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Research and Development Activity and Expected Returns in the United Kingdom

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Abstract. Fama and French (1992) show that size and book-to-price dominate CAPM beta and other variables such as the price-earnings ratio and dividend yield in explaining the cross-section of US stock returns. Comparable evidence for the UK points to a book-to-price effect, but not a size effect (Chan and Chui, 1996; Strong and Xu, 1997). In this paper, our first contribution is to show that a measure of research and development (RD) helps explain cross-sectional variation in UK stock returns. Our cross-sectional results on the association between stock returns and RD are consistent with recent US evidence reported by Lev and Sougiannis (1996, 1999) and Chan, Lakonishok and Sougiannis (2001). Fama and French (1993, 1995, 1996) also show that a three-factor model captures a high proportion of the time series variation in portfolio returns, again for the US. Our second contribution is to show, for the UK, that a modification to the three-factor model to take account of RD activity can significantly enhance the explanatory power of the three-factor model. We show that, as a practical matter, estimated risk premia based on the modified three-factor model can differ considerably from risk premia estimated using the CAPM or the three-factor model. In particular, risk premia for industries in which few firms undertake RD activities tend to be over-estimated.

1. Introduction

In this paper we build on recent US-based evidence suggesting that the relation between stock returns and the book-to-market ratio (BM) is associated with off-balance sheet research and development (RD) capital (Lev and Sougiannis, 1996, 1999; Chan, Lakonishok and Sougiannis, 2001). Consistent with prior research, our first contribution is to show that RD activity is informative in explaining the unconditional and conditional cross-section of returns for a large sample of UK stocks over a ten-year period. Indeed, RD dominates BM as an explanatory factor for returns. The cross-sectional analysis also shows that both BM and firm size, defined as the market value of equity (ME), are associated with RD activity.

Fama and French (1993, 1996) show that risk factors constructed on the basis of BM and ME are incrementally important beyond a market factor in explaining the time series of US portfolio returns. The cross-sectional association between RD

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and returns suggests the possibility that RD activity interacts with the Fama and French risk factors in explaining time series variation in returns. The second contribution of the present paper is to investigate this possibility. We document evidence that a modification of the Fama and French three-factor model, designed to capture RD activity, can considerably improve the performance of the three-factor model. The practical implications of this result are demonstrated with reference to industry-level risk premia estimated from single factor, three-factor and modified three-factor models.

The remainder of the paper is organized as follows. In Section 2 we review the relevant literature relating RD activity to expected returns and provide the motivation for the empirical analysis. In Section 3 we present the research design. In Section 4 we describe the sample and present the empirical results. Finally, Section 5 concludes.

2. Motivation

Previous research has identified two main reasons why research and development activity might be related to expected returns. First, a direct association between research and development activity and returns is predicted if the risk characteristics of RD investments are different from investments in physical assets. For example, RD benefits are often far from assured and are likely to materialize much later than benefits from investments in physical assets (Chan, Lakonishok and Sougiannis, 2001, p. 2432). If RD investments have different risk characteristics, we expect that the inclusion of information on RD activity will improve the performance of models of expected returns.

A second potential link between expected returns and RD arises as a result of the accounting treatment of research and development expenditures (Chan, Lakonishok and Sougiannis, 2001, p. 2431).[1] The conservatism principle underpinning financial reporting in both the UK and the US requires that most, if not all, RD spending be expensed. Empirical evidence for both the UK and the US supports the view that RD expenditure creates intangible assets (see, for example, Hirschey, 1982; Hirschey and Weygandt, 1985; Hall, 1993; Sougiannis, 1994; Lev and Sougiannis, 1996; Green, Stark and Thomas, 1996). If the market recognizes the value of such intangible assets then *ceteris paribus* BM will be inversely related to the level of RD assets. This predicted association between BM and RD suggests that if expected returns are related to BM, this could, at least partially, be attributable to RD-related effects.

[1] Theoretical models predicting an association between BM and expected returns also exist. For example, Berk, Green and Naik (1998) provide a model in which systematic risk dynamically evolves and variables such as BM and ME capture aspects of this dynamic process. BM captures the systematic risk of the firm's assets in place and ME captures the balance between assets in place and growth options. These effects are demonstrated via analytical methods and simulations.

Lev and Sougiannis (1996, 1999) examine this issue empirically for the US in a cross-sectional framework. They show that the role of BM in explaining the cross-section of returns is reduced by the inclusion of estimated RD capital (expressed as a fraction of ME) as an additional explanatory variable in cross-sectional regressions similar to Fama and French (1992). The relationship between RD capital and returns is positive and is particularly pronounced for firms with high levels of RD capital, where the BM effect becomes statistically insignificant.

Chan, Lakonishok and Sougiannis (2001) confirm the positive relation between RD and returns for US firms. They find that returns increase with the ratio of research and development expenditure scaled by ME (RD/ME) for each of the three years subsequent to portfolio formation. This finding continues to hold after controlling for potential risk differences related to BE and ME, market risk and levels of short-term and medium-term performance in the period prior to portfolio formation.

There is no systematic published research relating RD activity to UK stock returns. Prior research on the cross-sectional determinants of UK stock returns shows that BM is the dominant variable explaining cross-sectional variation in UK stock returns (Chan and Chui, 1996; Strong and Xu, 1997). ME is, at best, weakly associated with returns, after controlling for BM.[2]

Estimated CAPM beta does not appear to have explanatory power for the cross-section of UK stock returns. While the UK results relating to BM and beta are consistent with results for the US reported by Fama and French (1992), the absence of a consistently significant size effect in the UK is inconsistent with the US results.

