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Dynamics of R&D and investment: UK evidence

Otto Toivanen*, Paul Stoneman

Economics Department, Helsinki School of Economics, PO Box 1210, 00400 Helsinki, Finland

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Abstract

The dynamic relationship between R&D, investment and stock market value for 185 UK firms over 1984–1992 is analyzed. Investment Granger-causes R&D but not vice versa. R&D has an idiosyncratic shock and past R&D and investment explain only 1% of excess returns. © 1998 Elsevier Science S.A.

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1. Introduction

Although there exists a wide consensus that the key to a more prosperous future lies in gains in productivity and that the main tools for achieving such gains are investments in physical and human capital, our understanding of the underlying processes that involve the use of such tools—especially with respect to human capital—remains weak. A fruitful approach to these issues (Pakes (1985) and Lach and Schankerman (1989), henceforth LS) has been to explore by means of dynamic factor analysis (Sargent and Sims (1977)) the ''stylized facts'' of the relationship between R&D, investment in physical capital and firm market value. Using a sample of 191 US firms in science based industries over the period 1973–1981 LS generate a number of such stylized facts. The objective of this paper is to apply the same approach to a data set from a different country (the UK) over a different time period (1984–1992) and across a wider sample of industries to explore whether the LS results are robust. In Section 2 we outline the statistical approach taken and in Section 3 describe our data and report the empirical findings. Section 4 provides discussion and concluding remarks.

2. Statement of the model

Building on a theoretical investment model based on Lucas and Prescott (1971), where firms invest

*Corresponding author. Tel.: 358 (0)9 43 13 83 22; fax: 358 (0)9 43 13 87 38; e-mail; toivanen@hkkk.fi

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in capital goods and human capital (R&D) to maximize the expected discounted value of their cash flow, yields the following system of equations[1]

$$
\begin{aligned}
r_t &= A_{11}(L)\epsilon_t + A_{12}(L)\eta_t + A_{13}(L)\mu_t \\
i_t &= A_{21}(L)\epsilon_t + A_{22}(L)\eta_t + A_{23}(L)\mu_t \\
q_t &= A_{31}(L)\epsilon_t + A_{32}(L)\eta_t + A_{33}(L)\mu_t,
\end{aligned}
\tag{1}
$$

where r is (the log of) R&D, i (the log of) investment and q a measure of the value of the firm. $A(L)$ is a polynomial lag operator and $\{\epsilon_t, \eta_t, \mu_t\}$ are mutually uncorrelated white noise processes. As the one period excess rate of return on the firm's equity[2], under a no arbitrage condition, q, cannot be predicted from past information. In the next section, using our different data set, we follow Pakes (1985) and LS, first establishing that the no arbitrage condition holds and then test for interactions between R&D and investment. Different exclusion restrictions on (1) can be related to particular orderings of Granger-causality. Generalized Least Squares[3] yields consistent and efficient estimates of (1).

3. The data and empirical results

The data is a panel of 185 UK quoted companies over the period from 1984 to 1992. R&D reporting by UK companies is not obligatory but from 1989 became a recommended accounting practice and has since increased considerably. The Department of Trade and Industry has listed in a Score-board each year since 1991 the names and R&D of those companies reporting in that year. 331 reported in 1992 (Company Reporting Limited, 1993). Our sample comprises those firms in the 1992 Score-board for whom Datastream (from which all other data was sourced) also report the R&D spend in each year from 1984–1992. The sample covers 22 industrial sectors with 43% of the sample in industries labelled by LS as scientific (25% in the Electrical and Electronic sector, 8% in Health Services, 7% in the chemical industry, 3% in Aerospace) but also with 12% in general manufacturing, 8% in the construction industry and the remaining 37% spread across 16 other industrial sectors. All

[1] For a derivation, see Lach and Schankerman (1989).

