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R&D, IP, and firm profits in the North American automotive supplier industry*

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Economic theory implies that research and development (R&D) efforts increase firm productivity and ultimately profits. In particular, R&D expenses lead to the development of intellectual property (IP) and IP commands a return that increases overall profits of the firm.

This hypothesis is investigated for the North American automotive supplier industry by analyzing a panel of 5000 firms for the years 1950 to 2011.

Results indicate that R&D expenses in fact increase profitability at the firm level. In particular, increases in the R&D expense to sales ratio lead to increases in the profit contribution of intangible assets relative to sales. This indicates that more R&D intensive IP should command higher royalty rates per sales when licensed to third parties and within multinational enterprises alike.

JEL classification: D24, L20, L62, M21

Keywords: productivity, intellectual property, royalties, MNE, transfer pricing

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1. Introduction

The effects of R&D investments on productivity have long been the focus of research. There exists consensus theoretically that R&D investments increase productivity both in the aggregate and on the firm level and that is generally confirmed by empirical studies; see e.g. Griliches (1998) and Mairesse/Sassenou (1991) for an overview. However, due to conceptual problems with the central R&D capital model (based on production functions) and econometric problems such as endogeneity and data heterogeneity, much of the empirical work thus far presented remains controversial; see e.g. Griliches (1998), chapter 12.

This investigation does not try to identify the underlying production function but focuses instead on the profit and return structure resulting from earlier monetary and tangible capital formation treating the residual difference between the total value of assets of the firm and the sum of monetary and tangible assets as intellectual property (IP) capital. Total return to all assets is then decomposed using the weighted average cost of capital concept to yield a residual return on the IP asset. For a definition of intellectual property, we can refer, e.g., to Clarkson (2001) who states: "Intellectual property law identifies five major sources legal protection: patents, trademarks, industrial designs, confidential information/trade secrets, and copyright" (p. 5) and "Intellectual asset rights for a technology can be licensed" (p. 7) and from those transactions value can be imputed.

Econometric problems of earlier studies are partly avoided by simply using a much larger data set, both across sections (several thousand firms) and within time-series (up to 11 years of average time observations per firm).

I principally follow Clarkson (2001), who presents a model to test the relationship between the R&D-to-sales ratio and the profit contribution of intangible assets as percentage of sales. He finds that this relationship is significant and positive for the pharmaceutical industry and I apply the same methodology to the North American automotive supplier industry.

The remainder of the paper is structured as follows. Section 2 introduces the economic and institutional background, the resulting research questions posed here, as well as the hypotheses to be investigated. The underlying theory is presented in Section 3. Section 4 describes the data used. Section 5 presents the general modeling and summarizes the results. Section 6 concludes. Statistical and econometric results are presented in the appendix.

2. Background and research questions

In general, there is a large body of theoretical and empirical economic research showing that profitability increases with R&D expense; a large part of this is summarized in Hall/Mairesse/Mohnen (2010), Griliches (1998) and Mairesse/Sassenou (1991). The underlying mechanism lies in the build-up of R&D capital – in the form of intangible assets or intellectual property (IP) – as a result of R&D activities. Hall/Mairesse (2009) use Compustat data for about 5600 manufacturing, trade, and services firms for the years 1996 to 2005 and find significant positive effects of past R&D intensity on gross margins and EBIT margins. For the automotive industry, e.g. Jaruzelski et al. (2005) report that firms with above average R&D to sales ratios have on average a greater gross margin than those with below average R&D/sales.

Other research establishes "that intangible asset capitalization is associated with market values. In other words, market participants behave as if parts of R&D, labor and advertising expenditures were treated as assets that represent significant future economic benefits to the firm"; see Sydler et al. (2014) in an analysis of the pharmaceutical industry; see also e.g. Lev and Sougiannis (1996).