Given that UK and US evidence on the determinants of expected stock returns is inconsistent, our first contribution is to use UK data to investigate the robustness of the relation between stock returns and RD found in the US. Theoretical reasoning documented above leads us to speculate that RD activity interacts with other factors in explaining time series variation in stock returns. Our second and main contribution is to investigate whether a RD-related modification of the Fama and French three-factor model supports this speculation.

3. Research Design

The empirical analysis proceeds as follows. First, we examine the cross-section of expected returns conditional on the level of RD activity. We employ RD/ME as our proxy for research and development. One alternative considered is to estimate the stock of RD capital, based on RD expenditures in prior periods. Lev and Sougiannis (1996, 1999) estimate RD amortization rates based on the relation between earnings and lagged RD expenditure. RD capital is the unamortized balance of prior period RD expenditures. Chan, Lakonishok and Sougiannis (2001) approximate RD amortization using straight-line depreciation over five years. We

[2] Fama and French (1998) provide evidence, for a small subset of UK companies, of a BM effect in an international context when looking at value versus growth portfolio investment strategies.

use RD/ME as the proxy for RD activity for several reasons. First, estimation of RD capital imposes survivorship requirements on the data, resulting in a reduction of sample size. In this context we should also note that systematic disclosures of RD expenditure are only available for UK firms from 1990 onwards. As a consequence, reliable estimates of UK RD amortization rates and RD capital would be impossible to obtain for the full ten-year sample period. Second, Hall (1993) shows that for US firms using current RD expenditure as a proxy for research and development capital is superior to explicitly estimating research and development capital. Third, estimates of RD capital are highly correlated with RD expenditure for our sample. Using the estimation method in Chan, Lakonishok and Sougiannis (2001), we derived estimates of RD capital for the 1995–1999 period using RD expenditure data for 1990 onwards. For firms with RD data, we find that the Pearson and Spearman correlation coefficients between RD expenditure and estimated RD capital, both deflated by market value, exceed 0.95 in every year except one, when the Pearson correlation is 0.73. This suggests that the use of RD expenditures as a proxy for RD capital is reasonable in the UK context. Another possibility for the measurement of RD activity is to use the ratio of RD to sales. Here we note that Chan, Lakonishok and Sougiannis (2001) find that the relation between RD and subsequent returns is strongest when portfolios are formed based on RD/ME, rather than the ratio of RD to sales, again supporting RD/ME as a relevant measure of RD activity.

Similar to Chan, Lakonishok and Sougiannis (2001), we examine monthly returns for equal-weighted portfolios based on RD/ME, where portfolios are formed annually.[3] All firms without reported research and development expenditures in any given year are combined to form one equal-weighted portfolio. We allocate all remaining firms to one of five equal-weighted portfolios based on the value of RD/ME. Portfolio assignments are based on RD expenditure data disclosed in the most recent financial statements available at the end of year t. We examine stock returns on RD portfolios formed in year t for the twelve months beginning in July of calendar year $t + 1$. Thus, for example, RD data for a firm with a financial year ending on 31 March 1990 is matched with returns realized over the period July 1991 to June 1992.[4]

Additionally, we estimate 240 monthly cross-sectional regression models based on the following equation:

$$R = \alpha_0 + \alpha_1 \text{ Beta} + \alpha_2 \ln(\text{ME}) + \alpha_3 \ln(\text{BM}) + \alpha_4 \text{ RD/ME} + \epsilon, \qquad (1)$$

where R is the stock return in the relevant month in the interval July in year $t + 1$ to June in year $t + 2$; Beta is the stock's CAPM beta for firm-year t, estimated using returns for a minimum period of twenty-four months and a maximum period of sixty months ending in June of year $t + 1$, using the Dimson (1979) thin trading adjustment; ME is the market value of equity at the end of the June in calendar year

[3] Portfolio returns are realizable from a trading strategy involving monthly portfolio re-balancing.

[4] This procedure follows Fama and French (1992).

$t + 1$; BM is the ratio of the year end book value of common equity and reserves for the financial year ending in calendar year t to the market value of equity at the end of December in calendar year t; and RD/ME is the ratio of research and development expenditure reported for the financial year ending in calendar year t to the equity market value at the end of December in calendar year t.

The second stage of the analysis involves a simple modification of the Fama and French (1993) three-factor asset-pricing model to accommodate potential RD-related effects. We estimate risk models for various portfolios described below, based on times series of 240 monthly observations. The three-factor mimicking portfolios identified by Fama and French (1993) include the excess return on the market portfolio ($R_m - R_f$) and the returns on factor-mimicking portfolios for size (SMB) and book-to-market (HML). We define these portfolios as follows. ($R_m - R_f$) is the difference between the return on the market and the risk-free interest rate, where the market return is defined as the value-weighted return on all the sample stocks. SMB and HML are defined as in Fama and French (1993). Initially, six portfolios are formed according to size and then BM. Specifically, each year stocks are sorted into two size groups and three BM groups. Big stocks (B) are above the median market value of equity and small stocks (S) are below the median market value of equity. Stocks in the lowest thirty percent of firms ranked by BM are designated low BM (L), medium BM stocks (M) are in the middle forty percent and high BM stocks (H) are in the top thirty percent. Six portfolios are defined based on the intersections of the size and BM groups. These are S/L (small size/low BM), S/M (small size/medium BM), S/H (small size/high BM), B/L (big size/low BM), B/M (big size/medium BM), and B/H (big size/high BM). SMB then is the difference between the average of the returns on small firm portfolios, (S/L+S/M+S/H)/3 and the average of the returns on big firm portfolios, (B/L+B/M+B/H)/3. HML is the difference between the average of the returns on the high BM portfolios, (S/H + B/H)/2, and the average of the returns on the two low BM portfolios, (S/L + B/L)/2.