[2] We measure q as the annual rate of growth of the end year value of the firm's equity minus the interest rate (using Datastream item D003 (historical market value)). An anonymous referee has pointed out that q should also include (and LS include) the dividend yield i.e. the ratio of dividends to the value of equity. Although this will not affect our results relating to the directions of Granger causality between investment and R&D it might impact upon our estimates of the q equation, and the effects of q on the other dependent variables. However, although studies of dividends and equity prices in the UK are rare, in a recent unpublished paper Yadav (1995) has tested using UK data whether stock market returns can be predicted from dividend yields and concludes that for the period 1973–1992 one cannot reject the hypothesis that dividend yields cannot predict stock market returns. He also states ''It is well known that dividend payments follow persistent patterns and so variations in dividend yields are dominated by stock price movements''. This leads us to believe that our results will not unduly be influenced by the definition used.

[3] Time dummies are included in the equations to capture deterministic components.

firms in the sample reported positive R&D 1989–1992 but some reported zero R&D[4] prior to 1989. A particular problem with the data is that we cannot be sure whether pre-1989 zero reported R&D in Datastream indicates truly zero R&D or non reporting of R&D. In order to check the robustness of our results we have thus undertaken our analysis using not only the whole sample but also a subsample that excludes all firms that reported zero R&D in 1988 but positive R&D in 1989. In addition[5], as LS report findings based on a sample of only scientific industries we have also used a further subsample that includes only firms in the four industries defined as the scientific sector. Descriptive statistics for the three samples are given in Table 1.

LS report (pp. 881) that the ‘‘sample variance in the growth of investment is four times as large as the sample variance in the growth rate of R&D.... This conclusion also holds for the (log) levels’’. In our full sample, the variance in the growth of investment is three times as large as the variance in the growth rate of R&D but in contrast the variance (standard deviation) of the log levels of investment is only one half the variance of the log level of R&D. Orderings of variances also hold for both subsamples.

In Table 2 we report the results of restriction tests on (1) for each of our three samples. LS report that the no arbitrage condition holds and that investment is Granger-caused by R&D but not vice versa. They find a common factor causing both investment and R&D. We also find for each sample that the no arbitrage condition holds[6] and that past values of q do not explain r or i. In contrast, we find that R&D is Granger-caused by investment, but investment is not Granger-caused by R&D. In line with LS, we found a common factor shared by investment and R&D, but in contrast, we found that only R&D (not, as LS, only investment) has an idiosyncratic factor. As the essence of these (Granger-causality) results is not affected by the inclusion of zero reporting or non-scientific firms, these two factors cannot explain the difference between our results and those of LS.

The resultant restricted form of (1) can be written as (2):

$$
\begin{aligned}
r_t &= B_{11}(L)r_{t-1}B_{12}(L)i_{t-1} + \beta\epsilon_t + \gamma\eta_t \\
i_t &= B_{21}(L)i_{t-1} + \alpha\epsilon_t \\
q_t &= \epsilon_t + \eta_t + \mu_t,
\end{aligned}
\tag{2}
$$

where $B(L)$ is a lag operator. In Table 3 we present the parameter estimates based on (2)[7] using the

[4]In the estimations we approximate zero R&D by replacing it with R&D = 1 and a dummy variable that took the value unity when R&D = 0. This dummy obtains, for each of our samples, a significant (negative) value only in the R&D equation of the system.

[5]As suggested by an anonymous referee.

[6]We cannot always reject the hypothesis that lagged q’s (and r’s) in the q equation (and similarly for the other equations) are jointly significant at conventional levels. As with LS, however, none of the test statistics is even close to Leamer’s Bayesian F statistics and when, for the full sample and by implication the other samples, imposing the restrictions of market efficiency, the residual variance in q increases by less than 1% (and by similar small amounts in the other two equations when the respective restrictions are imposed). We follow LS in accepting the hypothesis that q is unpredictable and apply the same criteria to the other equations.

[7]In Table 3 the asymptotic standard errors are calculated using the fourth moments of the residuals of Eq. (2) (as LS report doing). We applied the formula (e.g. Greene (1993), pp. 94) $\mathrm{var}(s^2) = (2\sigma^4)/(n-1)$ where s^2 is the estimated variance.