Other research, in turn, establishes a relationship between profit margins and royalty rates for intangible assets; see Kemmerer/Lu (2008) and Goldscheider et al. (2002). For example, using data from RoyaltySource and Compustat for 21 years up to 2007, Kemmerer/Lu report that for a sample of 3800 firms from 14 4-digit SIC industries, average royalty rates lie between 25 percent of gross margin and 25 percent of EBIT margin. Regressing the royalty rates on EBIT margins yields a stable result of 50 percent whereas Goldscheider et al. (2002) present the well-known 25-percent rule. The 25-percent rule states that when licencing IP, a license should be set such that 25% of resulting profits go to the licensor and 75% to the licensee; see also Goldscheider (2011) who argued that this rule reflects commonly accepted practice in many industries.

Based on these two bodies of research, it can be shown that profit margins as percentage of sales are increasing in R&D intensities i.e. in R&D spending as percentage of sales. Clarkson (2001) shows this for the pharmaceutical industry and concludes that increases in R&D intensity lead to increases in the contribution of intellectual property (or intangible assets) to profits measured as percentage of sales (CPIA); a one percent increase in R&D intensity tends to increase CPIA by half a percent. This is consistent with the Sydler et al. (2014) analysis of the pharmaceutical industry showing that R&D expenditures lead to the formation of IP assets which in turn increase a firm's returns relative to book value.

These general observations should principally also hold for the automotive industry; compare e.g. Kroninger (2016), Egeland and Matshede (2015), PwC (2008). However, also due to the historically increasing role of IP for this industry, changes over time of the relatioinship between IP and profitability including structural breaks are to be expected; compare Sydler et al. (2014), Cadogan (2010).

3. Theoretical Basis

Following Clarkson (2001) we can equate a firm's total cost of capital with its total return on assets:

$$(1)\ WACC = r_i \frac{V_i}{V_t} + r_m \frac{V_m}{V_t} + r_{tan} \frac{V_{tan}}{V_t}$$

where $WACC$ is the weighted average cost of capital, V_i denotes the value of IP (IP capital), V_m denotes monetary assets, V_{tan} denotes tangible assets, V_t denotes total assets, r_i denotes return on V_i, r_m denotes the return on V_m, and r_{tan} denotes the return on V_{tan}.

The left-hand side of equation (1) represents the WACC as the weighted cost of the liability side of the balance sheet; this is defined in detail in equations (4) to (6) below. Compare e.g. Munn (2002) for traditional WACC approaches. This is equated with the ride-hand side of equation (1) as the weighted sum of returns on the asset side of the balance sheet. The WACC is then treated like a known variable and equation (1) is rearranged to yield the following:

$$(2)\ r_i = (WACC - r_m \frac{V_m}{V_t} - r_{tan} \frac{V_{tan}}{V_t})/(\frac{V_i}{V_t})$$

Since this is derived from equation costs to returns (the liability to the asset side of the balance sheet), we do not make specific assumptions about financing structure and need not evoke Modigliani-Miller (1958, 1963) for a capital structure irrelevance assumption.

We can now define the contribution of profits due to intangible assets as a share of sales, CPIA, as

$$(3)\ \ CPIA = r_i * (\frac{V_i}{V_t})/WACC * EBIAT/sales$$

where EBIAT is profit before interest but after taxes and represents debt-free net income, i.e. net income plus interest expense after tax.

Given information on $WACC$, V_t, V_m r_m, V_{tan}, r_{tan} and $EBIAT$, $CPIA$ can be calculated. With information on R&D expense and sales, the relationship between CPIA and the R&D expense to sales ratio can be investigated. Note that in contrast to other studies, such as Sydler et al. (2014), a separate calculation of a measure of IP Capital is not necessary.

The US t-bill rate can be used for measuring r_m and the US t-bond rate for measuring r_{tan} as well as the risk-free rate of interest r_f (used to calculate individual firm WACC values).

The $WACC$ can be calculated as

(4) $WACC = (1 - d_a) * ROE + d_a * (1 - t) * r_m$

(5) $V_t = \dfrac{E_i(1-\tau)}{(D_t/V_t)r_i^d(1-\tau) + (1-(D_t/V_t))(r_f + \alpha_i\sigma_i) - g_i} - D_t$

with an assumed average tax rate of t=0.4, d_a is the debt to V_t ratio, D_t is total debt, and roe is the rate of return to equity. Following Damodaran (2011a, 2011b) and Lutz (2012a, 2012b), roe can be expressed by:

(6) $ROE = r_f + \alpha * \sigma_{ROE}$

where individual return volatility per firm is calculated as the moving standard deviation of the ratio of net income to total equity.

