may or may not innovate, a state of affairs indicated by positive or zero values of I_{it}. The simplest view of the effect of innovation on performance is that it is transitory and timed to occur with the appearance of specific innovations (referred to as "the product view" hereafter). This view is embodied in the models

$$\pi_{it} = \beta_0(L)\, x_{it} + \alpha_0(L)\, I_{it} + \mu_{it} \tag{1}$$

$$g_{it} = \beta_1(L)\, z_{it} + \alpha_1(L)\, I_{it} + \eta_{it}\,, \tag{2}$$

where the sets of exogenous variables x_{it} and z_{it} may overlap, μ_{it} and η_{it} are white noise residuals and the $\beta(L)$'s and $\alpha(L)$'s denote polynomials in the lag operator L. α_0 and α_1 are the effects that one wishes to measure, and are identified whenever the indicator variable I_{it} is positive. Estimates of the co-efficients in α_0 and α_1 indicate how transitory the effects of innovation on corporate performance are.

The second view of innovation is that it reflects a generic transformation in how a firm operates (referred to as "the process view" hereafter). The core notion here is that a firm is best thought of as a bundle of skills and/or distinctive capabilities. Competitive advantage arises whenever a firm accumulates a set of skills which more than match those of its rivals, and competitive strategy describes the choice of both the speed and the direction of this process of accumulation. Since many of the more important skills which give rise to competitive advantages are knowledge based, it follows that implementing competitive strategies may be as much a matter of learning and developing existing skills internal to the firm as it is of purchasing assets in the appropriate factor markets. The process of innovating affects corporate performance, then, because it helps to develop a firm's internal capabilities, enhancing its ability to learn about new technology, to match technological possibilities with the characteristics of demand and, as a consequence, to sustain its market position in the face of changes in supply and/or demand conditions.[5]

If it is the process of innovation that matters, then the models of profits and growth embodied in Equations (1) and (2) have two major deficiencies. First, the causal presumption that the occurrence of an innovation ($I_{it} > 0$) leads to a (transitory) increase in profits and/or growth makes no sense. When it is the process of innovation (rather than the product of the innovative process) that matters, the effects of innovation which one might expect to observe on profits and growth will occur even when $I_{it} = 0$ at some date t. Indeed, since the primal causal forces affecting a firms performance are its internal capabilities, one might think of the event $I_{it} > 0$ as no less a consequence of superior competitive ability as high profits or fast growth are. Second, since the process of innovation describes a process by which a firms capabilities are transformed, it follows that the effects of innovation are as likely to be observed in differences in the β's between innovating and non-innovating firms as they are to be associated with the occurrence of a specific innovation. That is, innovation is likely to transform the whole process by which profits and growth are generated, and this means that the models of profits and growth described in Equations (1) and (2) may differ between innovating and non-innovating firms.

An appropriate way to model the process view of the effect of innovation on corporate performance is as follows. Using the event $I_{it} > 0$ for any t in the sample period to distinguish innovating firms (denoted with a superscript I) from non-innovating firms (denoted with a superscript N) for whom $I_{it} = 0$ throughout the sample period, then

$$\pi^I_{it} = \beta^I_0(L)\, x^I_{it} + \mu^I_{it} \tag{3}$$

$$\pi_{it}^N = \beta_0^N(L)\, x_{it}^N + \mu_{it}^N \, , \tag{4}$$

and

$$g_{it}^I = \beta_1^I(L)\, z_{it}^I + \eta_{it}^I \tag{5}$$

$$g_{it}^N = \beta_1^N(L)\, z_{it}^N + \eta_{it}^N \, , \tag{6}$$

where the indicator variable I_{it} may also be an element of the sets x_{it} and z_{it}. The difference in the profits and growth performance of innovating and non-innovating firms is then

$$(\pi^I - \pi^N) = \beta_0^I(x^I - x^N) + x^N(\beta_0^I - \beta_0^N) \tag{7}$$

and

$$(g^I - g^N) = \beta_1^I(z^I - z^N) + z^N(\beta_1^I - \beta_1^N) \, , \tag{8}$$

where we have suppressed the subscripts and the distributed lag notation to reduce clutter.

