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Why Do Some Firms Undertake R&D Whereas Others Do Not?

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Abstract
Data for the UK show Northern Ireland remains at the bottom of the productivity league table, and that its R&D performance is consistently amongst the lowest across the UK regions. This paper analyses the data from a survey of some 250 matched firms operating in Northern Ireland (approximately half undertaking R&D and half not), in order to provide a more detailed analysis of attitudes to undertaking R&D in the Province. We consider a range of factors that determine whether R&D takes place (such as absorptive capacity, market orientation, business objectives, and competitive advantages). Conditional on whether R&D occurs, the analysis then looks at, firstly, the determinants of the R&D capital stock and intensity; before concentrating on those firms who undertook *no* R&D and analysing which factors might make them likely to engage in such activities in the future. Policy conclusions are then drawn as to what might be done to boost both the amount of R&D undertaken *and* the number of firms engaged in R&D in the Province.

Keywords: R&D, regional policy, matching
JEL Classifications: D24, H32, O18, O32

1 INTRODUCTION

In recent years, innovation has become one of the cornerstones of economic policy in industrialized countries such as the UK; it is regarded as the key to higher productivity and increasing prosperity (DTI, 2003; HM Treasury, 2004; DIUS, 2008; European Commission, 2006a, 2006b). A major contributor to innovation is the investment that firms make in R&D; a relationship that is well-documented in the empirical literature (e.g. Acs and Audretsch, 1988; Freeman and Soete, 1997; Mairesse and Mohnen, 2005). It is recognized that such investment also brings benefits to the firm that are additional to those which are directly associated with the increase in product and process innovation outputs. These non-tangible benefits relate to the development of the firm's capabilities and increased absorptive capacity whereby the firm can utilize external knowledge and technology to improve productivity (Cohen and Levinthal, 1990; Teece and Pisano, 1998; Pavitt, 1984). Such benefits have the potential to advance the firms' international profile since R&D and higher absorptive capacity, interalia, reduce barriers to exporting – see Harris and Li (2009) for a review of the literature and empirical evidence. Thus there are considerable benefits from the decision by the firm to undertake R&D.

The purpose of this paper is to consider the factors that determine the choice that firms make to undertake R&D, together with the amount of R&D investment, and for those firms *not* engaged in R&D, what factors would encourage them to undertake R&D in the future. Our analysis is based on a unique survey of matched firms located in Northern Ireland. The rationale for using the matched firm technique is that it allows us to compare firms that undertake R&D with firms that do not carry out R&D, but which on the basis of their characteristics (e.g. size, sector, ownership) these firms have the propensity to do so. That is, the firms compared have similar characteristics but differ in their decision as to whether or not they carry out R&D; we exclude from our analysis firms with dissimilar characteristics e.g. those with low levels of employment and/or those operating in sectors where R&D is much less likely to occur. The survey included questions on attitudes to participating (or not) in firm-level R&D activities along with questions that enable us to measure absorptive capacity in the firm.

Northern Ireland was chosen as a case study because it, along with a number of peripheral regions, has a relatively low level of business investment in R&D. Government data from the Business Enterprise R&D (BERD) surveys for 1995-2006 show that the amount spent on (real) business R&D as a proportion of regional GVA was on average 85% below the UK average, ranging from nearly 126% below in 1995 to nearly 67% below in 2006 (Office for National Statistics, 2008a, 2008b). Despite evidence that the lagging regions have been catching-up over the last 10 years, R&D spending in Northern Ireland remains significantly below the UK average at 0.5% of GDP compared to a UK figure of 1.2% (in 2003 prices).[1] Thus perhaps it is not surprising that improving the level of R&D spending is seen as a major instrument for closing a significant productivity gap

[1] Comparable 2005 EU data on R&D spending as a percentage of GDP puts the UK (at 1.76%) just below the EU average (of 1.84%), and significantly behind countries like Denmark (2.45%), Germany (2.48%), France (2.13%), Austria (2.41%), Finland (3.48%) and Sweden (3.89%).

between Northern Ireland and the rest of the UK (Northern Ireland Executive, 2008)

The next section of the paper discusses the survey in terms of the characteristics of the firms included and their attitudes to R&D. Section 3 presents the models used in the estimation of the determinants of R&D for both those firms engaged in this activity and those that are not, along with the results obtained and their interpretation. The final section draws conclusions and considers the implications for policy.