4. The Data

I analyze North-American firm level data from Compustat for the NAICS code range 334000 to 336999. The data set spans the years 1950 to 2011 and includes over 5000 firms. About 75% of that data spans the years 1980 to 2010; so there are fewer observations in earlier years and in the last year of the sample. However, all observations from all years are included in the estimations;

using only data from 1980 to 2010 for estimations would not qualitatively change the results (not reported in the paper).

Data on US treasury bills and bonds is taken from the IMF's International Financial Statistics.

A full list of data sources utilized and data obtained is given in Table 1 in the appendix. A list of variables used is given in Table 2 in the appendix.

Summary statistics are provided in Tables 3a and 3b. These include descriptive time-series data of our sample on numbers of firms per year and related R&D expense and profitability variables.

5. Modeling and results

Given the panel data available, we can use the following generalized regression model to investigate the economic hypotheses presented:

(8) $$y_{i,t} = \alpha + \mathrm{B}F_i + \Gamma G_{i,t} + \Delta M_t + \varepsilon_{i,t} + \eta_i$$

where the dependent variable $y_{i,t}$ is a profit or sales level indicator (e.g. EBIT, sales, or profit margin) of company *i* in period *t*; F_i is a vector of determinants specific to firm i but invariant over time (such as country or industry); $G_{i,t}$ is a vector of determinants that may vary between firms and also over time (e.g., R&D expense); M_t is a vector of period-specific determinants outside of a particular firm (e.g. global economic factors and market indicators); $\varepsilon_{i,t}$ is an idiosyncratic error term that may vary between firms and also over time and is independently distributed with E($\varepsilon_{i,t}$) = 0; and η_i represents unobserved heterogeneity across firms, i.e., a company specific random effect that is independently distributed.

For the detailed model specification of equation (8) in Section 5, let I= number of firms, T = number of years, (TxI) the product of T and I; let β, γ, δ be the number of included F, G, and M variables, respectively. The general model specification in Section 5 inludes a constant α, line vectors B(1xβ), Γ(1x γ), Δ(1xδ), matrixes F(βx(TxI)), G(γx(TxI)), M(δx(TxI)), and column vectors Y, ε, η with dimension (1x(TxI)). The exact number of variables per model varies with the models and is reported in Tables 4.1-4.4.

This general specification allows for either random-effects (RE) or fixed-effects (FE) modeling, where the random or fixed effects are firm-specific components. The more general approach is to allow for random firm-specific effects; the case where these effects are fixed, that is determinate constants instead of random variables, is a special sub-case. All model variants reported below were estimated with both FE and RE panel models. All models are estimated also with lagged explanatory variables to capture the effects of past research expenditure on present firm performance and profits. All models were also run with controls for years in order to address historical differences and structural breaks. Compare e.g. Cadogan (2010) or Sydler et al. (2014) for related discussions on model specifications.

Controlling model estimations for years also aims at addressing the value reference issue as discussed in Lev and Sougiannis (1996) and Ciftci, et al (2014). This issue includes the observation that “R-squared is lower for intangible-intensive industries than for non-intangible-intensive industries and has declined over time for intangible-intensive industries” (Ciftci, et al, Abstract).

The data available contains several firm-specific, time-invariant variables that can be assumed to capture a significant part of present fixed effects (e.g. country, industry indicators, functional dummies, etc.). Hence a random-effects specification seems to be a priori more appropriate. However, Hausman tests for FE versus RE modeling undertaken for the models reported below (not reported here) tend to reject the null of consistency in the RE modeling – consequently the FE models reported should be considered more reliable. Estimations and results are summarized below.

In a first exercise, I investigated the principal effect of R&D spending on profit, sales, and the profit-sales margin. Estimations yielding the following results are reported in Table 4.1.

1) A one-percent increase in R&D spending tends to increase EBIT by ½ to ¾ percent

2) A one-percent increase in R&D spending tends to increase sales by 0.1 to 0.4 percent

3) A one-percent increase in R&D-sales ratio tends to increase the EBIT-sales margin by ¼ to 1/2 percent

The first two relations have been estimated with IV RE and FE models using logs in the variables and they explain over 80% of the EBIT variation and over 90% of the sales variation in the data.