Equations (7) and (8) suggest that differences in the performance of innovating and non-innovating firms may arise from one of two sources. First, the exogenous determinants of profits and growth may differ between the two types of firm (this corresponds to the term in the first set of brackets in (7) and (8)), say because innovating firms have larger market shares or operate in industries where rich technological opportunities affect the ability of firms to make profits and/or grow. Second, innovating firms may perform differently from non-innovating firms because the effects of an given exogenous determinant of profits or growth is different for the two types of firm (this corresponds to the term in the second brackets of (7) and (8)), say because the effects of a given market share or a given technological environment are more readily transformed into a superior profit or growth outcome by innovative firms. Comparing (3)–(6) with (1)–(2), it is clear that the former models generalize the latter by allowing the data to reveal a performance differential in performance which varies across firms and over time. In (1)–(2), innovating firms outperform non-innovating firms simply because $I_{it}^I > 0$ while $I_{it}^N = 0$; (3)–(6) adds to this the possibility of differences in performance associated with a range of further exogenous factors.

The second decision that one must make when modelling the effects of innovation on corporate performance is the nature of the "experiment" needed to measure the effect one is interested in. The principle consideration of importance is to avoid omitting important exogenous determinants of profitability and growth which are correlated with innovation. Similarly, since we are only interested in measuring the effect of innovation on performance, the omission of important exogenous determinants of profitability or growth is not a major concern if they are not correlated with innovative activity. The literature on the determinants of innovation often focuses on the role played by firm size and market structure, and many scholars believe that innovative activity is pro-cyclical. Hence, we include variables reflecting cyclical shifts in economic activity, and variables measuring the salient features of market structure. In addition, innovations produced or used by one firm may have an effect on the performance of other firms through spillovers, and these spillover effects need to be allowed for.[6]

These considerations have led us to specify the vector of variables x_{it} in (1) as: current and lagged values of the number of innovations produced by firm i, INN_{it}, spillover variables measuring the number of innovations used and the number of innovations produced by firm i's rivals (in the same three digit industry), IPI_{it} and IUI_{it}, the degree of concentration, import penetration and unionization in firm i's industry, CON_{it}, IMP_{it} and UN_{it}, firm i's market share, MS_{it}, and interaction variable between market share and concentration, a lagged dependent variable to capture disequilibrium dynamics, and a full set of firm specific and time dummies to control for other omitted factors.[7] The vector of variables z_{it} in (2) includes: current and lagged values of the basic variables of interest, INN_{it}, the two spillover variables, IPI_{it} and IUI_{it}, firm size lagged, $SIZE_{it}$, several lags of the dependent variable, and current and lagged values of industry and aggregate growth rates, Ig_{it} and Ag_{it}.[8] By and large, these specifications encompass most of the work reported in the literature that has worked with equations like (1) and (2).

3. Innovating and Non-Innovating Firms

Most of the basic data that we will be working with is described on Table I, which also provides a brief characterization of innovating and non-innovating firms. The basic variable of interest is the innovativeness of each firm, and the data that we have used is a count of major innovations produced and used in the UK over the period 1945–1983 constructed by the Science Policy Research Unit at the University of Sussex (for further details, see Pavitt *et al.*, 1987). The selection criteria used by SPRU to assemble this database was that the innovation had to be both a technical breakthrough and a commercial success.[9] The data tape records somewhat in excess of 4000 major innovations over the period 1945–1983, but less than 10% of these were produced by our sample of 539 firms over the period 1972–1983. Using this information on innovativeness, we partitioned the data into one subset of 98 firms who produced a major innovation during the period (about 18% of the sample), and a second subset of 441 firms who did not.[10]

The means displayed on Table I suggest that innovating firms operate in more innovative sectors (that is, sectors in which large numbers of innovations were produced and/or used), and may, therefore, be exposed to more spillovers than non-innovative firms. Innovative firms in our sample are slightly more likely to be unionized than non-innovators, at least partly because they operate in slightly more concentrated industries than non-innovators. It is not, however, unambiguously clear that innovative firms operate in less competitive markets than non-innovators, since import penetration is relatively high in the markets which innovators inhabit. All of these differences are fairly small however, and they all pale into relative insignificance when compared to what seems to be the truly substantive difference between innovators and non-innovators in this sample: namely, that the former have market shares which are, on average, just under five times larger than those enjoyed by the latter.[11]