2 DATA AND FIRM CHARACTERISTICS

The data used in this paper mostly comes from a survey of 251 matched firms in the manufacturing sector operating in Northern Ireland in 2005. The matched sample was drawn from the total population of plants operating in Northern Ireland manufacturing in 2004, using the Annual Respondents Database (ARD) linked to data from the Business Enterprise R&D Database (BERD)[2]. In order to select the sample of firms, a stepwise logit regression was undertaken using the 2004 plant-level data from the BERD-ARD. With the dependent variable coded as 1 if the plant had a non-zero R&D capital stock in 2004 (coded 0 otherwise), the set of right-hand-side regressors comprised the age of the plant, size, the capital-labour and intermediate-inputs to labour ratios, labour costs per employee, and ownership, sub-region and industry dummy variables. The sample selected for the survey comprised 568 plants aggregated up into 445 firms, with details of the selection technique and its appropriateness provided in an unpublished appendix (available upon request).

Of the 445 firms approached to complete a telephone survey (in May-July 2005), 251 responses were obtained.[3] Table 1 confirms that the two sub-groups of firms that responded had similar ownership characteristics (see also Table A4 in the appendix); in terms of employment size, they were larger than the initial sample chosen for the survey (see Table A2) but the ratio between those undertaking R&D and those not was of a similar magnitude. Table 1 also shows that the sample of 247 manufacturing firms that responded to the survey (with completed data) were predominately small (employing less than 250) and with their headquarters in Northern Ireland. Thus, this is a very appropriate sample of firms for analysing local attitudes towards R&D; in particular the respondent firms that did not spend on R&D in 2005 had the propensity to undertake R&D, based on their characteristics.

In Table 2, the two sub-groups of firms are compared in terms of the markets they supply. Those firms undertaking R&D were significantly more likely to supply markets in Great Britain and the rest of the EU, while companies that did no R&D were much more likely to sell only within the region.

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[2] These micro-level data were made available to us to undertake a larger project in 2005 on the case for a higher level of R&D tax credit in Northern Ireland; see Harris *et al*. (2006, 2009) for details.

[3] We have checked that the average characteristics of the 445 firms approached are broadly similar to the average characteristics of the 251 respondents from whom data were collected, which suggests there was no substantive response bias in the data used here.

Table 1: Location of company headquarters and employment size of respondent firms

	R&D undertaken		No R&D undertaken	
	Number	%	Number	%
Company HQ				
Northern Ireland	87	79.8	109	79.0
Great Britain	9	8.3	12	8.7
Republic of Ireland	2	1.8	2	1.4
Other EU	3	2.8	5	3.6
North America	7	6.4	7	5.1
Japan	0	0.0	0	0.0
Other country	1	0.9	3	2.2
Size				
Small (< 250 employees)	86	79.6	124	89.9
Large (250+ employees)	22	20.4	14	10.1
Mean size	245		103	

Source: See unpublished appendix for details and Harris *et al.* (2006) for the questionnaires.

Table 2: Mean percentage value of destination of sales from operations in Northern Ireland

Location:	R&D	No R&D	All
Northern Ireland	28.7	44.9	37.8
Great Britain	32.1	24.5	27.9
Republic of Ireland	16.7	14.8	15.7
Other EU	13.3	8.4	10.6
North America	5.3	2.9	4.0
Japan	0.3	0.4	0.4
Other country	3.8	2.7	3.2

*Significant: NI at 0.01; GB at 0.05; Other EU at 0.1.
Source: See unpublished appendix for details and Harris *et al.* (2006) for the questionnaires.

In terms of what the firm tries to achieve and what provides its competitive edge, Table 3 shows that those undertaking R&D were marginally more likely to aim for growth in market niches and/or growth of profits (or earnings or rates of return), while non-R&D firms were more likely to concentrate on sales growth. This suggests that they take a different strategic approach in terms of quality versus cost, which is confirmed in the bottom half of Table 3. Firms that undertake R&D were much more likely to concentrate on product design (and to some extent marketing), while non-R&D firms were more likely to look to lower costs (and improvements in their process technology) to provide a competitive edge.