In a second exercise, I follow Clarkson's methodology in order to isolate the effect of R&D spending on the value of intangible assets and the return to intangible assets. According to the step-by-step procedure applied, I report several sets of regressions:

1) Regressions in logs show that R&D increases EBIT and sales, but EBIT by a larger percentage. These regressions explain at least 80% of variation in all model setups. It follows that R&D increases the EBIT margin! The corresponding estimations are reported in the first four models in Tables 4.1. and 4.2., respectively.

2) Additional regressions of EBIT-sales margin against lagged R&D expenditure as share of sales show that past R&D-sales ratios significantly influence present EBIT-sales margins. The corresponding estimations are reported in the last two models in Tables 4.1. and 4.2., respectively.

3) Regressions of intangible asset levels (measured as total assets minus tangible and current assets) against past R&D levels indicate that past R&D explains at 75% of current intangible asset values (for the Delphi data set). Intangible asset values are increasing in R&D! Undertaking the regressions from set 3 with sales ratios also yields significant positive results with the R&D-sales ratio explaining about a quarter of the intangible-asset-sales ratio. The corresponding estimations are reported in Table 4.3.

4) Lastly, CPIA – contributions to profit by intangible asset – values following the method of Clarkson have been calculated. The wacc/roe calculations were done following Damodaran (2012b) and Lutz (2012b) where roe= tbond-rate +alpha*risk and risk is measured as the individual firm's volatility of returns to capital. Here the results show a stable positive relationship between the R&D-sales ratio and CPIA. The corresponding estimations are reported in Table 4.4.

According to the model estimates, an increase of one percent in the R&D to sales ratio increases the profit contributions of intangible assets by 1/4 to 1.25 percent of sales. The models explain between one third and half of the variation in the profit contributions of intangible assets.

6. Conclusions

I conclude that there is strong evidence that firm profits, profit margins and the contributions by returns to IP increase with R&D in the automotive (supplier) industry. While the reverse causality – from past sales and profits to current R&D expenditure – may also be present, our model specifications examined the relationships between past R&D expenditures over several years with current sales and profits and the results obtained appear to be robust.

These results in turn imply that royalty rates (as percentage of sales) should increase in R&D intensity (as percentage of sales). This is so because licensors and licensees often negotiate royalty rates to target a stable profit split (Goldscheider et al. (2002) and therefore a stable positive relationship between profit (shares) and royalties can be observed (Kemmerer/Lu (2008)). For the automotive industry, royalty rates to target a stable profit split are also common; this has been confirmed to me during several expert interviews with managers from the US automotive industry conducted in 2012.

In conclusion, there is strong support for the notion that royalty rates (as percentage of sales) should increase in R&D intensity (as percentage of sales) of the licensor that created the licensed IP, because the profits (sales margins) to be gained by exploitation of the IP tend to increase in R&D intensity.

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Appendix

Table 1. Data sources

#	Data type	Source	Downloaded / data	Date
1	Firm data (balance sheet, profit/loss)	Wharton Research Data Services (WRDS) [2]: Compustat	https://wrds-web.wharton.upenn.edu/wrds/ (Data set: compm/funda/ ann / Jan 1950 - Jan 2012, TIC, all, NAICS ge 33000 and NAICS lt 34000)	21 August 2012
7	U.S. stocks and bonds data	International Financial Statistics	International Monetary Fund (2012): International Financial Statistics (Edition: August 2012). ESDS International, University of Manchester. DOI:http://dx.doi.org/10.5257/imf/ifs/2012-08. Annual IFS series. Table title: United States (August 2012), series 60C..ZF, 61..ZF.	August 2012

[2] Wharton Research Data Services (WRDS) was used in preparing part of the data set used in the research reported in this paper. This service and the data available thereon constitute valuable intellectual property and trade secrets of WRDS and/or its third-party suppliers.

