

THE APPLICATION OF COINTEGRATION TO R&D AND FIRM PERFORMANCE

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ABSTRACT

This paper employs the cointegration methodology to investigate the long-run relationship between research & development (R&D) expenditures and firm performance across four industry groups - chemical and allied products, industrial machinery and computer equipment, electronic equipment, and measuring instruments and photography goods. Using one of the more robust tests of cointegration with annual data collected from COMPUSTAT for the 20-year period 1983-2002, most firms in each of these industry groups showed cointegration between R&D and firm performance measured in terms of net sales.

INTRODUCTION

During the past few decades the empirical literature on the relationship between Research and Development expenditures (R&D) and the current and expected performance of firms has focused on three broad issues: One, the effect of R&D intensity (i.e., the ratio of R&D to sales) on the operating performance (sales; sales growth; profitability) of firms; two, the effect of R&D expenditures on the market value of firms; and three, the feedback effects between R&D expenditures and various measures of firm performance.

The empirical evidence on these issues is mixed, with considerable variability in findings about the effects of R&D intensity on firm performance across studies [Chan, *et al.*, 2001; Connolly and Hirschey, 1994; Doukas and Switzer, 1992; Zantout and Tsetsekos, 1994]. In addition, there are conflicting results on the direction of causation between R&D

expenditures and firm performance measures

such as sales or profitability [Brenner and Rushton, 1989; Hall and Mairesse, 1995]. Yet, recognition of the potential for R&D investments to facilitate innovation as well as firm survival ensures that this aspect of resource allocation within firms will continue to receive considerable scrutiny by researchers and practitioners.

The aim of this paper is to explore the relationship between R&D spending and a measure of firm performance using the cointegration methodology. The appeal of this approach to the study of R&D spending and indicators of firm performance is that it allows for the analysis of short-run dynamics and a long-run relationship between these variables within the same framework. Thus, despite evidence of a volatile R&D coefficient in relation to measures of performance (Hall, 1993) such as a firm's expected economic results (e.g. market value of the firm), this paper seeks to determine whether on average, a stable relationship exists between R&D spending and measures of firm performance such as sales.

Using one of the more robust tests of cointegration with annual data collected from COMPUSTAT for the period 1983-2002, we report a number of findings: first, there are evident differences among firms within industries and across industries with regard to the stability of the relationship between R&D behavior and sales. Second, within the manufacturing sector, the Electronic Equipment industry (SIC 36) had a higher proportion of firms exhibiting a long-run relationship between R&D intensity and sales,

compared to the Chemical and Allied Products industry (SIC 28), the Industrial Machinery and Computer Equipment industry (SIC 35), and the Measuring Instrument and Photography Goods industry (SIC 38). Finally, the results of causality tests show that R&D intensity lead to sales for more firms than vice versa and their bi-directional causality between R&D intensity and sales are rare.

The rest of the paper proceeds as follows. Section II explores the concept of cointegration and its usefulness in studying the relationship between R&D intensity and sales. Section III discusses the data used in the paper while section IV presents the empirical results based on the Johansen test for cointegration. Finally section V provides some concluding remarks.

COINTEGRATION AND THE R&D-SALES RELATIONSHIP

Cointegration is a statistical property possessed by some time series data that is defined by the concepts of stationarity and the order of integration of the series. A stationary series is one with a mean value which will not vary with the sampling period. For instance, the mean of a subset of a series does not differ significantly from the mean of any other subset of the same series. Further, the series will constantly return to its mean value as fluctuations occur. In contrast, a non-stationary series will exhibit a time varying mean. The order of integration of a series is given by the number of times the series must be differenced in order to produce a stationary series. A series generated by the first difference is integrated of order 1 denoted as $I(1)$. Thus, if a time series, is $I(0)$, it is stationary, if it is $I(1)$ then its change is stationary and its level is non-stationary.

Cointegration is said to exist between two or more non-stationary time series if they possess the same order of integration and a linear

combination (weighted average) of these series is stationary. Thus, if x_t and y_t are non-stationary and are of the same order, there may exist a number b such that, the residual series, g_t ($= y_t - bx_t$) is stationary. In this case x_t and y_t are said to be cointegrated with a cointegrating factor of b .

The significance of cointegration analysis is its intuitive appeal for dealing with difficulties that arise when using non-stationary series, particularly those that are assumed to have a long-run equilibrium relationship. For instance, when non-stationary series are used in regression analysis, one as a dependent variable and the other as an independent variable, statistical inference becomes problematic [Granger and Newbold, 1974]. Cointegration analysis has also become important for the estimation of error correction models (ECM). The concept of error correction refers to the adjustment process between short-run disequilibrium and a desired long run position. As Engle and Granger (1987) have shown, if two variables are cointegrated, then there exists an error correction data generating mechanism, and vice versa. Since, two variables that are cointegrated, would on average, not drift apart over time, this concept provides insight into the long-run relationship between the two variables and testing for the cointegration between two variables such as R&D expenditures and sales would also be a test of the validity of an error correction specification involving these variables. With regard to testing procedures for the error correction model, once cointegration is ascertained, then the residuals from the cointegrating test, lagged one period, are used in a vector autoregression involving the appropriate differencing of the series (to ensure stationarity) forming the hypothesized relationship.

