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R&D and firm growth rate variance

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Abstract

Investment in R&D is positively associated with the variance of sales growth and, to a lesser extent, employment growth. The magnitude of this effect has not increased in recent decades, however.

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1 Introduction

In this paper we aim to improve our understanding of firm-level innovation and firm performance by focusing on the link between innovation and growth rate variance. The existing literature has shown an interest in explaining growth rate variance, although it has concentrated on the link between firm size and growth variance (for a survey see Coad (2008)). To the best of our knowledge, this is the first paper looking directly at the influence of R&D on growth rate variance. This subject is not without importance, however. Shareholders and managers may well be concerned about the variance of a firm's sales growth. Furthermore, employees and economists may well be concerned about variance of employment growth.

R&D is an uncertain investment, and the returns to innovation are remarkably skewed (see for example Grabowski et al. (2002)). In many cases, R&D investment has no detectable effect on firm performance (e.g. Geroski et al. (1997); Bottazzi et al. (2001)), although in a minority of cases successful innovators experience significant sales growth (Coad and Rao (2008); Hölzl (2009); Stam and Wennberg (2009); Goedhuys and Sleuwaegen (2010)). As such, investment in R&D may increase the variance of sales growth rates in a sample of firms.

R&D investment may also have implications for the variance of employment growth rates. In the case of employment growth, we must not only distinguish between successful and unsuccessful R&D attempts, but also between innovations (R&D outcomes) that are labour-intensive or labour-saving.

We undertake a non-parametric and parametric analysis of the relationship between R&D intensity and growth rate variance. We also investigate the hypothesis that R&D investment has had a stronger impact on growth rate variance in recent years.

2 Database

Our analysis is based on the well-known Compustat¹ dataset of US listed companies. We focus on the years from 1973 since the disclosure of R&D expenditure was made compulsory for US firms in 1972.² Our analysis thus covers the thirty-two year period from 1973 to 2004 (although we lose one year of data in calculating growth rates). For the sake of comparability with previous studies, we focus on the manufacturing industries (SIC classes 2000-3999). Our dataset is an unbalanced panel, and we have about 1000 observations in each year. We argue that our choice of database is well-suited to our research question (because of reliable quantitative R&D reporting and long time coverage).

Our measure of growth rates is calculated by taking the differences of the logarithms of size: $g_{it} = \log(S_{it}) - \log(S_{i,t-1})$; where S is measured in terms of total sales or employees for firm i at time t . Where sales is used as an indicator of firm size, we deflate to (millions of) 1980 dollars using the consumer price index. Employment figures are expressed in thousands.

¹Compustat has the largest set of fundamental and market data representing 90% of the world's market capitalization. Being included in the Compustat database means that the number of shareholders in the firm was large enough for the firm to command sufficient investor interest to be followed by Standard and Poor's Compustat, which basically means that the firm is required to file 10-Ks to the Securities and Exchange Commission on a regular basis. It does not necessarily mean that the firm has gone through an IPO. Most firms are listed on the NASDAQ or the NYSE.

²Although we do actually have some observations for R&D expenditure for firms before 1972, due to the voluntary nature of disclosure of R&D expenditure during this period these observations are prone to sample selection bias (i.e. self-selection bias). Furthermore, we have relatively few observations before the 1970s which discourages analysis of these earlier years.