Table 3: Primary business objective and most important factor for future competitiveness of operations in Northern Ireland

	R&D		No R&D	
	Number	%	Number	%
Primary objective of business in Northern Ireland:				
Growth or maintenance of market share in focused market segments	38	35.8	38	28.4
Growth or maintenance of sales in general	36	34.0	49	36.6
Maintained or increased return on sales	12	11.3	27	20.1
Maintained or growth of profit, earnings per share, or return on investment	18	17.0	13	9.7
None of these apply	2	1.9	7	5.2
Most important factor providing competitive edge in next 3-5 years:				
Product design	44	40.7	21	15.6
Process technology	12	11.1	19	14.1
Cost effectiveness	31	28.7	66	48.9
Marketing	18	16.7	17	12.6
Financial management	2	1.9	7	5.2
Other	1	0.9	5	3.7

Note: There was no statistically significant difference in terms of the distribution of respondents across primary business objectives by sub-categories relating to whether R&D was undertaken or not; the null that there was no relationship between undertaking R&D or not and the distribution of respondents across factors providing competitiveness is rejected at the 1% significance level (using a χ^2-test of association).
Source: See unpublished appendix for details and Harris *et al.* (2006) for questionnaires.

Both R&D active and non-active firms were asked a series of questions that focused on the source of external technologies, the level of knowledge and experience present in the firm that is capable of making use of such technologies, and the diversity of the knowledge structures employed in the business in Northern Ireland. Responses were recorded on a 5-point attitudinal scale ranging from strongly agree to strongly disagree. After recoding the results into a dichotomous indicator with strongly agree/agree coded 1, other responses coded 0, factor analysis was used to extract data with which to compute measures that would be indicative of the firm's aptitude to assimilate, evaluate and exploit new technology.[4] The first factor we associate with the firm's absorptive capacity i.e. its ability to internalise external knowledge. The variables with the highest factor loadings (shown in bold italic in Table 4) associate strongly with the firm obtaining external information and having high innovative capabilities. Factor 2 is linked more to the firm sourcing technology externally, while factor 3 is strongly linked to human capital (internal skills, training, knowledge sharing and internal R&D). The fourth factor is linked positively with firms that have multi-site, multi-functional capabilities and where licensing and the ability to get novel innovations into global markets is strongest;

[4] Based on the guidance in Costello and Osborne (2005), the 'best' result was obtained with the oblimin oblique horst method which gave a 4-factor outcome.

Table 4: Questions relating to the capability of the firm to undertake R&D activities

	Factor 1 Absorptive capacity	Factor 2 External linkages	Factor 3 Human Capital	Factor 4 Branch plant	KMO	Uniqueness
Staff systematically undertake technological awareness surveys.	0.1813	0.2639	0.1929	0.0070	0.8565	0.7905
Frequent market research informs firm about customer needs	***0.5107***	0.2180	0.1657	-0.0695	0.8704	0.5342
Licensing is used to acquire technology	0.1201	***0.4065***	-0.0123	***0.3541***	0.8465	0.6205
Development of new products/processes in collaboration with others	***0.3244***	0.1143	0.0182	0.1433	0.8343	0.8092
R&D budget spent on subcontracting research from external sources	0.2572	***0.3176***	***-0.4126***	0.0851	0.6131	0.6879
Aware of the technologies being developed by competitors	***0.4087***	0.2161	0.2806	-0.1872	0.8353	0.5647
Technology supplier to other firms in the sector	0.1666	0.1448	0.0964	0.1361	0.7937	0.8786
Use private sector bodies as information source regarding new products	-0.1668	***0.7774***	0.0413	0.0933	0.7241	0.4394
Use public sector bodies as information source regarding new products	-0.1207	***0.7180***	0.0930	0.0471	0.7782	0.5082
Staff are qualified and skilled	0.0585	0.0736	***0.6322***	0.0464	0.8700	0.5456
Firm invests in training	0.0733	0.1893	***0.5197***	0.0811	0.8182	0.6136
Innovate by modifying competitors products	0.2928	***0.3417***	0.0533	-0.1007	0.7928	0.7165
At the forefront in developing and launching new technologies	***0.6281***	-0.0263	0.0894	0.0479	0.8785	0.5590
Capacity to adapt others' technologies	***0.5591***	0.0811	0.1451	0.0195	0.8950	0.5669
Internal R&D leads to innovation	***0.6552***	0.1511	-0.2626	-0.106	0.7795	0.5417
Capability to produce novel innovations for global market	***0.5548***	-0.1958	0.0322	***0.3843***	0.8182	0.5053
Sizeable capacity for technological development	***0.5247***	0.0437	0.1176	0.1999	0.8889	0.5673
Single site production activities	0.1361	-0.0504	0.1963	***-0.7002***	0.5813	0.4801
Numerous managerial posts within the organisation	0.0850	-0.0438	0.2100	***0.6463***	0.7872	0.4871
Each management level has a number of sections	0.1033	0.0057	0.0600	***0.7321***	0.7555	0.4098
Interactions between the various activities within the firm is first-rate	0.0562	-0.0213	***0.6440***	-0.0165	0.7996	0.5639
Staff have a range of educational and training backgrounds	0.1066	0.0776	***0.6301***	-0.0009	0.8242	0.5251
Payment for R&D employees is linked to results	0.1298	***0.4702***	-0.0192	-0.1927	0.7153	0.7099
Specialisation in a few technologies	***0.6953***	-0.1883	0.1133	-0.1095	0.8790	0.5308
Development work undertaken by multidisciplinary teams	***0.6910***	-0.0978	0.0289	0.0981	0.9089	0.5148