The following steps will be followed in the application of cointegration. First, the order of integration of R&D and sales data are tested. Next, if these series are integrated of the same order, then a cointegrating regression is estimated and the null hypothesis that the residuals of that regression are non-stationary is tested. Only if non-cointegration is rejected would the

estimation of an ECM be attempted.

DATA SOURCES AND SAMPLE DESIGN

Cross sectional and time series data of R&D expenditure and sales revenue are collected from the COMPUSTAT annual file for the period 1983-2002.¹ The database includes over 9,500 active firms as of January 2004. In selecting the sample firms, the following criteria were used:

(a) Obtaining the longest possible common sample period for both R&D expenditure and firm performance data, which resulted in data series with 20 annual observations.²

(b) The fiscal year had to coincide with the calendar year for each firm selected over the 1983-2002 period. This criterion is needed to ensure consistency in the time frame over which R&D decisions are made. In addition, approximately two thirds of the firms in COMPUSTAT have fiscal years that end on December 31.

(c) The sample firm was required to have an R&D/sales ratio (i.e., R&D intensity) that is greater than or equal to one percent.

The two-digit SIC code is applied to classify a firm's industry because the application of more detailed four-digit SIC code resulted in a small number of firms in each industry class. Forty three two-digit industry classes are identified with a low one firm in SIC code 31 (Footwear) to a high 40 firms in SIC code 28

(Chemicals and Allied Products). This study selects the following four manufacturing industries: Chemicals and Allied Products (SIC code 2800-2899), Industrial Machinery and Computer Equipment (SIC code 3500-3599), Electronic Equipment (SIC code 3600-3699), and Measuring Instruments and Photography Goods (SIC code 3800-3899), which are subsequently referred to as SIC 28, SIC 35, SIC 36, and SIC 38, respectively. These manufacturing industries were selected because of the number of firms covered in the sample and likely differences in the R&D-performance relationship given the nature of the product groups.

The final sample is made up of 110 firms for 2,200 firm-year observations in the four industry categories. Chemicals and Allied Products, Industrial Machinery and Computer Equipment, Electronic Equipment, and Measuring Instruments and Photography Goods are represented by 40, 27, 23, and 20 firms, respectively. Time series data of average annual R&D expenditures and sales are computed for each industry to conduct the cointegration test of a long-run relationship between R&D intensity and firm performance. The description of our sample is summarized in table 1.

EMPIRICAL RESULTS

As noted earlier, a necessary condition for two series to be cointegrated is that they are integrated of the same order. R&D expenditures is denoted as RD_t and sales as S_t . The order of integration for RD_t and S_t are examined with the Augmented Dickey-Fuller (ADF) test³ presented in Table 2. Based on the ADF test with one lagged difference, the null hypothesis of a non-stationary series cannot be rejected for RD_t , and S_t in the 98 firms of 110 total sample firms. These results suggest that the R&D intensity and

¹ COMPUSTAT is a proprietary database of Standard and Poor's Compustat Services, Inc. Its annual file contains various accounting and financial information for more than 14,000 active and inactive firms for the most recent 20 years.

² Although this criterion may introduce a selection bias toward mature firms, it was dictated by the fact that cointegration analysis becomes more robust with longer time series. We initially collected annual data from 1983-2003. Annual data for the most recent year (2003) are deleted because many variables have missing values.

³ See Engle and Granger (1991) for a discussion of the basis and the nature of the Dickey-Fuller and Augmented Dickey-Fuller tests for unit roots.

sales series are integrated of order 1. Because the data appear to be stationary in first differences for 89.1% of the 110 sample firms and because our data series are short with 20 annual observations, no further tests were conducted⁴.

Given that the two series are I(1) processes for a number of firms in the three industry groups, the next step involved the application of a cointegration test. Among the available tests, the Johansen method was used and the results are shown in table 3⁵. Table 3 indicates the results of testing the null hypotheses of no cointegrating relationship and at most one cointegrating equation. Table 4 reports the results of Granger causality tests. Overall, the direction of causation runs from R&D intensity to sales for 32 companies compared to causation from sales to R&D intensity for 8 firms. Only 2 firms exhibited bi-directional causation. However, no causality between R&D intensity and sales could be detected for 57 percent of the firms in the sample of 98 firms.