Our extension to the three-factor model introduces an additional instrument (RDMNRD) that captures within-BM group differences in the returns generating process between firms with RD activity and firms without RD activity. We partition each BM group (L, M and H) into two sub-groups comprising, respectively, firms with reported RD activity and firms without reported RD activity in the relevant year. The L, M and H sub-groups with RD expenditures are referred to as LRD, MRD and HRD respectively. Similarly, the L, M and H sub-groups with no reported RD activity in the relevant year are referred to as LNRD, MNRD and HNRD respectively. The RDMNRD instrument is defined as the difference between the average of the value-weighted with-RD portfolio returns, (LRD + MRD + HRD)/3, and the average of the value-weighted returns on the without-RD portfolios, (LNRD+MNRD+HNRD)/3.

We compare alternative factor models based on time series regressions of portfolio returns on factors as follows:

$$(R_p - R_f) = a + b(R_m - R_f) + sSMB + hHML + rRDMNRD + e, \qquad (2)$$

where $R_p - R_f$ is the excess return on portfolio p relative to the risk-free interest rate. The single-factor CAPM assumes s = h = r = 0. The Fama and French (1993) three-factor model assumes r = 0. The RD-modified three-factor model imposes no restrictions on equation (2). If RD activity is associated with risk differences, or if RD activity is associated with the ability of SMB and HML to explain portfolio returns, then we expect RDMNRD to add to the explanatory power of the three-factor model.

Similar to Lev and Sougiannis (1999) and Chan, Lakonishok and Sougiannis (2001), we use versions of model (2) to examine the time series association between the four factors and returns on portfolios sorted by RD/ME, including one portfolio comprising all firms where RD is zero. Further, we examine portfolios formed on the basis of a two-way sequential sort: first by BM and then by RD, including one zero-RD group. Subsequently, we examine a number of industry portfolios and use the approach recommended by Fama and French (1997) to estimate the risk premia for these portfolios using the three models.

4. Empirical Results

4.1. DATA

All data used in this study are collected from *Datastream*. The sample comprises all UK-listed non-financial firms in the *Datastream* active and research files with relevant data for any of the financial years ending 1990 to 1999. The beginning of the sample period is governed by the introduction of mandated RD disclosures in the UK in 1990.[5] Firms are included in the sample for year t if data are available on ME, the book value of equity and RD for the financial year ending in calendar year t, and if stock returns data are available for at least the twenty-four months prior to July of calendar year $t + 1$ and for some or all of the twelve months commencing in July of year $t + 1$.

Table I describes characteristics of the sample. The distribution of the sample of 10,874 observations over the ten-year period 1990–1999 is reported in Panel A and the industry composition is presented in Panel B. Sample firms are drawn from a wide variety of industries and most industries contain both firms that report RD activity and firms that do not. Although RD activity is more prevalent in some industries (e.g., electronic and electrical equipment), on the basis of panel B there appears to be no reason for believing that RD activity serves merely as a proxy for industry membership in the UK.

Table II reports descriptive statistics of the monthly returns for sample firms. The average of the reported means indicates that monthly returns averaged 1.18%

[5] The accounting treatments of RD in the UK and the US have many similarities. Notable differences include the possibility that development expenditures can be capitalized in the UK, but not in the US. In practice, very few companies take advantage of this possibility. Additionally, in the UK smaller enterprises are exempted from disclosing RD information. In general the exemption is not expected to apply to many firms listed on the London Stock Exchange.

Table I. Sample characteristics.

Panel A: Number of Observations by Year

Year	Number of observations
90	1,029
91	1,018
92	1,033
93	1,054
94	1,086
95	1,122
96	1,153
97	1,186
98	1,160
99	1,033
Total	10,874

Panel B: Industry sector distribution and frequency of firms with RD

Industry	With RD	Without RD	Total	% With RD
Aerospace & Defence	113	40	153	73.8
Automobiles	65	70	135	48.1
Beverages	23	95	118	19.5
Chemicals	189	102	291	64.9
Construction & Building Materials	191	949	1140	16.8
Distributors	67	601	668	10.0
Diversified Industrials	37	49	86	43.0
Electricity	50	31	81	61.7
Electronic & Electrical Equipment	403	187	590	68.3
Engineering & Machinery	487	511	998	48.8
Food & Drug Retailers	12	154	166	7.2
Food Producers & Processors	117	268	385	30.4
Forestry & Paper	28	6	34	82.4
Gas Distribution	1	3	4	25.0
Health	119	153	272	43.8
Household Goods & Textiles	180	666	846	21.3
Information Technology Hardware	99	8	107	92.5
Leisure, Entertainment & Hotels	39	459	498	7.8
Media & Photography	84	697	781	10.8
Mining	20	52	72	27.8
Oil & Gas	34	170	204	16.7
Other Business	0	3	3	0.0
Packaging	51	131	182	28.0

Table 1. Continued.

Panel B: Industry sector distribution and frequency of firms with RD				
Industry	With RD	Without RD	Total	% With RD
Personal Care & Household Products	48	36	84	57.1
Pharmaceuticals	141	29	170	82.9
Restaurants, Pubs, Breweries	24	255	279	8.6
Retailers, General	29	620	649	4.4
Software & Computer Services	289	214	503	57.4
Steel & Other Metals	41	59	100	41.0
Support Services	91	612	703	12.9
Telecom Services	18	47	65	27.7
Tobacco	9	5	14	64.3
Transport	26	311	337	7.7
Water	94	62	156	60.3
Total	3,219	7,655	10,874	29.6

Note: Panel A contains the distribution of firm-year observations over time. In Panel B, column 2 (column 3) reports the number of firm-years in the respective industry with (without) reported RD, column 4 contains the total number of firm-year observations and column 5 reports the percentage of firm-years for which RD is reported. Industry classifications are based on *Datastream* Level 4 definitions.