Table 5: Reasons for not undertaking R&D

	Factor 1 Finance	Factor 2 Risk	Factor 3 No need for R&D	Factor 4 Lack of skill	KMO	Uniqueness
The nature of our product does not require or justify expenditure on R&D	0.0400	-0.1385	***0.8801***	-0.0070	0.6692	0.2635
The nature of our production processes do not require or justify expenditure on R&D	0.0345	-0.0863	***0.8894***	-0.1004	0.6579	0.2420
It is a corporate decision not to invest in R&D in Northern Ireland	0.0695	0.1514	***0.6502***	-0.1242	0.8707	0.4879
External economic/market conditions prevent us from undertaking R&D	0.1035	0.2372	0.2239	0.3186	0.8491	0.6502
Lack of access to internal finance restricts our ability to undertake R&D	***0.8227***	0.0793	-0.0410	-0.1605	0.8368	0.3276
We are unable to secure the external funding that would be required if we were to undertake R&D	***0.8571***	0.0015	0.0286	-0.1492	0.7651	0.2992
There is limited competition in the market for our products, so we do not engage in R&D	-0.0943	0.0345	***0.5621***	0.2638	0.8723	0.5889
Our product is highly price sensitive, so we are unable to pass on the costs of R&D	0.4088	-0.0268	***0.4736***	0.2640	0.8943	0.3950
We are unable to engage in R&D due to a lack of appropriate skills within the business	-0.0425	0.0178	-0.0574	***0.9069***	0.6647	0.1966
If we were confident of generating a high rate of return and/or a low level of risk we would invest in R&D	***0.5645***	0.1725	0.0114	0.3253	0.8970	0.3413
The time lag between undertaking R&D and generating financial returns is too long	***0.5357***	0.2588	0.0829	0.1716	0.9103	0.3991
It makes more sense to wait and copy the innovations of competitors than undertake the R&D ourselves	0.0101	***0.7781***	0.1392	-0.1529	0.8344	0.3532
We have a lack of clarity on potential markets for any R&D outputs	0.0858	***0.7605***	-0.1085	0.0936	0.8188	0.3538
We have a lack of clarity about evolving technologies	0.0252	***0.8333***	-0.1225	0.0766	0.7861	0.2935
Senior management do not regard R&D as a strategic priority	-0.1114	0.4909	***0.5104***	-0.0925	0.8616	0.4336
We are unable to develop links with external bodies/organisations that would stimulate R&D activities	0.1874	0.3777	-0.0158	0.1914	0.7855	0.6795
There are insufficient government grants or tax incentives to make R&D spending worthwhile	***0.8268***	-0.0994	-0.0024	0.1076	0.8483	0.3184

hence we have labelled this factor as representing the status of the firm as a 'branch plant'.[5]

In addition, for firms not engaged in R&D, the survey asked a series of questions to help ascertain the reasons why these firms had decided against participating in R&D activities. Table 5 lists the reasons that firms did not take part in R&D activities along with the resulting factor loadings. As before the answers to the statements were recoded as 1 if the respondent strongly agreed/agreed (0 otherwise), and, a factor analysis was carried out using the same approach as above. Again it was possible to extract 4 factors, representing issues relating to finance (factor 1); risk (factor 2); the lack of any 'need' or culture for R&D (factor 3); and lastly a lack of appropriate skills with which to undertake R&D (factor 4).

The resultant principal components obtained from the two factor analyses each have a mean of 0 and a standard deviation of 1. The results of the factor analysis are used in the subsequent statistical modelling of the determinants of R&D in an attempt to understand better the motivations lying behind which firms spend on R&D, how much they spend, and whether firms that did not currently engage in this type of investment might become involved in the 3 years following the survey.