The top two rows of Table I show that there are, on average, modest performance differences between innovative and non-innovative firms. The former enjoy profits about 11.9% larger than the latter, and their rate of growth is about 5.6% higher. One must, however, be slightly careful about interpreting these differences for three reasons. First, there is a considerable variation in growth rates across the sample that should make one rather leery of reading too much into differences in means. The difference in mean profit margins between the two groups is about 18% of the standard deviation across the whole sample, while the mean difference in growth rates is about 3% of the full sample standard deviation in growth rates (both profit and growth rates are approximately normally distributed).[12]

Second, comparing means in this way attributes all of the difference between the two groups to the fact that the one group of firms produced at least one innovation during the sample period, while the other did not. In fact, work on this and similar samples using (1) and (2) applied to a group of innovating and non-innovating firms suggests that the simple comparison shown on Table I understates the effects of innovation on both profits and growth. In particular, Geroski *et al.* (1991) used a slightly larger sample of firms and found that each additional innovation produced raised margins by 1.57 percentage points, some 16.5% relative to the mean. The instantaneous increase in total profits associated with each additional innovation was £500,000, rising to some £2,100,000 in the longer run. Using the current sample of firms, Geroski and Machin, 1992, found that the production of a single innovation raised growth rates by 1.4 percentage points in the long run, an increase of just under 13% relative to the sample mean.

The third reason why the data displayed on Table I must be read with care is that Table I fails to capture what is arguably the most interesting feature of the data. This is displayed on Figures 1–3. Figure 1 shows the total number of innovations produced by firms in the full sample over the period. The important point to note is that the total number of innovations produced by firms in our sample falls off markedly towards the end of the period, dropping from a high of 45 in 1979 to a low of 7 in 1983. Using (1) or (2), one would immediately infer from this that differences in profits and growth between innovating and non-innovating firms are likely to have decreased during the period: one would expect to see much larger differences in profits and growth between the two subsets of firms in the middle 1970's than in the early 1980's. Figures 2 and 3 show that the average profit and growth rates for the two types of firms throughout the period do not conform to this pattern. Profit differences are rather smaller at the beginning of the period (the difference is 0.008 in 1976) than they are at the end (the differences were 0.016,

TABLE I. The characteristics of innovating and non-innovating firms, 1976–83

Variable	Description	The full sample (539 firms)	Innovators (98 firms)	Non-innovators (441 firms)	Source
g	first difference in the log of sales	0.1083	0.1132	0.1072	Datastream, Item 104
ROR	net profits derived from normal trading activities before tax and interest payments divided by ssles	0.0953	0.1043	0.0932	Datastream, Item 26, Item 104
INN	total number of innovations produced in all innovating units owned by the firm	0.0513	0.2819	0	SPRU Innovations tape
IPI	total number of innovations produced by by all members of the two-digit industry	12.580	15.948	11.831	SPRU Innovations tape
IUI	total number of innovations used by all members of the two-digit industry	6.279	7.207	6.073	SPRU Innovations tape
UN	industry union density across 15 two-digit industries	0.6815	0.7084	0.6755	updated from Price and Bain, 1983
MS	total sales divided by industry total sales work done	0.0282	0.0797	0.168	Datastream, Item 104, ACOP, Table P1002a
CON	five firm concentration ratio by sales	0.3952	0.4033	0.3933	ACOP, Table P1002a
IMP	import intensity, defined relative to home demand	0.2548	0.2671	0.2520	Business Monitor, Table MQ12
$SIZE$	defined as the log of firm sales $(t-1)$	3.2644	4.7762	2.9285	Datastream, Item 104
Ig	first difference in the log of industry sales	0.0972	0.0990	0.0970	ACOP, Table P1002a
Ag	aggregate real GDP growth	0.0165	0.0165	0.0165	Economics Trends