Table 1: Summary statistics

	Mean	Std. Dev	10%	25%	Median	75%	90%	Obs.
1974-1980								
Sales	1269.669	5048.950	12.840	38.527	137.229	660.838	2703.770	8008
Sales Gr	0.050	0.173	-0.145	-0.035	0.047	0.134	0.241	8008
Empl	13.712	45.119	0.219	0.619	2.183	9.603	33.007	8008
Empl Gr	-0.005	0.173	-0.165	-0.084	-0.019	0.058	0.186	8008
R&D intensity	0.025	0.026	0.003	0.007	0.015	0.033	0.061	8008
1981-1988								
Sales	1566.997	5809.997	10.400	30.554	129.438	802.725	3108.892	7917
Sales Gr	0.051	0.201	-0.154	-0.051	0.042	0.141	0.273	7917
Empl	15.282	47.900	0.168	0.484	1.990	10.345	38.751	7917
Empl Gr	-0.019	0.206	-0.195	-0.105	-0.037	0.050	0.186	7917
R&D intensity	0.039	0.041	0.005	0.011	0.025	0.055	0.094	7917
1989-1996								
Sales	1720.995	6150.944	11.268	34.733	136.118	770.193	3656.187	8691
Sales Gr	0.068	0.204	-0.127	-0.034	0.047	0.148	0.290	8691
Empl	13.886	46.461	0.143	0.440	1.668	8.115	32.800	8691
Empl Gr	-0.018	0.210	-0.190	-0.109	-0.042	0.047	0.192	8691
R&D intensity	0.049	0.053	0.006	0.012	0.031	0.069	0.117	8691
1997-2004								
Sales	2129.347	7609.458	15.144	49.132	202.659	933.980	4245.039	8540
Sales Gr	0.062	0.222	-0.147	-0.037	0.051	0.153	0.299	8540
Empl	14.701	40.053	0.159	0.514	2.200	9.700	36.624	8540
Empl Gr	-0.021	0.229	-0.201	-0.113	-0.042	0.052	0.195	8540
R&D intensity	0.059	0.078	0.006	0.013	0.033	0.077	0.146	8540
Full sample								
Sales	1680.396	6256.312	12.115	37.713	148.669	788.993	3313.553	33156
Sales Gr	0.058	0.202	-0.142	-0.039	0.047	0.144	0.277	33156
Empl	14.387	44.931	0.166	0.507	2.000	9.362	35.300	33156
Empl Gr	-0.016	0.206	-0.189	-0.103	-0.035	0.052	0.189	33156
R&D intensity	0.043	0.055	0.005	0.010	0.025	0.058	0.105	33156

R&D intensity is defined as R&D expenditure divided by total sales.

Summary statistics are presented in Table 1. Over the period of analysis, manufacturing firms have become visibly more R&D intensive, and they have grown in terms of sales but have declined in terms of total employment. (Indeed, some of the decrease of employment in manufacturing may be due to labour-saving technological progress.)

Table 2 presents some basic tabulations, which show that show how the variance of sales and employment growth rates varies. Growth rate variance generally appears to increase with R&D intensity, but the relationship is not monotonic.

3 Analysis

Figure 1 plots R&D intensity against standard deviation of growth rates, and shows a positive relationship between these two variables.

We also perform parametric regressions to assess the relationship between firm size and growth rate variance. Using a similar approach to previous work³ we estimate the following heteroskedastic regression model:

$$g_{i,t} = e^{\alpha r_{i,t-1}} \varepsilon_{i,t} \quad (1)$$

where $r_{i,t-1}$ is the R&D intensity of firm i in year $t-1$. $\varepsilon_{i,t}$ is the residual term. The variables $g_{i,t}$ and $r_{i,t-1}$ have had their means removed. We estimate this equation using both OLS and minimum absolute deviation (MAD) regression methods. The MAD regressions are to be

³See e.g. Bottazzi et al. (2010) and Coad (2008).

Table 2: Changes in the standard deviation of growth rates (sales growth and employment growth) over different classes of R&D intensity.

R&D int	σ (Sales gr.)	σ (Empl. gr.)	Obs.
<0.01	0.1924	0.1986	8128
0.01-0.02	0.1868	0.1936	6302
0.02-0.04	0.1865	0.1995	6995
0.04-0.07	0.2011	0.2133	5276
0.07-0.1	0.2088	0.1993	2818
0.1-0.15	0.2339	0.2213	2292
0.15-0.25	0.2546	0.2358	1090
>0.25	0.3393	0.3329	255
			33156