Table II. Descriptive statistics: UK monthly returns 1991–2001

	Mean	Std	Min	Max	Q1	Q3
July 91–June 92	1.17	13.89	−88.89	284.00	−4.56	5.88
July 92–June 93	2.15	15.32	−75.00	339.39	−4.69	7.45
July 93–June 94	1.73	11.81	−83.74	150.15	−4.11	6.07
July 94–June 95	0.32	9.53	−81.79	146.15	−3.77	4.11
July 95–June 96	1.97	10.64	−80.00	224.07	−2.97	5.81
July 96–June 97	0.28	11.34	−66.67	216.21	−4.75	4.46
July 97–June 98	1.51	13.61	−69.01	500.00	−4.63	6.72
July 98–June 99	0.50	17.89	−95.83	775.00	−7.89	6.63
July 99–June 00	2.49	21.59	−100.00	457.14	−7.08	7.59
July 00–June 01	−0.33	14.75	−82.35	227.27	−7.06	6.24

Note: Return is the monthly return (%).

Table III. Mean characteristic values for RD portfolios

Portfolio	Return (%)	Beta	ln(ME)	BM	RD/ME	RD/S	# Firms
0	1.23	0.97	3.67	1.00	0.0000	0.0000	765
1	0.89	0.95	6.11	0.53	0.0026	0.0681	65
2	0.68	1.09	5.34	0.51	0.0083	0.0390	65
3	1.09	1.01	4.99	0.60	0.0170	1.3772	65
4	1.52	0.98	4.51	0.74	0.0340	1.0633	65
5	2.47	0.99	3.59	1.23	0.1142	0.7853	65

Note: Return is monthly return (%). Beta is the CAPM beta computed using the Dimson (1979) methodology. BM is the ratio of book equity to market equity, RD/ME is the ratio of research and development expenditure to market equity and RD/S is the ratio of research and development expenditure to sales. All ratios are computed as at the end of year t. Portfolios are formed annually based on RD/ME. Portfolio 0 comprises all firms reporting zero RD for year t. Portfolio 1 (portfolio 5) comprises the lowest (highest) quintile of firms based on RD/ME.

over the sample period, equivalent to an annualized return of approximately 15%. Interest rates over the period from July 1991 to June 2001 averaged approximately 6.5% per annum. The realized market risk premium of approximately 8.5% per annum suggests that the sample period is not unusual.

4.2. THE CROSS-SECTION OF EXPECTED RETURNS

Panel A in Table III reports the mean values of monthly returns and other characteristics of six portfolios sorted by RD/ME – CAPM beta, ln(ME), BM, RD/ME and, to facilitate comparison with Chan, Lakonishok and Sougiannis (2001), RD/Sales (RD/S). The table shows preliminary evidence of significant variation in expected returns conditional on RD/ME. When RD/ME is relatively high (portfolio 5), mean monthly returns are more than twice as high as for firms with a relatively low level of RD/ME (portfolio 1). Similar to the results reported in Chan, Lakonishok and Sougiannis (2001), firms with no RD activity (portfolio 0) have higher returns than the three lowest RD/ME portfolios.

Panel A of Table III also indicates that differences in CAPM beta cannot explain differences in expected returns across RD portfolios. However, it also shows that other potential determinants of expected returns do vary systematically across RD portfolios. Specifically, RD/ME is negatively associated with ME and positively associated with BM. This suggests that it is necessary to control for variation

Table IV. Monthly cross-sectional regressions of returns on market value of equity, book-to-market equity and research and development-to-market equity (120 monthly regressions)

Model	Intercept	ln(ME)	ln(BM)	RD/ME
1	0.0137	−0.0007		
	(2.86)	(−1.02)		
2	0.0123		0.0026	
	(3.60)		(2.26)	
3	0.0102			0.0735
	(2.83)			(3.49)
4	0.0129	−0.0002	0.0024	
	(2.70)	(−0.18)	(1.61)	
5	0.0119	−0.0001	0.0024	0.066
	(2.58)	(−0.12)	(1.65)	(3.37)

Note: Cross-sectional regressions are estimated month-by-month based on equation (1):

$$R = \alpha_0 + \alpha_1 \ln(ME) + \alpha_2 \ln(BM) + \alpha_3 RD/ME + \epsilon.$$

The dependent variable is monthly return. BM is the ratio of book equity to market equity, and RD/ME is the ratio of research and development expenditure to stock price. All ratios are computed as at the end of year t. The table reports the mean of the estimated coefficient values from 120 monthly regressions. Fama and MacBeth (1973) t-statistics are reported in parentheses.

in ME and BM in attempting to establish whether RD/ME contains independent information relevant for estimating expected returns.[6,7]

For comparison purposes, we also examine the relationship between RD activity and stock returns using the portfolio approach in a number of different ways. First, panel B shows results based on portfolios sorted by RD/S. It reveals similar results to those in panel A, although the difference between returns on the lowest and highest RD portfolios is substantially lower than when portfolio assignments are based on RD/ME.

[6] The results in Table III are qualitatively unchanged if returns are calculated starting six months after the financial year-end for each firm in any given portfolio. However, the returns calculated for portfolios using this method of matching do not necessarily represent the outcomes of an implementable trading strategy.

[7] Further analysis of portfolios formed by sorting two ways, first on BM and then within BM portfolios based on RD/ME, reveals that RD/ME is not simply serving as a proxy for BM. Average returns vary markedly across RD/ME groups within BM portfolios. Nonetheless, average ME decreases across the RD/ME groups within BM portfolios, suggesting that the results could be caused by a size effect. Details are available from the authors on request.