Table 1
Descriptive statistics (1985 prices)

A. Whole sample (over all N firms and T periods)

	Log of R&D	R&D growth % p.a.	Log of investment	Investment growth % p.a.
Average	3.25	8.26	8.82	55.21
Standard dev.	4.11	153.24	2.37	492.67
Firm level	Log of R&D	R&D growth	Log of investment	Investment growth
Average of the firm level standard deviations	1.28	0.37	0.42	1.53

B. Subsample excluding firms with zero R&D in 1988 and positive R&D in 1989

	Log of R&D	R&D growth % p.a.	Log of investment	Investment growth % p.a.
Average	4.07	16.48	10.39	86.09
standard dev.	4.49	214.97	2.35	699.49
Firm level				
	Log of R&D	R&D growth	Log of investment	Investment growth
Average of the firm level standard deviations	2.43	0.54	0.96	2.11

C. Subsample of firms in the scientific industries

	Log of R&D	R&D growth % p.a.	Log of investment	Investment growth % p.a.
Average	3.66	12.68	8.55	84.65
standard dev.	4.31	129.91	2.25	807.42
Firm level				
	Log of R&D	R&D growth	Log of investment	Investment growth
Average of the firm level standard deviations	2.86	0.43	0.90	2.24

Note: all data is sourced from Datastream. R&D is measured by item 119, investment by item 435 (Total New Fixed Assets Purchased).

whole sample (on which we now concentrate). The revealed pattern of significance shows a similar ordering to that reported by LS, but in general our estimates are less precise than those of LS.

LS find that the response of investment to the shock shared by investment and R&D (ϵ_t) is much larger than that of R&D (2.78 vs. 1.38). In our data (see rows 1 and 2 of Table 3) the response of

Table 2
Restriction tests equation

A. Whole sample			
restricted variables	q	r	i
Lagged q's	3.80	4.57	1.66
Lagged r's	2.41	100.64	4.38
Lagged i's	0.96	103.45	143.30
Lagged r's and i's	1.72	–	–
Lagged q's, r's and i's	2.58	–	–
Lagged q's and r's	–	–	2.03
B. Subsample excluding firms with zero R&D in 1988 and positive R&D in 1989			
Lagged q's	0.87	0.80	2–38
Lagged r's	2.36	75.67	0.67
Lagged i's	1.12	59.85	95.51
Lagged r's and i's	1.62	–	–
Lagged q's, r's and i's	1.53	–	–
Lagged q's and r's	–	–	1.61
C. Subsample of firms in the scientific industries			
Lagged q's	0.39	2.26	1.45
Lagged r's	2.03	28.30	1.90
Lagged i's	1.19	43.81	61.97
Lagged r's and i's	1.73	–	–
Lagged q's, r's and i's	1.37	–	–
Lagged q's and r's	–	–	1.78

NOTE: F-tests with 4, 8 and 12 d.f. for the numerator, 723 (sample A), 375 (B) and 251 (C) for the denominator. Critical values are (5% level): 2.37, 1.94 and 1.80 respectively.

investment to the factor that is common between R&D and investment is also larger (.365) than the response of R&D (.017). LS report that the response of investment to the idiosyncratic shock is larger than to the common shock (11.7 vs. 1.38). In our data, the response of *R&D* to the idiosyncratic factor (η_t) is larger (.252) than the response to (ϵ_t) the common factor (.017). Contrasting our results further with those of LS, the variances of the three shocks (σ_k^2, $k = \epsilon, \mu, \eta$) are larger than those reported by LS by a factor of 1000. In line with LS we find i) most of the variance in the growth rate of R&D (for LS growth rate of investment) is due to the idiosyncratic factor as the common factor accounts for one tenth of a percent of the variance in the growth rate of R&D (row 7 in Table 3. LS report 5.9%) and ii) a large proportion of the total variance in q is unrelated to r and i, LS report 96% whereas our corresponding figure is 97% (row 8 in Table 3), and thus R&D and investment which are two of the most important assets of the firm, do a relatively poor job in explaining the variation in q[8]. In terms of establishing stylized facts it is quite remarkable that these findings are so close to each other in two data sets that in many respects are so very different.