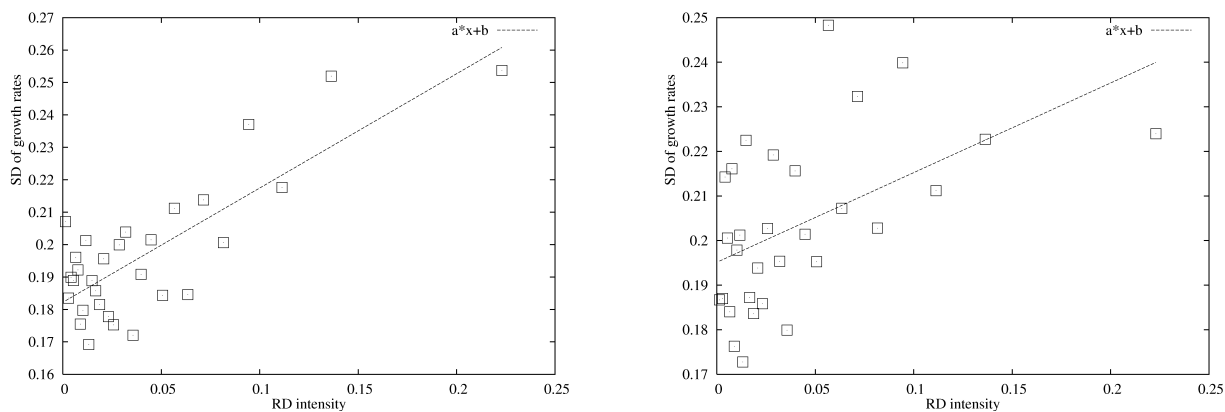


Figure 1: R&D intensity vs standard deviation of growth rates, where growth is measured as sales growth (left) or employment growth (right); 33156 observations. Firms are sorted into 30 equipopulated groups according to increasing R&D intensity. Fitted lines are also shown as a visual aid. The slopes of the fitted lines are 0.35 (left) and 0.20 (right).

Table 3: Estimates of α from Equation (1)

		OLS		MAD		
		α	SE	α	SE	obs
Total	Sales gr	0.8290	0.0606	0.5412	0.0108	33156
	Empl. gr	0.5877	0.0573	0.3594	0.0119	33156
1974-1980	Sales gr	0.7713	0.1013	0.6074	0.0287	8008
	Empl. gr	0.5269	0.1218	0.5512	0.0266	8008
1981-1988	Sales gr	0.7645	0.0865	0.5309	0.0258	7917
	Empl. gr	0.4922	0.0987	0.3531	0.0264	7917
1989-1996	Sales gr	0.7191	0.0884	0.5024	0.0225	8691
	Empl. gr	0.6100	0.0763	0.3728	0.0243	8691
1997-2004	Sales gr	0.8490	0.0904	0.5282	0.0191	8540
	Empl. gr	0.6178	0.0907	0.3446	0.0213	8540
SIC 35-38	Sales gr	0.5608	0.0571	0.4305	0.0157	14337
	Empl. gr	0.4269	0.0800	0.3020	0.0164	14337

preferred because they are more robust to outliers. Standard errors are calculated using the jackknife method in MacKinnon and White (1985).⁴

Results are reported in Table 3. Our results are strongly significant and clearly show that growth rate variance increases with R&D intensity. Estimates of α are in all cases lower in the case of employment growth, suggesting that R&D investment has less of an impact on the variance of employment growth than for sales growth. Our results also offer little support to the hypothesis that R&D has become ‘riskier’ in recent years, because α shows no clear tendency to increase across our four subperiods.

The bottom panel of Table 3 corresponds to four two-digit industries that are known for their relatively high R&D expenditure levels.⁵ By focusing on these R&D-intensive sectors we hope to obtain the best possible quantitative indicators of R&D investment. Our results are similar to those obtained previously, however.

4 Discussion

We investigate the relationship between R&D intensity and the variance of firm growth rates, where growth is measured in terms of sales or employment. The data we analyze comes from US manufacturing firms over the period 1973-2004. Investment in R&D is positively associated with the variance of sales growth and, to a lesser extent, employment growth. We also investigate the magnitude of this effect over several subperiods but fail to find any systematic change in this magnitude over time.

The results presented in this research note raise a number of questions, two of which are mentioned here. First, we saw that firms that have higher R&D levels experience higher

⁴Our estimates of Equation (1) made use of the gbutils 5.2 software package developed by Giulio Bottazzi.

⁵The two digit SIC codes that we analyze are classified as ‘complex technology sectors by Cohen et al. (2000), and correspond to SIC 35 (industrial and commercial machinery and computer equipment), SIC 36 (electronic and other electrical equipment and components, except computer equipment), SIC 37 (transportation equipment) and SIC 38 (measuring, analyzing and controlling instruments; photographic, medical and optical goods; watches and clocks).

variance in the growth rates of both sales and employment growth, although the magnitude of the effect is much larger for sales growth than for employment growth. How can this finding be explained? We offer the following speculation as a possible explanation. Among R&D-intensive firms, sales growth could be more volatile than employment growth if firms smooth their employment levels in the face of labour market rigidities (such as hiring and firing costs), or also if firms persist in long-term strategies and commit to maintaining their current levels of resources and capabilities (embodied in the workforce) even in the face of temporary shocks in demand.

Second, while we observe a positive relationship between R&D and growth rate variance, we cannot be sure of the direction of causality. One might expect that R&D causes increases in growth rate variance, since R&D investment is uncertain and the distribution of returns from R&D is highly skewed. However, causality may run in the opposite direction, if firms that operate in turbulent submarkets self-select into R&D-intensive strategic trajectories. While the results presented in this research note are not able to answer these questions, further work along these lines would be welcome.

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