Table 2. List of variables

Variable	**Definition**
Firm	group(gvkey)
fyear	Fiscal year
at	Assets - Total
ebit	Earnings Before Interest and Taxes
ni	Net Income (Loss)
ppegt	Property, Plant and Equipment - Total (Gross)
sale	Sales/Turnover (Net)
txt	Income Taxes - Total
xrd	Research and Development Expense
mkvalt	Market Value - Total - Fiscal
loc	Current ISO Country Code - Headquarters
naics	North American Industry Classification Code
naicsn	North American Industry Classification Code
sic	Standard Industry Classification Code
state	State/Province
seq	Stockholders Equity - Total
ebiat	ebit-txt
rshf	ni/seq
std3rshf	3-period standard deviation of rshf
xrds	xrd/sale
countryn	group(loc)
roe	tbond+0.3*std3rshf
da	1-seq/at
wacc	da*(1-0.4)*tbill+(1-da)*roe
ai	mkvalt-act-ppegt
ais	ai/sale
margin	ebit/sale
nmargin	ni/sale
cpia_req	ria*ai/sale
ria	(wacc-act/mkvalt*tbill-ppegt/mkvalt*tbond)/(ai/mkvalt)
cpia	ai/mkvalt*ria/wacc*ebiat/sale
ln_var	ln(_var)
TBillRate_ifs	Treasury bill rate, percent per annum
TBondRate10y_ifs	Ten year government bond yield, percent per annum
tbond	TBondRate10y_ifs*100
tbill	TBillRate_ifs*100

Table 3a. Summary statistics (selected variables)

Variable	Obs	Mean	Std. Dev.	Min	Max
firm	54385	1937.03	1373.78	2	5144
fyear	54385	1992.87	11.0166	1950	2011
at	54365	1540.02	10870.2	0	479921
ebit	54385	99.1433	639.385	-12193	33790
ni	54372	40.6556	831.674	-85162	104821
ppegt	54192	766.367	5336.22	0	200717
sale	54385	1366.04	8000.68	-0.019	262394
txt	54379	29.2095	251.44	-5878	37162
xrd	54385	66.5922	402.967	-0.307	10924
mkvalt	18319	1916.6	10075.8	0.0007	467093
naicsn	54385	334773	1838.61	331000	339999
ebiat	54379	69.942	520.803	-37506	25507
rshf	53905	0.01793	35.6914	-894	7770.33
avg3rshf	46781	0.02467	32.8783	-5380	1850.22
std3rshf	46763	1.88655	40.4585	0.00138	5376.07
xrds	53440	0.97124	26.3349	-218.74	3309
countryn	54385	34.6064	7.35702	1	40
roe	46763	0.63405	12.1373	0.02934	1612.9
da	50108	0.44174	0.22225	0	1
wacc	43804	0.15616	2.45843	0.00377	473.162
ai	18128	610.989	8732.42	-248669	452978
ais	17676	26.6996	600.3	-643.63	55726.2
margin	53440	-2.3929	63.8009	-8869	394.474
nmargin	53427	-2.8388	81.8323	-8684	1332
cpia_req	15850	11.6948	599.408	-32816	43263.7
ria	16011	0.0003	16.5845	-1842.6	546.594
cpia	15849	-4.525	172.431	-15162	1276.43
tbond	54331	0.06857	0.02557	0.02402	0.13911
tbill	54385	0.05146	0.02882	0.00058	0.14078

Table 3b. Time series statistics (selected variables)