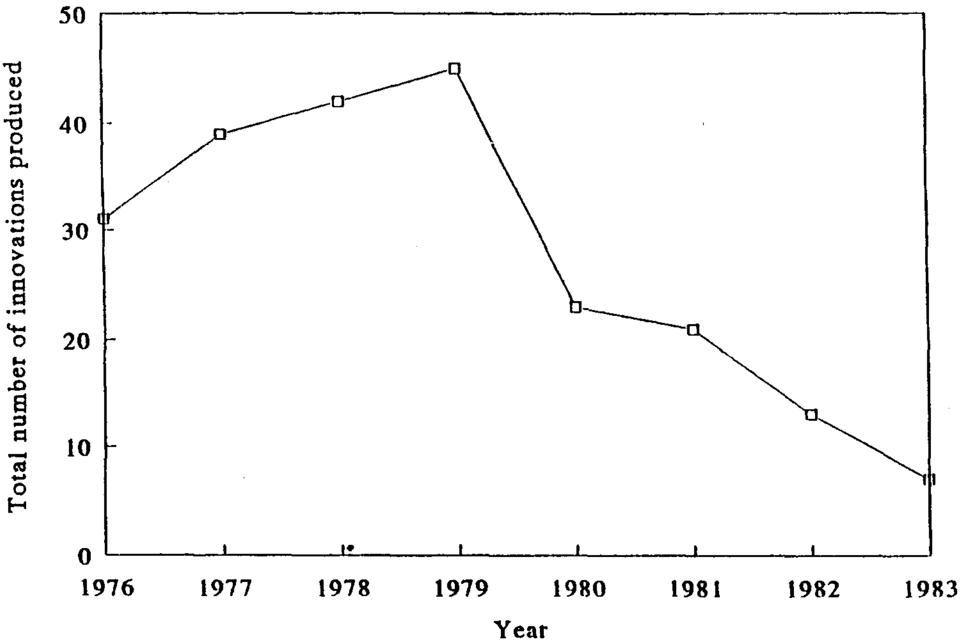

Fig. 1. Total number of innovations produced by firms in the sample.

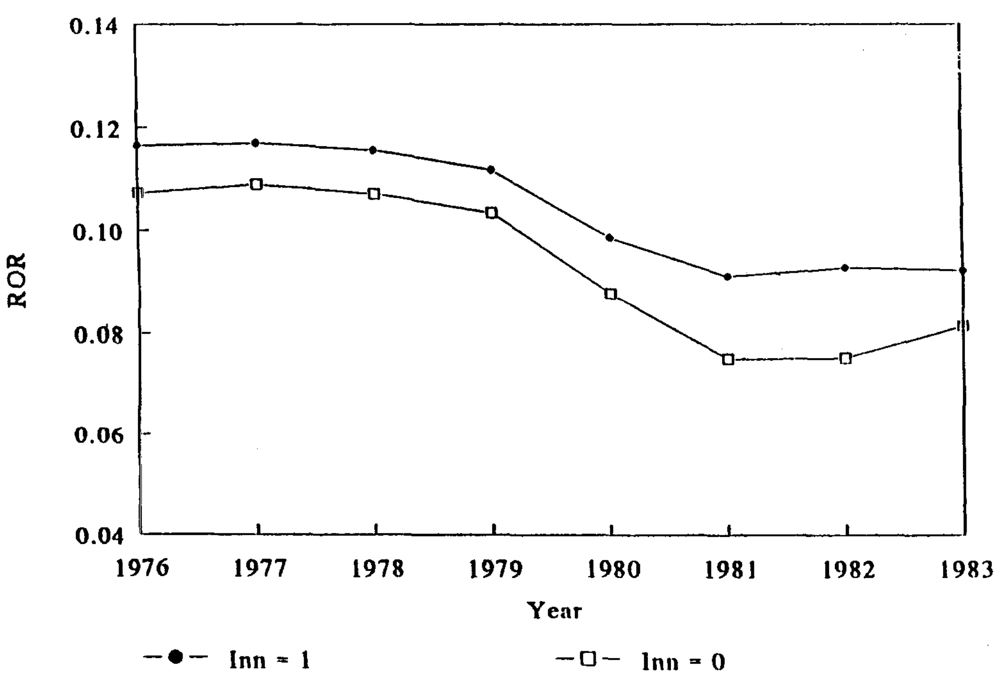

Fig. 2. Average profitability for innovators and non-innovators.