In Table IV we summarize the results of estimating equation (1) as monthly cross-sectional regressions of returns on the logarithm of ME, the logarithm of BM and RD/ME. The reported t-statistics are based on standard errors estimated from the time series of the sets of 120 monthly regression coefficients following Fama and MacBeth (1973).[8] Although the univariate regressions (models 1–3) indicate that returns are not significantly associated with ME over the sample period, there is significant association between returns and BM and RD/ME. When ME and BM are used in combination (model 4), the level of statistical significance of BM falls below the 5% level. Model 5 indicates that RD/ME is incrementally informative in explaining the cross-section of returns beyond ME and BM, at a significance level of better than 1%. The average values and significance of the coefficients on ME and BM in model 5 are similar to those in model 4. As a consequence, the only instrument to have clearly significant explanatory power for the cross-section of returns for the full period studied appears to be RD/ME.

We investigate the robustness of these results to time period and industry effects. First, the Fama and MacBeth methodology automatically controls for time period effects through the constant terms in the monthly regressions. When industry dummies are included in these regressions, only the coefficient on the Gas Distribution industry dummy is significantly different from zero. The coefficient on RD/ME remains positive, and significant at the 10% level, and the coefficient on BM is also positive and significant at the 5% level. If industry dummies are replaced by a variable representing the annual proportion of firms reporting RD activity in an industry, the results reported above are not altered in a qualitatively significant way. Second, if the data is pooled and equation (1) is modified to include annual time and industry dummies, all annual time dummies are statistically different from zero, all coefficients on the industry dummies are statistically indistinguishable from zero and both RD/ME and BM have positive and significant coefficients. Again, if industry dummies are replaced by a variable representing the annual proportion of firms reporting RD activity in an industry, the results reported above are not altered in a qualitatively significant way. If industry dummies are replaced in the pooled regression by a variable equal to the year-specific proportion of firms reporting RD activity in the firm's industry, the coefficients on RD/ME and BM are again positive and significant and the coefficient on the industry RD proportion variable is statistically indistinguishable from zero. In summary, the robustness checks suggest that the role of RD/ME in explaining the cross-section of returns is not wholly attributable to time and industry effects.

We also investigate the effect of substituting different measures of RD activity. When RD/S is used in place of RD/ME in the Fama–MacBeth (1973) regressions, it is not significant on a univariate basis, but it is significant when included with ln(ME) and ln(BM). Its degree of significance in the latter case is lower than for RD/ME. Similar results hold on a limited sample if we use the ratio of RD capital

8 Tests similar to this using the ratio of RD capital to ME are reported upon in Lev and Sougiannis (1996).

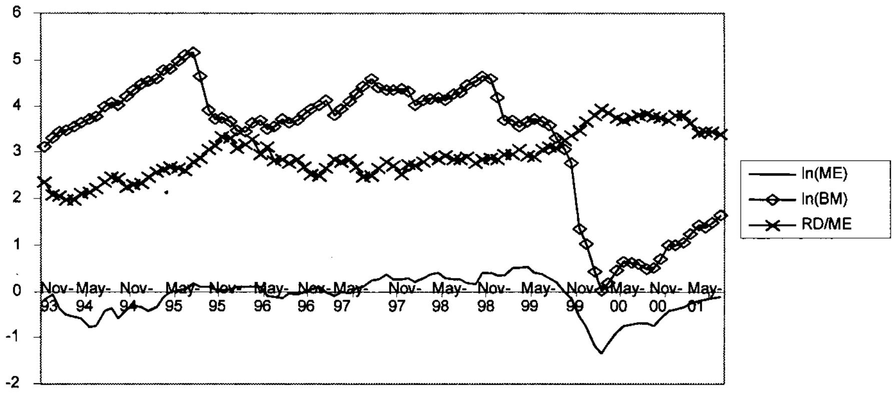

Figure 1. t-statistics from month-by-month cross-sectional multivariate regressions of stock returns on ln(ME), ln(BM) and RD/ME starting from the 29th month of the sample period.

to ME or the ratio of RD capital to sales, based on the method employed by Chan, Lakonishok and Sougiannis (2001) for estimating RD capital. The results for RD capital to sales are slightly stronger than for RD/S because the ratio of RD capital to S is significant on a univariate as well as a multivariate basis. If we use either the change in RD/ME or the change in RD/S, this does not produce significant results on either a univariate or a multivariate basis. If the regressions reported on in Table V are run on RD firms only, results are qualitatively the same. If we use ln(RD/ME) on this sample, again the results are unchanged qualitatively. Further, neither ln(ME) or ln(BM) are significant in explaining the cross-section of returns for zero-RD firms.

However, it would be premature to conclude that size and BM are necessarily unimportant in explaining the cross-section of returns. Further analysis shows that the results summarized in Table IV are sensitive to the time period selected for time-series averaging. We estimate average coefficients and t-statistics for model 5 over successively longer sample periods, starting with the first twenty-nine months of our sample period and adding one month at a time, up to the maximum sample length of 120 months. Figure 1 shows the plot of the t-statistics obtained on this basis.

The figure shows that the coefficient on BM is uniformly positive and significant until late-1999, when a period of strong market decline began. In contrast, the coefficient on ME is always insignificant and often negative, until late-1999. Perhaps most strikingly, Figure 1 highlights the robustness of the significance of RD/ME in explaining returns. Irrespective of the sample period selected, the average coefficient on RD/ME is always positive and statistically significant.[9] In summary, Figure 1 confirms the importance of RD/ME as a determinant of the cross-section of expected returns.

[9] If RD/S is used as the measure of RD activity, RD/S is always significant at the 5% level, although with lower t-statistics than for RD/ME.