Fiscal year	No. firms	R&D expense to sales	WACC	Return on equity	Return on intangible assets
		Average	Average	Average	Average
1950	8	.0204968			
1951	13	.02198378			
1952	15	.02670928			
1953	18	.02906584			
1954	24	.03586493			
1955	31	.03202328			
1956	33	.03154611			
1957	33	.04017907			
1958	33	.04181862			
1959	33	.04159643			
1960	39	.04160234			
1961	41	.04679791			
1962	52	.04622581			
1963	52	.04645989	.02864825	.17208183	
1964	57	.04920585	.10899481	.25640983	
1965	63	.04874116	.05391879	.22246505	
1966	66	.04851276	.05825473	.22454052	
1967	75	.08239294	.06071714	.23643387	
1968	90	.08917022	.65010324	.2493162	
1969	96	.0738535	.09441627	.22930614	
1970	234	.11051225	.08182723	.19859182	
1971	399	.04489734	.06930722	.07847149	
1972	491	.03647877	.08356062	.17674221	
1973	570	.03088553	.08789939	.17757471	
1974	767	.03039975	.08542425	.25684577	
1975	773	.04461636	.0862524	.23443135	
1976	786	.0348744	.08768999	.23204745	
1977	771	.0338756	.08799722	.25934549	
1978	790	.04895852	.1070427	.35725399	
1979	835	.05608803	.1230126	.28441881	
1980	902	.19702149	.1271205	.07377574	
1981	967	.20699333	.1578595	.22771068	
1982	1,125	.1963603	.14928191	.18846223	
1983	1,234	2.5818267	.1507463	.01000474	
1984	1,303	.16734036	.14274375	.70449239	
1985	1,416	.273632	.12656434	1.5048382	
1986	1,454	.24962976	.11512106	-.26264632	
1987	1,458	.35313462	.1190283	-4.4204179	
1988	1,408	.57976732	.13974224	.03014611	
1989	1,401	.85735083	.15628584	.06333706	
1990	1,401	.38375859	.12476007	-.08291916	
1991	1,445	.45082161	.11949236	.21660423	
1992	1,514	.54486757	.16002771	.14682146	
1993	1,600	.72671998	.19195474	-.04193248	
1994	1,706	.30442691	.15495376	-.18527267	
1995	1,875	.93851863	.11666554	.10142158	
1996	1,891	2.3944955	.14406699	.03705963	
1997	1,854	.90751209	.17390201	.06661403	
1998	1,930	1.6429378	.12287624	.49942974	.14638078
1999	1,873	1.3558145	.15618603	1.245576	-1.0583237
2000	1,780	3.0436565	.27939962	-.02299623	.2732389
2001	1,702	1.1359925	.16319402	.09701145	.09238216
2002	1,663	1.7278879	.19004077	.61870458	-.56223728
2003	1,636	1.1650982	.19133156	.12040953	.20275462
2004	1,616	.95939638	.5116775	-2.1612725	.7115438
2005	1,584	1.3623727	.24004927	-.06237868	.08639784
2006	1,524	1.5625884	.13170451	.8426404	.15784096
2007	1,465	.84572506	.12837754	.20063137	.10019286
2008	1,423	1.8705099	.09527514	.01448189	.0022496
2009	1,392	3.0177079	.08986617	.04448965	.11467628
2010	1,291	.86667218	.14503386	-.11239394	-.29530764
2011	264	2.3628166	.1056944	.10837632	.38675232

Table 4.1. Results: Effects of R&D on EBIT, sales, and margins (1)

Model	(4.1.1) IV-FE	(4.1.2) IV-RE	(4.1.3) IV-FE	(4.1.4) IV-RE	(4.1.5) RE	(4.1.6) FE
Dep. Variable	lnebit	lnebit	lnsale	lnsale	margin	margin
lnxrd	0.7434***	0.5640***	0.4445***	0.0792***		
lnebit (-1)	0.0984**	0.4286***				
lnsale (-1)			0.4443***	0.9064***		
margin (-1)					0.1684***	0.2653***
xrds (-1)					0.2731***	0.5391***
Observations	1252	1252	1602	1602	31741	31741
Groups (Firms)	384	384	467	467	2725	2725
R-sq. within	0.3597	0.3464	0.8506	0.8453	0.0110	0.0145
R-sq. between	0.8068	0.8894	0.9349	0.9861	0.0127	0.0006
R-sq. overall	0.8243	0.8864	0.9499	0.9892	0.0191	0.0106
Prob > chi2 (>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes. (i) Models (1), (3), and (6) estimated with fixed effects; Models (2), (4) and (5) estimated with random effects. Models (1) to (4) IV regressions with lnxrd instrumented by lagged observations of lnre, lnam, lntlcf and other variables. (ii) All equations include a constant and controls for years. (iii) *** denotes significant at the 1%, ** at the 5%, * at the 10% level.