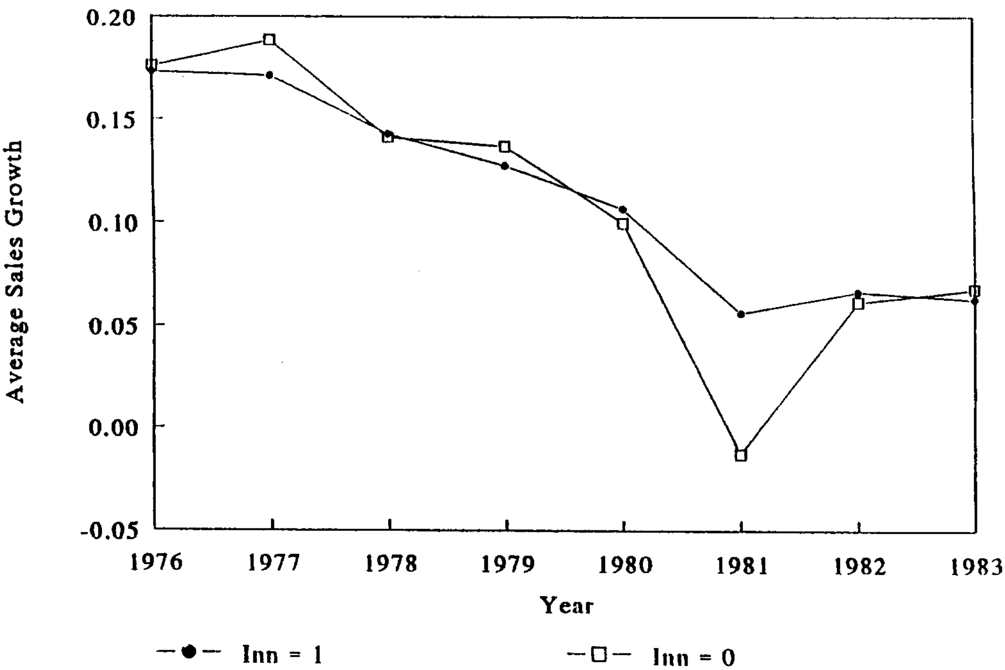

Fig. 3. Average growth rates of innovators and non-innovators.

0.018 and 0.011 in 1981, 1982 and 1983), while the difference in growth rates is negligible in virtually every year except 1981. In fact, what emerges most clearly from Figures 2 and 3 is that the performance differences between innovators and non-innovators are most noticeable during recessions.

It seems evident, then, that modelling the effect of innovations on corporate performance using Equations (1) and (2) misses what seems to be the most intriguing feature of the data: namely, that performance differences between innovating and non-innovating firms are not constant over time and, in particular, are not closely correlated with variations in the total volume of innovative activity. There are, of course, numerous potential causes of this non-constancy in performance differentials, and it seems natural to turn to equations (3)–(6) to help identify them.

Table II reports estimates of Equations (3) and (4). Comparing Equations (3) and (4) to estimates of a similarly specified Equation (1) leads one to reject the null hypothesis that the differences between the estimates of (3) and (4) are not significant (asymptotic p-value for the appropriate Wald test < 0.001); that is, (1) is not an acceptable simplification of the system (3)–(4). The results shown on Table II suggest that each innovation produced by an innovating firm has a short run impact on profitability of 0.23 of a percentage point (raising profitability by just over 2% relative to the mean profitability of innovators), and a long run effect of 0.006 (raising profitability by 5.8% relative to the mean profitability of

TABLE II. Models of profitability estimated using (3) and (4)*

	(i) Innovating firms	(ii) Non-innovating firms
Constant	0.0015 (0.810)	0.0084 (4.764)
INN	0.0023 (3.804)	–
$IPI/100$	0.0078 (0.736)	–0.0047 (0.370)
$IUI/100$	0.0031 (1.812)	0.0061 (0.412)
UN	0.072 (1.853)	–0.0385 (1.741)
MS	0.2205 (2.916)	0.4743 (3.871)
CON	0.009 (0.222	0.1518 (3.735)
$MSxCON$	–0.4822 (4.012)	–0.7781 (3.677)
IMP	–0.0480 (3.686)	–0.0207 (3.677)
$ROR(-1)$	0.1950 (4.710)	0.5601 (15.311)
$INN(-1)$	–0.0008 (1.319)	–
$INN(-2)$	0.0001 (0.121)	–
$INN(-3)$	0.0007 (0.946)	–
$INN(-4)$	–0.0004 (0.507)	–
$INN(-5)$	0.0021 (2.897)	–
$INN(-6)$	0.0009 (1.224)	–
$D1977$	–0.0026 (0.980)	–0.0039 (1.515)
$D1978$	–0.0037 (1.631)	–0.0112 (5.655)
$D1979$	–0.0069 (3.530)	–0.0093 (5.068)
$D1980$	–0.0144 (5.587)	–0.0140 (6.767)
$D1981$	–0.0047 (1.198)	–0.0130 (5.339)
$D1982$	0.0065 (1.584)	–0.0024 (0.832)
$D1983$	0.0021 (0.644)	–0.0045 (1.767)
Average fixed effect	0.037	0.008
Number of firms	98	441
Sample size	784	3528