Table V. Returns model factor characteristics

Panel A
Distribution of Monthly Returns on $R_m - R_f$*, SMB, HML and RDMNRD*

	Mean	Std	Q1	Med	Q3
$R_m - R_f$	1.12	3.67	−0.86	1.24	3.77
SMB	1.67	5.99	−1.61	0.90	3.59
HML	0.08	4.40	−1.11	0.45	1.62
RDMNRD	0.00	2.66	−1.52	0.07	1.39

Panel B
Pearson correlations between factor returns
(p-values in parentheses)

	$R_m - R_f$	SMB	HML
$R_m - R_f$	1.00		
SMB	−0.02	1.00	
	(0.855)		
HML	−0.12	−0.36	1.00
	(0.180)	(0.000)	
RDMNRD	−0.23	0.49	0.30
	(0.013)	(0.000)	(0.001)

Note: $R_m - R_f$ is the excess return on the market portfolio. SMB (HML) is the return on the factor mimicking portfolio related to size (book-to-market) defined as in Fama and French (1993). RDMNRD is defined as follows. First, we partition each BM group (L, M and H) into two sub-groups comprising, respectively, firms with reported RD activity and firms without reported RD activity in the relevant year. The L, M and H sub-groups with RD expenditures are referred to as LRD, MRD and HRD respectively. Similarly, the L, M and H sub-groups with no reported RD activity in the relevant year are referred to as LNRD, MNRD and HNRD respectively. Second, RDMNRD is then defined as the difference between the average of the value-weighted with-RD portfolio returns, (LRD + MRD + HRD)/3, and the average of the value-weighted returns on the without-RD portfolios, (LNRD + MNRD + HNRD)/3.

4.3. FACTOR MODELS OF RETURNS

Table V summarizes the characteristics of the factors used to explain portfolio returns based on equation (2). Panel A reveals that RDMNRD has a mean return very close to zero. This is consistent with the results reported in Table III above where the average return for the zero-RD portfolio lies between the average returns for the third and fourth RD portfolios. We also note from panel A that the average return on the HML portfolio is close to zero, although there is considerable variation over time. Only $R_m - R_f$ and SML have average returns significantly different from zero. Panel B of Table V reports the correlations between the four factors. Given the association between RD activity and ME and BM documented in Table III, it is not surprising to observe a significant degree of correlation between RDMNRD and SMB and HML. Nonetheless, none of the correlation coefficients are particularly large.

Estimates of equation (2) suggest that adjustment of the Fama and French three-factor model to allow for RD activity can generate significant improvement in the ability of the three-factor model to explain portfolio returns. Table VI provides the results of estimating three- and modified three-factor models for each of the six portfolios formed on the basis of RD (i.e., the portfolio containing firms with no reported RD, and the five sorted RD portfolios based on RD/ME). Panel A of Table VI provides evidence that the Fama and French three-factor model incorporating SMB and HML factors explains between 49% and 89% of the time series variation in the returns on these portfolios. Explanatory power is lowest for portfolios comprising firms with relatively high levels of RD. The results in Panel B of Table VI indicate that the modified three-factor model generally performs better than the Fama and French model in explaining portfolio returns. R^2 statistics increase for all portfolios, and particularly for the zero-RD portfolio where the RD factor loading is negative (as expected) and highly significant.

We interpret the result for the zero-RD portfolio as suggesting that the RD factor "cancels out" RD-related effects embedded in the other three returns factors. Comparison between panels A and B of Table VI shows that adding the RD factor decreases the loading on $R_m - R_f$ and SML, while increasing the loading on HML. We will observe later that this is a consistent pattern for other sub-portfolios containing firms with no RD activity. The results are consistent with there being quite complex interactions between the RD factor and the other three factors, consistent with the correlations reported in Table V.

As noted earlier, conservatism in accounting measurement causes negative correlation between BM and RD/ME. Thus, partitioning on the basis of RD activity also induces differences in BM across RD portfolios, potentially reducing the ability of the Fama and French factor model to explain returns across portfolios. To obtain a clearer understanding of the marginal impact of including the RD factor we examine the comparative performance of the three- and modified three-factor models in explaining the returns of portfolios formed on the basis of BM and then a secondary partitioning based on RD/ME. Thus, we investigate the properties of the excess returns of the six portfolios used in constructing the RD factor.

Table VII presents the results. Consistent with Table VI, the modified three-factor model characterizes returns better than the three-factor model, particularly when BM is high. The adjusted-R^2 statistic increases from 0.62 to 0.79 for portfolio HNRD and from 0.54 to 0.64 for portfolio HRD. The modified three-factor model reveals generally very consistent results. The HML factor is significant for all portfolios. The RD factor is highly significant in all cases. For portfolios comprising firms without RD activity (LNRD, MNRD and HNRD) the loading on RDMNRD

Table VI. Regressions of excess returns for six RD/ME portfolios on $R_m - R_f$, SMB and HML (Panel A) and $R_m - R_f$, SMB, HML and RDMNRD (Panel B)