The findings in this paper support the notion that cointegration can allow for more in depth examination of feedback effects while avoiding the problems of dealing with non-stationary data. In particular, for four industry groups the evidence on feedback effects implies that an efficient analysis of the R&D intensity-sales relationship would need to treat these variables in a multivariate framework.

SUMMARY AND CONCLUSIONS

Although the importance of R&D in a firm's budget varies across product groups and firms, there has been an ongoing search for a general rule or empirical regularity in the sales-R&D

⁴ Further confirmation was obtained from an inspection of the time plots of the differenced series as well as their autocorrelation functions.

⁵ See Dickey, et al., (1991) for a fairly non-technical discussion of alternative cointegration tests including the Johansen approach.

relationship. This paper addresses the issue of a long-run relationship using annual data from 1983 to 2002 for four industry groups from the COMPUSTAT PC database. The findings indicate that for each of the four industry groups considered, a number of firms pass the cointegration test between R&D intensity and sales growth. Further, 43 percent of the sample firms exhibited uni- or bi-directional causality between R&D intensity and sales.

These findings underscore the need to check the nature of common trends which often appear to be the case upon casual inspection of sales and R&D data. Based on the results it is also important to ascertain the validity of the assumed relationship between sales and R&D that underlies much of the empirical work on this topic. Of course, the results of this paper must also be viewed with some caution because of the length of the sample period. In this sense it is only with subsequent work along these lines involving more observations for different firms and industries that the merits of cointegration analysis would be adequately assessed.

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Table 1. Descriptive Statistics of Total Sample and Four 2-digit SIC Subsamples

Variable	Total (110 firms)		SIC 28 (40 firms)		SIC 35 (27 firms)		SIC 36 (23 firms)		SIC 38 (20 firms)	
	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev
R&D Intensity (%)	6.96	13.83	7.84	19.32	4.06	2.89	6.59	6.10	9.48	15.26
Sales (in million \$)	4320.32	8093.01	5581.29	8124.28	3636.90	5498.40	5296.71	11917.77	1598.14	3495.44
Total Assets (in million \$)	4965.54	10680.23	6189.92	9936.28	4461.13	8783.91	6139.30	16016.58	1847.93	4114.69
Operating Profit Margin (%)	8.87	21.73	11.32	23.31	8.12	6.42	8.76	8.76	5.09	36.66
Net Profit Margin (%)	3.91	22.58	5.38	23.34	3.81	6.29	4.71	9.70	0.15	39.23
Return on Total Assets (%)	5.22	12.69	7.21	9.62	4.51	7.52	5.12	8.40	2.32	22.97
Return on Equity (%)	3.05	395.48	14.85	96.7	-24.51	789.92	9.71	27.11	8.94	27.09
Growth in Sales (%)	9.18	17.18	7.62	12.53	7.52	14.30	9.10	14.37	14.62	27.57
Growth in Operating Profit per Share (%)	12.79	65.39	8.35	28.12	16.77	117.18	16.39	49.87	13.32	38.39
R&D per Employee (in thousand \$)	11.00	13.36	13.94	15.51	6.21	5.91	11.04	15.16	11.49	11.91
Sales per Employee (in thousand \$)	180.18	115.50	234.38	126.06	149.51	70.64	161.21	139.22	134.19	55.53

Notes: These descriptive statistics are based on 2,200 firm-year observations from 1983-2002 period for our total sample. Some variables have less than 2200 observations due to missing values.

Table 2
Number of Firms Passed
Augmented Dickey-Fuller Test for Non-Stationary Series: 1983 - 200

	SIC 25	SIC 35	SIC 36	SIC 38	Total
Number of Firms	40	27	23	20	110
Non-Stationarity	36	26	21	15	98

Notes: The data used are 20-year annual data on R&D expenditures and net sales.

Table 3
Results of Johansen Cointegration Test between R&D Intensity and Sales

Industries	Hypothesized No. of Cointegrating Equation(s)	No. of Firms Passed ADF Test with Cointegration	No. of Firms Passed ADF Test with Cointegration
SIC 28	One	36	31 (86.1%)
SIC 35	One	26	22 (84.6%)
SIC 36	One	21	19 (90.4%)
SIC 38	One	15	11 (73.3%)
Total		98	83 (84.7%)

Notes: The number of firms with cointegration indicates that the null hypothesis of cointegration between R&D intensity and sales cannot be rejected at the 5 % significance level, i.e. 1 cointegrating equation at 5 % significance level.

Table 4
Causality Between R&D Intensity and Sales for SIC
28, 35, 36, and 38

Industry	RD causes S Bi-directions	S causes RD No Causality		
SIC 28	10	4	1	21
SIC 35	10	1	0	15
SIC 36	5	2	1	13
SIC 38	7	1	0	7
Total	32	8	2	56