* The estimation period is 1976–1983; absolute t-statistics in parenthesis; these regressions include firm specific fixed effects, and the variables DN are dummy variables isolating particular years n.

innovators, and 6.4% relative to non-innovators). Innovation spillovers seem to be rather modest in size, and their size is imprecisely determined in both samples. Like many other studies, we find that market share has a positive and significant impact on profitability, as does industrial concentration for non-innovators (it is statistically insignificant in the innovators sub-sample). Industry unionization takes opposite signs but is not very well determined in both cases, whilst import penetration and the market share/concentration interaction exert a negative effect in both samples. Probably the two most important differences between innovators and non-innovators are the coefficients on the lagged dependent variable and on the time dummies. Lagged profitability has a precisely determined effect in both samples, but it is evident that the dynamics of profitability differ significantly between the two types of firm. In particular, the long run impact of any exogenous variables, x_{it}, on the profitability of innovating firms is about 1.25 times larger than its short run effect; for non-innovating firms, long run effects are twice as large as short run effects.[13] The second noticeable difference concerns the common macroeconomic effects captured by the time dummies, especially in the early 1980s. The sum of the time dummy coefficients between 1980 and 1982 is –0.0126 for innovators and –0.0294 for non-innovators; converted to long run analogues these become –0.0156 and –0.0668 respectively. That is, the early 1980's recession saw a more marked fall in the margins of non-innovators (relative to trend profitability) than in the margins of innnovating firms, suggesting that innovators were more able to insulate themselves during this severe downturn than non-innovators were.

Turning to corporate growth, Table III displays estimates of Equations (5) and (6). Comparing (5) and (6) to estimates of a similarly specified Equation (2) once again leads one to reject the null hypothesis that the differences between the two types of firms shown on Table III are not statistically significant (asymptotic p-value for Wald-test < 0.001). Table III shows that each innovation produced by an innovating firm has a short run effect on growth of just under 1 percentage point (raising growth by 8% relative to the mean growth of innovators), and a long run effect of 1.4 percentage points (raising growth by 12.4% relative to the mean growth rate of innovators, and by 13% relative to that of non-innovators). Innovation spillovers are positive, but small and very imprecisely estimated. The lagged sales growth variables have positive and fairly precisely determined effects, and it is evident that the dynamics of growth do not differ too much between innovating and non-innovating firms: the long run effects on growth of a change in any exogenous variable z_{it} is 1.3 times larger for innovating firms but only 1.13 times larger for non-innovating firms. However, the most noticeable difference between the two types of firms is in their sensitivity to macroeconomic shocks. An industry specific shock that increases industry growth rates by 1% raises the growth rate of innovative and non-innovative firms by about 0.5 percentage points. However, a macroeconomic shock which increases aggregate growth raises the growth rate of innovative firms by a mere 0.124 percentage points; the growth of non-innovative firms increases by 1.09 percentage points.

Using (7) and (8) to decompose the differences between innovators and non-innovators shown on Tables II and III adds relatively little to what we have already observed. Most of the profit difference emerges from differences in the fixed effects of the two types of firms (0.037 for innovators and 0.008 for non-innovators), although relatively permanent positive differences are associated with market share and unionization. However, a clearly cyclical component to this difference is evident in the time dummies, and the recession year of 1981 stands out as a year in which profit differences between innovators and non-innovators are relatively large. In fact, the sum of the co-efficients on the 1981, 1982 and 1983 year dummies contributes 0.4 of a percentage point to the mean differential (which is about 1.0