Table 4.2. Results: Effects of R&D on EBIT, sales, and margins (2)

Model	**(4.2.1)** **FE**	**(4.2.2)** **FE**	**(4.2.3)** **RE**	**(4.2.4)** **RE**	**(4.2.5)** **FE**	**(4.2.6)** **RE**
Dep. Variable	**lnebit**	**lnsale**	**lnebit**	**lnsale**	**margin**	**margin**
lnxrd (-1)	0.2547***	0.1067***	0.2253***	0.0805***		
lnebit (-1)	0.5036***		0.6480***			
lnsale (-1)		0.7367***		0.8178***		
margin (-1)					0.1907***	0.2136***
xrds (-1)					0.3934***	0.3946***
xrds (-2)					-0.0010	-0.0220***
xrds (-3)					0.0069	0.0000
Observations	29769	47515	29769	47515	39921	39921
Groups (Firms)	2985	4056	2985	4056	3491	3491
R-sq. within	0.5165	0.7890	0.5143	0.7884	0.0051	0.0037
R-sq. between	0.9123	0.9677	0.9240	0.9688	0.0000	0.0364
R-sq. overall	0.8690	0.9617	0.8755	0.9632	0.0012	0.0057
Prob > chi2 (>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes. (i) Models (1), (2), and (5) estimated with fixed effects; Models (2), (3) and (6) estimated with random effects. (ii) All equations include a constant and controls for years. (iii) *** denotes significant at the 1%, ** at the 5%, * at the 10% level.

Table 4.3. Results: Effects of R&D on intangible assets

Model	(4.3.1) FE	(4.3.2) RE	(4.3.3) FE	(4.3.4) FE	(4.3.5) RE	(4.3.6) RE
Dep. Variable	lnai	lnai	ais	ais	ais	ais
lnxrd (-1)	0.0881***	0.5277***				
xrds			6.1616***	7.8259***	6.3858***	8.2368***
xrds (-1)			-0.3285***		-0.1039	
xrds (-2)			2.1246***		2.1011***	
Observations	10217	10217	16481	17676	16481	17676
Groups (Firms)	1940	1940	2330	2462	2330	2462
R-sq. within	0.0026	0.0026	0.2876	0.0879	0.2873	0.0879
R-sq. between	0.5837	0.5837	0.2127	0.1865	0.2171	0.1865
R-sq. overall	0.5384	0.5384	0.2806	0.1376	0.2817	0.1376
Prob > chi2 (>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes. (i) Models (1), (3), and (4) estimated with fixed effects; Models (2), (5) and (6) estimated with random effects. (ii) All equations include a constant and controls for years. (iii) *** denotes significant at the 1%, ** at the 5%, * at the 10% level.

Table 4.4. Results: Effects of R&D on contributions to profit by intangible assets

Model	**(4.4.1) FE**	**(4.4.2) FE**	**(4.4.3) FE**	**(4.4.4) RE**	**(4.4.5) RE**	**(4.4.6) RE**
Dep. Variable	**cpia**	**cpia**	**cpia**	**cpia**	**cpia**	**cpia**
cpia (-1)	0.0296***	0.0296***	0.0296***	0.7465***	0.7465***	0.7465***
xrds (-1)	0.3582***	0.3083***	0.2619***	1.1250***	1.1203***	1.0999***
xrds (-2)	0.2616	0.1162		-0.2294	-0.2898*	
xrds (-3)	0.0017			-0.0549		
Observations	12928	13145	13333	12928	13145	13333
Groups (Firms)	1919	1961	1985	1919	1961	1985
R-sq. within	0.0042	0.0032	0.0024	0.0007	0.0007	0.0007
R-sq. between	0.6235	0.7446	0.8545	0.9864	0.9875	0.9877
R-sq. overall	0.2409	0.2973	0.3563	0.5731	0.5731	0.5727
Prob > chi2 (>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes. (i) Models (1), (2), and (3) estimated with fixed effects; Models (4), (5) and (6) estimated with random effects. Models (1) to (4) IV regressions with lnxrd instrumented by lagged observations of lnre, lnam, lntlcf and other variables. (ii) All equations include a constant and controls for years. (iii) *** denotes significant at the 1%, ** at the 5%, * at the 10% level.