	a	b	s	h	r	t(a)	t(b)	t(s)	t(h)	t(r)	R^2 (adj)
Panel A: $R_p - R_f = a + b\,(R_m - R_f) + sSMB + hHML + \epsilon$											
RD = 0	−0.0037	1.1158	0.1156	0.0390		−2.53	30.49	4.86	1.20		0.89
LOW	−0.0009	0.9849	−0.1051	0.0698		−0.48	19.83	−3.26	1.58		0.78
2	−0.0012	1.0651	−0.0050	−0.0447		−0.37	13.18	−0.10	−0.62		0.60
3	−0.0007	1.0157	0.0069	0.0445		−0.20	12.00	0.13	0.59		0.54
4	0.0087	0.8641	−0.1918	−0.1236		2.53	9.97	−3.41	−1.60		0.49
High	0.0040	1.0568	0.4119	0.0071		0.91	9.54	5.73	0.07		0.51
Panel B: $R_p - R_f = a + b\,(R_m - R_f) + sSMB + hHML + rRDMNRD + \epsilon$											
RD = 0	−0.0013	1.0410	0.0216	0.0695	−0.4657	−1.27	39.60	1.17	3.05	−11.19	0.95
LOW	−0.0020	1.0173	−0.0644	0.0566	0.2014	−1.00	20.27	−1.82	1.30	2.54	0.79
2	−0.0021	1.0950	0.0326	−0.0569	0.1862	−0.65	13.16	0.56	−0.79	1.41	0.60
3	0.0008	0.9685	−0.0524	0.0637	−0.2937	0.25	11.24	−0.86	0.85	−2.15	0.56
4	0.0070	0.9171	−0.1252	−0.1452	0.3300	2.04	10.44	−2.02	−1.91	2.37	0.51
High	0.0019	1.1243	0.4967	−0.0203	0.4199	0.43	10.00	6.27	−0.21	2.36	0.53

Note: $R_m - R_f$ is the excess return on the market portfolio. SMB (HML) is the return on the factor mimicking portfolio related to size (book-to-market) defined as in Fama and French (1993). RDMNRD is defined as follows. First, we partition each BM group (L, M and H) into two sub-groups comprising, respectively, firms with reported RD activity and firms without reported RD activity in the relevant year. The L, M and H sub-groups with RD expenditures are referred to as LRD, MRD and HRD respectively. Similarly, the L, M and H sub-groups with no reported RD activity in the relevant year are referred to as LNRD, MNRD and HNRD respectively. Second, RDMNRD is then defined as the difference between the average of the value-weighted with-RD portfolio returns, (LRD + MRD + HRD)/3, and the average of the value-weighted returns on the without-RD portfolios, (LNRD + MNRD + HNRD)/3.

Table VII. Regressions of excess returns for six BE/ME-RD/ME portfolios on $R_m - R_f$, SMB and HML (Panel A) and $R_m - R_f$, SMB, HML and RDMNRD (Panel B)

	a	b	s	h	r	t(a)	t(b)	t(s)	t(h)	t(r)	R^2 (adj)
Panel A: $R_p - R_f = a + b\,(R_m - R_f) + sSMB + hHML + \epsilon$											
LNRD	−0.0059	1.1641	0.1344	−0.1349		−2.63	20.53	3.65	−2.67		0.80
LRD	0.0027	0.9078	−0.0991	−0.2474		1.81	23.76	−4.00	−7.27		0.85
MNRD	−0.0018	1.0455	0.0687	0.1818		−0.90	20.53	2.08	4.01		0.78
MRD	0.0014	0.9961	−0.0757	0.3134		0.84	23.56	−2.76	8.32		0.84
HNRD	0.0016	1.1073	0.2310	0.3752		0.47	13.38	4.30	5.09		0.62
HRD	0.0049	0.9310	0.0034	0.5523		1.35	10.21	0.06	6.80		0.54
Panel B: $R_p - R_f = a + b\,(R_m - R_f) + sSMB + hHML + rRDMNRD + \epsilon$											
LNRD	−0.0039	1.1015	0.0557	−0.1094	−0.3898	−1.85	20.31	1.46	−2.33	−4.54	0.83
LRD	0.0020	0.9312	−0.0697	−0.2569	0.1455	1.32	24.04	−2.56	−7.64	2.37	0.86
MNRD	0.0005	0.9710	−0.0248	0.2121	−0.4634	0.30	21.44	−0.78	5.40	−6.47	0.84
MRD	0.0000	1.0390	−0.0218	0.2960	0.2672	0.03	25.35	−0.75	8.32	4.12	0.86
HNRD	0.0065	0.9510	0.0346	0.4388	−0.9729	2.59	14.86	0.77	7.90	−9.61	0.79
HRD	0.0010	1.0533	0.1570	0.5025	0.7611	0.31	12.63	2.67	6.94	5.77	0.64

Note: $R_m - R_f$ is the excess return on the market portfolio. SMB (HML) is the return on the factor mimicking portfolio related to size (book-to-market) defined as in Fama and French (1993). RDMNRD is defined as follows. First, we partition each BM group (L, M and H) into two sub-groups comprising, respectively, firms with reported RD activity and firms without reported RD activity in the relevant year. The L, M and H sub-groups with RD expenditures are referred to as LRD, MRD and HRD respectively. Similarly, the L, M and H sub-groups with no reported RD activity in the relevant year are referred to as LNRD, MNRD and HNRD respectively. Second, RDMNRD is then defined as the difference between the average of the value-weighted with-RD portfolio returns, (LRD + MRD + HRD)/3, and the average of the value-weighted returns on the without-RD portfolios, (LNRD + MNRD + HNRD)/3.

is negative and highly significant, as expected from Table VI. For these portfolios, the impact of modifying the three-factor model to include the RD factor is, as mentioned above, to decrease the loading on $R_m - R_f$ and SML and to increase the loading on HML. In relation to the portfolios of firms with RD activity, the most marked improvement in explanatory power is observed for the HRD portfolio, where the adjusted-R^2 statistic increases from 0.54 to 0.64. The effects of adding in the RD factor on the factor loadings on $R_m - R_f$, SML and HML are reversed relative to the zero-RD portfolios.

In summary, the results from Tables VI and VII provide strong evidence that the Fama and French factors capture variation in returns that is associated with RD activity. They also indicate that a simply modification of the three-factor model is capable of improving the explanatory power of the three-factor model.[10] The improvement in explanatory power for zero-RD portfolios in particular is consistent with the RD factor canceling out RD-related effects embedded in the other three Fama and French factors.