TABLE III. Models of sales growth estimated using (5) and (6)*

	(iii) Innovating firms	(iv) Non-innovating firms
Constant	0.039 (1.364)	0.028 (2.198)
SIZE	–0.002 (0.710)	–0.004 (1.552)
$g(t-1)$	0.097 (2.043)	0.080 (3.229)
$g(t-2)$	0.032 (0.457)	–0.017 (0.800)
$g(t-3)$	0.097 (2.565)	0.054 (1.793)
$INN(t)$	0.009 (1.256)	–
$INN(t-1)$	–0.007 (0.976)	–
$INN(t-2)$	0.001 (0.137)	–
$INN(t-3)$	0.008 (1.077)	–
$Ig(t)$	0.171 (2.190)	0.120 (3.055)
$Ig(t-1)$	0.252 (3.710)	0.187 (5.011)
$Ig(t-2)$	0.070 (1.074)	0.150 (3.521)
$Ig(t-3)$	–0.125 (1.426)	0.013 (0.336)
$IPI/100(t)$	0.061 (0.614)	0.117 (2.085)
$IPI/100(t-1)$	0.039 (0.283)	0.013 (0.191)
$IPI/100(t-2)$	–0.122 (0.682)	–0.079 (0.981)
$IPI/100(t-3)$	0.055 (0.578)	–0.087 (1.326)
$IUI/100(t)$	0.349 (1.949)	0.104 (1.282)
$IUI/100(t-1)$	–0.175 (0.944)	–0.024 (0.324)
$IUI/100(t-2)$	0.220 (1.437)	0.063 (0.903)
$IUI/100(t-3)$	–0.278 (1.863)	0.015 (0.221)
$Ag(t)$	0.177 (0.384)	0.230 (1.183)
$Ag(t-1)$	0.092 (0.180)	1.587 (7.277)
$Ag(t-2)$	–0.204 (0.470)	–1.201 (6.332)
$Ag(t-3)$	0.031 (0.104)	0.352 (2.551)
R^2	0.114	0.128
Number of firms	98	441
Sample size	784	3328

* The estimation period is 1976–1983; absolute t-statistics in parenthesis; these regressions do not include firm fixed effects.

percentage point). Differences in growth performance, by contrast, are more difficult to discern (the mean growth differential is 0.006), and they are not permanent. Most of the difference becomes manifest in 1981, and the most sizeable effect is captured by differences in the co-efficients on the aggregate growth variables. These indicate that a 1% fall in real GDP increases the growth differential by 1.6 percentage points (or 200%).[14]

4. Some Conclusions

In order to make progress in assessing the magnitude of the effects of innovation on corporate performance, one needs to know how such effects occur. We have contrasted two views of the effect of innovation – "*the product view*" and "*the process view*" – and have provided some evidence to suggest that both effects are evident in the data. Although it is clear that individual innovations themselves have a positive (if fairly modest and perhaps rather short lived) effect on profitability and growth, it is equally clear that the process of innovation seems to transform firms in some way that gives rise to what look like generic differences between innovators and non-innovators. As a consequence, the process by which profitability and growth are generated differs noticeably between the two types of firms. Perhaps the clearest of these differences is that innovating firms seem to be much less sensitive to cyclical shocks than non-innovating firms are.

There is something deeply sensible and unsurprising about this result (at least when it is looked at with the benefit of hindsight). Whatever it is that creates a generic difference between innovating and non-innovating firms, the result is likely to be that innovators are more flexible and adaptable. They have the internal capabilities to respond quickly to new technological developments, and to bring technological possibilities into harmony with changing consumer needs. One suspects that in many cases, they have organizational structures designed to cope with the challenge of change. If one thinks of the economic environment as a selection mechanism and asks: "when are these kinds of characteristics are likely to increase a firms survival value?", the answer is: "almost certainly during times of adversity". In particular, recessions are a major exogenous change in a firms market environment, and coping with a recession often requires a fundamental reorientation of a firms activities. If the innovation process really does transform a firm's internal capabilities, then one would only ever expect to see the effects of this transformation during periods of adversity. Most firms, innovative or not, can prosper in a buoyant market, but only a few of the more innovative ones can continue to do so when the going gets tough.

Notes

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1. For example, Odagiri (1992) describes the behavior of Japanese firms in terms of a preference for growth; more generally, see the survey and discussion in Mueller (1987).
2. Measuring profitability has been the source of much recent controversy, the problem being that of insuring that capital inputs are properly valued. This (and other measurement errors) can give rise to large differences between different measures of profitability. However, even when accounting and "economic" profits do diverge, it is nevertheless the case that persistently high

levels of accounting profits imply persistently high levels of economic profits (see Fisher and McGowan, 1983; Fisher, 1987; and Edwards *et al.*, 1987). Measurement problems associated with growth are likely to be no less serious than those associated with profitability, but growth rates are so inherently variable that this additional source of variation is likely to be relatively insignificant (see Hall, 1987).