[8]Perhaps this is not that surprising. Literature in a different theoretical tradition, based on Tobin's q models (see Hall (1993) for the US and Green (1996) for the UK), tends to show that R&D does have an impact upon the market value of firms but, once net assets are accounted for, there is very little variance in market values left to be explained by R&D and investment.

Table 3
Parameter values of the model (full sample)

1. α	0.365*
	(0.210)
2. β	0.017
	(0.016)
3. γ	0.252*
	(0.140)
4. σ^2_ϵ	24.485
	(26.116)
5. σ^2_η	18.672
	(20.702)
6. σ^2_μ	1588.843***
	(328.825)
7. $\beta^2\sigma^2_\epsilon/\sigma^2_r$	0.001
8. σ^2_μ/σ^2_q	0.974
9. $V(\epsilon)$	1.006
10. $V(\eta)$	1.051

Numbers shown are parameter value and asymptotic standard error (in parenthesis).
*=significant at the 10% level.
**=significant at the 5% level.
***=significant at the 1% level.

In Fig. 1, the response patterns (MA coefficients) of r and i to the common shock and the response pattern of r to the idiosyncratic shock for the whole sample are plotted. These are clearly different to those reported by LS[9]. Finally, we report in Table 3 (rows 9 and 10) the ''benefit/cost'' ratios, $V(\epsilon)$ and $V(\eta)$, of changes in R&D and investment as responses to the common shock ϵ and the shock that is idiosyncratic to R&D (η). LS report considerably higher benefit/cost ratios for both shocks (1.18 compared to 1.006 for the common shock; 1.22 compared to 1.051 for the idiosyncratic shock).

4. Conclusions

We report results on stylized facts relating to interactions between R&D and investment using data from a panel of UK firms over the period 1984–1992. In contrast to Lach and Schankerman (1989), we find, using the whole sample, that the variance of the log levels of R&D is twice as large as that of investment; that investment Granger-causes R&D but not vice versa; and that R&D, not investment, has an idiosyncratic factor. Our results with respect to responses to the common and the idiosyncratic factors are similar to those of LS. We find that the idiosyncratic R&D factor explains more of the variation in the growth of R&D than the common factor. LS report a similar finding with respect to

[9]We calculated the MA coefficients following LS's footnote 11 and Hamilton (1994) pp. 769. However, when following the procedure detailed by Hamilton and using LS's coefficients we could not replicate the response patterns reported in LS. The response patterns we have calculated on the UK data differ both from those reported by LS and from those that we calculated according to Hamilton using LS's coefficients.