4.4. INDUSTRY RISK PREMIA

To illustrate the implications of the findings in Tables VI and VII, we use the various factor model representations to estimate risk premia for portfolios of firms drawn from selected industries. Risk premia are estimated using ex post factor risk returns and factor loadings. Fama and French (1997) suggest that this simple method is reasonably competitive with other methods. The expected risk premium for a given portfolio p is defined as:

$$E[R_p - R_f] = bE[R_m - R_f] + sE[SMB] + hE[HML] + rE[RDMNRD], \quad (3)$$

where b, s, h and r are the estimated loadings from estimates of equation (2) and $E[R_m - R_f]$, E[SMB], E[HML] and E[RDMNRD] are the annualized in-sample mean returns on the four factors, based on panel A of Table V.[11]

First, we examine industries having relatively large numbers of firms and where the frequency of RD activity is relatively low. We only consider zero-RD firms within these industries. The results are reported in Table VIII, panel A. With one exception (Retailers, General), the impact of the three-factor model relative to the CAPM is to substantially increase the estimated risk premium. The impact of introducing the RD factor is always to decrease the estimated risk premium relative to the three-factor model estimate, again by substantial amounts. Although not reported, the RD factor is always significantly negative in the modified three-factor

[10] We also replicated the three-factor Fama and French (1993) analysis on the whole sample on the S/L, S/M, S/H, B/L, B/M and B/H portfolios and found very similar results. As in the USA, the main benefit of the three-factor model is in explaining the returns of the small firm portfolios.

[11] In the case of the CAPM and three-factor models, appropriate parameter restrictions are applied in estimating the factor loadings based on equation (2).

Table VIII. Estimates of annualized risk premia (%) from single factor CAPM, Fama–French 3-factor model and the RD-modified model for selected industry portfolios

Panel A: Zero-RD Firms in Industries With Low Proportion of RD Firms			
	CAPM	Fama–French	RD-modified Fama–French
Construction	17.52	22.35	18.44
Distributors	14.58	20.76	16.52
Leisure	16.39	20.22	14.76
Media and photography	16.58	24.15	21.16
Retailers, general	11.71	8.96	5.42
Support services	14.21	19.12	16.96
Panel B: Zero-RD Firms in Industries with Balanced Proportion of RD Firms			
	CAPM	Fama–French	RD-modified Fama–French
Chemicals	11.07	13.31	10.53
Electronics	10.53	22.49	19.63
Engineering and machinery	11.15	19.68	15.75
Food producers	9.98	11.60	9.75
Health	9.07	10.02	10.29
Software	19.61	39.17	39.78
Panel C: RD Firms in Industries With Balanced Proportion of RD Firms			
	CAPM	Fama–French	RD-modified Fama–French
Chemicals	12.38	15.94	12.92
Electronics	17.29	23.79	20.01
Engineering and machinery	15.08	17.29	14.85
Food producers	8.24	2.60	2.26
Health	9.68	9.06	9.27
Software	19.46	31.19	32.73

Note: Risk premia are defined as the difference between estimated cost of capital and the risk-free rate over the sample period.

model regressions, consistent with other results we have reported for zero-RD portfolios.

Given that E(RDMNRD) is effectively zero, the changes in estimated risk premia can only arise because inclusion of the RD factor reduces the loadings on the other factors (in particular, SMB and $R_m - R_f$, as discussed above for other zero-RD portfolios). For all industries in panel A, moving from the single-factor to the three-factor model increases the loading on the market factor and, with one exception, introduces a positive loading on SMB. These two effects produce an increase in the estimated risk premia. Moving from the three-factor to the modified three-factor model reduces the loadings on the market factor and on SMB for all the industries, thus reducing estimated risk premia.[12]

Second, we examine industries with large numbers of firms and with a reasonable balance between firms with RD and firms without RD. We examine estimated risk premia for portfolios of RD and zero-RD firms within industry groups. The results for the portfolios of firms with zero RD are shown in panel B of Table VIII. For the first four industries, the results are consistent with those in panel A. For the last two industries, the modified three-factor model has negligible impact relative to the three-factor model.

Estimated risk premia for portfolios of firms with RD within industry groups are reported in panel C of Table VIII. In general, the impact of the three-factor relative to the one-factor model is to increase the estimated risk premium by at least 2% (Health being the exception). The impact of the modified three-factor model relative to the three-factor model is only substantive for the first three industries.

Overall, the results reported in this sub-section suggest that modification of the Fama and French (1993, 1996) three-factor model to allow for differences in RD activity across firms can have a substantive impact. This is especially the case for the zero-RD industry portfolios studied.

5. Summary and Conclusions

In this paper, we present evidence that the cross-section of UK expected stock returns is positively related to RD activity. The association between returns and RD activity is significant even after controlling for ME and BM. The cross-sectional results are consistent with intangible assets resulting from research and development activities having higher risk than tangible assets.

The results from time series analysis suggest that allowing for research and development activity in constructing factor models of returns can be important. The explanatory power of factor models generally improves after controlling for RD activity, particularly for portfolios of firms with no RD activity. This result can be explained by the three factors in the Fama and French model partially capturing effects associated with research and development activity. Inclusion of

[12] When we perform similar exercises with the zero-RD, LNRD, MNRD and HNRD portfolios, similar patterns emerge when moving from the three-factor model to the modified three-factor model.

the RD factor effectively cancels out some of these effects. Overall, we believe that our results suggest that research and development is a relevant factor in modelling returns. Our illustrative analysis of industry portfolios indicates that estimated risk premia are very sensitive to factor model specification, especially for firms with no RD activity.

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