3. In what follows, we shall presume that innovation is exogenous to current period growth and profitability. While there is no doubt that firms undertake innovative activities to increase their size and improve their profitability and use past profits to finance current R&D efforts, the many lags that occur during the innovation process mean that it is highly unlikely that there exists a strong feedback between current values of profitability and growth on the one hand, and innovation on the other.
4. It is important not to confuse this distinction between "the product of" and "the process of" innovation with the conventional distinction between "product" and "process" innovations. It is conceivable that product and process innovations have different effects on profits and growth, but these effects are transitory and associated with the occurrence of a particular innovation of either type. Effects associated with the process of innovation are generic, and can be observed even when innovations are not produced.
5. For example, Cohen and Levinthal (1989) contrast the view of R&D as a process which produces innovative outputs with the view of R&D as a process which builds up internal capabilities (see also Mowery and Rosenberg, 1989; Pavitt, 1991; Willman, 1991; and others).
6. See Cohen and Levin (1989) for a survey of empirical studies of the determinants of innovation. Much of this work suggests that the role of firm size and market structure in affecting innovation is fairly modest, and is probably dominated by the effects of variations in "technological opportunities". For a survey of work on spillovers, see Geroski (1992).
7. For a justification of the market share/concentration interaction variable, see Kwoka and Ravenscraft (1986), Machin and Van Reenan (1992), and others; Geroski and Jacquemin (1988), and Mueller (1986 and 1990) make the case for allowing for dynamics explicitly in a model like (1). Fixed effects are included to pick up relatively permanent factors which affect the profitability of firms, and might be best interpreted as (indirect) measures of the height of mobility barriers. The time dummies are designed to capture macroeconomic effects which all firms feel. For a fuller discussion, see Geroski *et al.* (1991).
8. The inclusion of a size variable has been standard in growth equations for some time, and reflects an interest in testing the Law of Proportionate Effects. The inclusion of lagged dependent variables, industry growth and aggregate growth rates is designed to capture unobserved firm, industry and macroeconomic shocks, and the persistence of the effects of these shocks on firm growth can be untangled from the estimated co-efficients on these observables. Firm specific effects are not included because there is very little persistence in corporate growth rates over time; see Geroski and Machin (1992), and references cited therein for a fuller discussion.
9. That these innovations are selected into the sample because (*inter alia*) they are commercial successes means that we are unlikely to see negative effects on corporate performance associated with them. If these innovations are set against those that were introduced but failed, then the returns to total innovative activities are likely to be lower than those estimated below.
10. Relatively few of the innovations recorded in this data set were first used by the firm that produced them. That is, the data only identify innovation producing firms, and there are good grounds for thinking that users capture many of the benefits yielded by these innovations (see Geroski, 1991). It follows that however accurately our estimates measure the effects of these innovations on innovation producing firms, they are likely to understate the total effects of these innovations on the profits and growth of all of the firms who are associated with them.
11. The relationship between firm size and innovativeness across all firms and innovations in the SPRU data tape is more complex than this, since very small firms contribute disproportionately to total innovative activity (see Pavitt *et al.*, 1987). What Table I shows is a pro-Schumpeterian positive correlation between size and innovation within the (sub) population of large, quoted firms.
12. Growth rates are far more variable than profits and the range over which they vary is several times larger. What is more – and what is more interesting – most of the variation in growth rates is within firm variation while most of the variation in profitability is between firms (with percentage of variation that is within firm is 86% for growth and 7% for profits). This lack of

persistence in growth over time is particularly evident when one looks at the serial correlation in the data. The correlation between growth rates in 1983 and 1982 is – 0.056, and falls to –0.026 between growth rates in 1983 and 1974; for profitability, the same correlations are 0.914 and 0.459. We have also used robust regression methods to downgrade the importance of outliers in our growth equations, but the resulting estimates were very similar to those reported in the text.

13. That is, thte profitability of innovating firms is less persistent over time (all else constant) than that of non-innovators, although variations in innovators profits are not noticeably less predictable than those of non-innovators.
14. Since most of the innovations in the SPRU data come from engineering or chemicals firms, it is unlikely that the (relative) cyclical insensitivity of innovating firms which we have observed arises because innovators are in cyclically less turbulent markets than non-innovators.

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