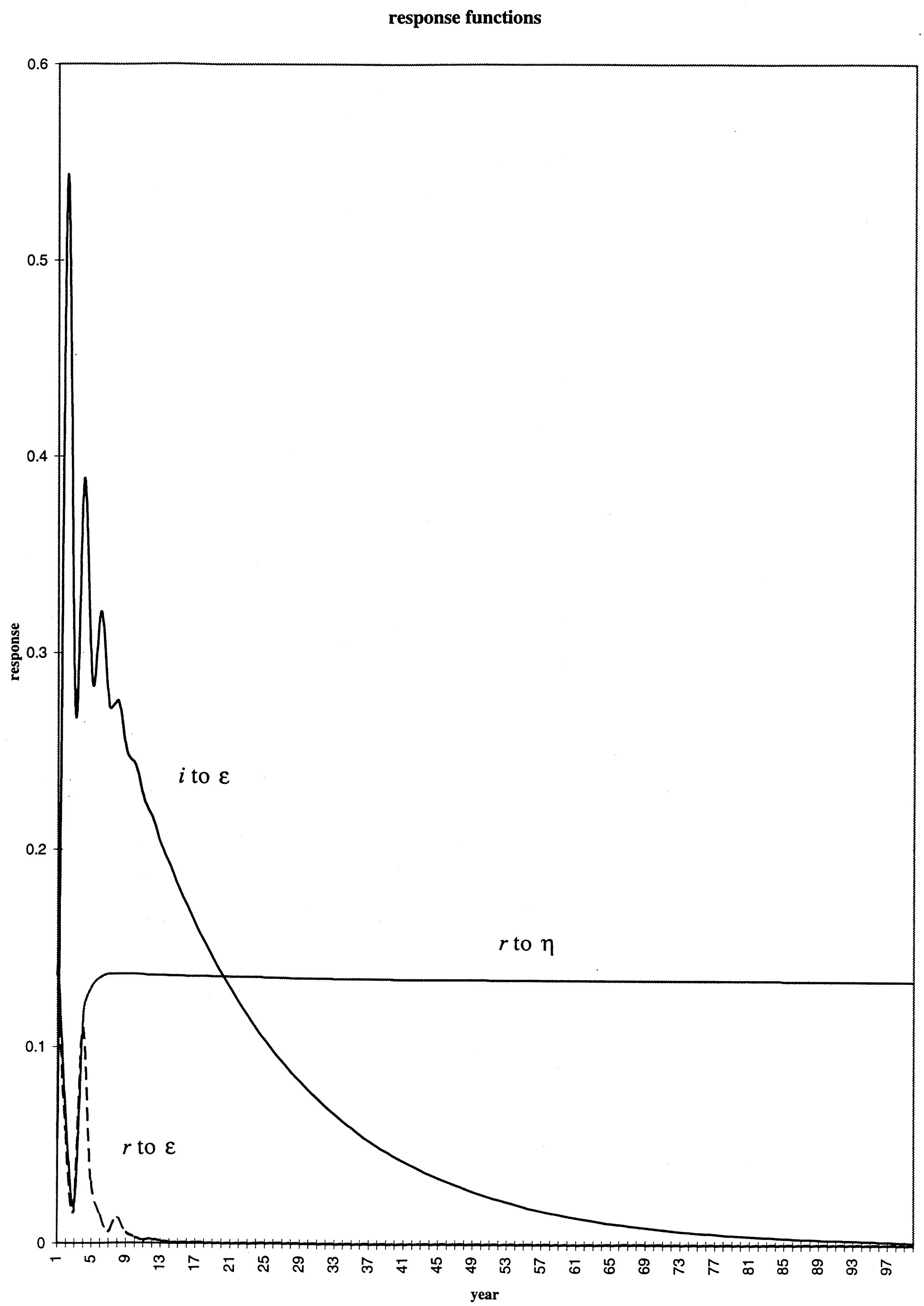
response functions
0.6
0.5
0.4
0.3
0.2
0.1
0
response
i to ε
r to η
r to ε
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
year

Fig. 1.

investment. We confirm the LS result that R&D and investment explain only a tiny fraction of the variation in q, the excess rate of return on the firm's equity. The main difference between our results and those of LS centre around the reversed patterns of Granger-causality. We explored the effects of sample specification on this, but in each case the results showed the same directions of causality as for the whole sample. In particular, restricting the sample to include only firms in the scientific sector (as in LS) did not change our findings. Our results are thus robust to sample specification but what is seen in the UK data is different from what is seen in the US data.

Why might investment Granger-cause R&D but not vice versa? On the latter, we hypothesize that it is reasonable to expect that technological opportunities will stimulate investment, but that firm's own R&D is not a good indicator of such opportunities. Technological opportunities may arise from the R&D of other firms in the same industry (domestic and overseas), other industries, universities etc. In addition new offerings from the capital goods industries, learning, design and other such activities may all generate new technological opportunities that are not adequately proxied by the firms own R&D. On the former one might hypothesize that investment causes R&D in that the adoption of new technologies requires adaptation and other (product development) expenditures. In other work we are exploring such hypotheses as these, but more generally we can state that the results above indicate that some of the stylized facts as stated by LS are not as stylized as might have originally been thought and that more empirical work in the area of the dynamic relationship between R&D and investment is still required.

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