Lastly, we supplemented the information obtained from the survey carried out in 2005 with appropriately matched data at the firm level from the ARD and BERD (data for 2004 was made available by the relevant Northern Ireland department as part of the larger study carried out by Harris *et al*. 2006). The full range of variables used is set out in Table 6. As explained in the next section, four models are estimated (although model 1, involving whether R&D takes place or not, is estimated jointly with models 2 to 4). Note, the mean values reported in Table 6 are based on only those firms with no missing data in the various models estimated.

3 MODELS AND RESULTS

In modelling the determinants of R&D expenditure three separate models were estimated that take into account potential self-selection effects. The first model estimated is concerned with the determinants of the R&D capital stock, using a two-stage Heckman (1979) approach.[6] The R&D capital stock was obtained using a perpetual inventory approach with BERD micro-data available for Northern Ireland. Full details of the approach, and an overview of the results obtained is available in the appendix in Harris *et al.* (2006). This modelling approach recognises that those firms that spend on R&D are not a random sub-set of all firms; rather, we take into account that those with non-zero spending

[5] There is a strong positive (and significant) correlation between factor 4 and the firm being foreign-owned, stronger than the correlation between overseas ownership and factor 1 (absorptive capacity). The other two factors have a much lower correlation (insignificant at the 95% level for factor 2).

[6] In reality, stages 1 and 2 are estimated simultaneously using a FIML estimator since this is more efficient than using a two-stage approach. But the principle of the approach (and early implementation procedures after it was first introduced in 1979) is based on a two-stage procedure.

Table 6: Variable definitions and data

Variable	Definitions	$\overline{X}$ [a]	σ	Source[b,c]	Model[d]
R&D	R&D undertaken (coded 1) or not	0.440	0.497	Survey	1
R&D capital stock	ln R&D capital stock	-1.389	-1.956	ARD-BERD	2
R&D per worker	ln R&D capital stock per employee	-6.148	1.673	ARD-BERD	3
GB-owned	Dummy coded 1 if firm is GB-owned	0.084	0.278	ARD-BERD	1 – 4
HQ outside UK	Dummy coded 1 if firm is foreign owned	0.124	0.330	ARD-BERD	1 – 4
ln TFP	TFP obtained from equation (5.2) of Harris et al. (2006)[e]	0.002	-0.596	Survey	1 – 4
No sales to NI	Dummy coded 1 when no sales are sold in Northern Ireland	0.088	0.284	Survey	1 – 4
ln sales to NI	% sales sold in Northern Ireland	2.987	1.465	Survey	1 – 4
Product design	Dummy coded 1 when product design most important for competitiveness in next 3-5 years	0.260	0.440	Survey	1 – 3
Cost	Cost effectiveness most important for competitiveness in next 3-5 years	0.388	0.488	Survey	1 – 3
AC1	Factor 1 from Table 4 measuring absorptive capacity	0.000	-1.000	Survey	1 – 4
AC2	Factor 2 from Table 4 measuring 'external linkages'	0.000	-1.000	Survey	1 – 4
AC3	Factor 3 from Table 4 measuring 'human capital'	0.000	1.000	Survey	1 – 4
AC4	Factor 4 from Table 4 measuring 'branch plant' status	0.000	-1.000	Survey	1 – 4
Single plant	Dummy coded 1 when firm is a single plant firm	0.844	0.364	ARD-BERD	1 – 4
North/North West	Dummy coded 1 if firm located in Coleraine or Ballymena TTWA	0.140	0.348	Survey	1 – 4
South	Dummy coded 1 if firm located in Newry or Craigavon TTWA	0.188	0.391	Survey	1 – 4
West	Dummy coded 1 if firm located in Londonderry, Strabane, Enniskillen or Omagh TTWA	0.112	0.316	Survey	1 – 4
Belfast	Dummy coded 1 if firm located in Belfast TTWA	0.344	0.476	Survey	1 – 4
20-49 workers	Dummy coded 1 when firm employs 20-49 in NI	0.304	0.461	Survey	1 – 4
50-99 workers	Dummy coded 1 when firm employs 50-99 in NI	0.284	0.452	Survey	1 – 4
100-199 workers	Dummy coded 1 when firm employs 100-199 in NI	0.156	0.364	Survey	1 – 4
200+ workers	Dummy coded 1 when firm employs 200+ in NI	0.192	0.395	Survey	1 – 4

Table 6 (cont.)

Variable	Definitions	$\overline{X}$ [a]	σ	Source[b,c]	Model[d]
Capital-labour	$k_{it} - n_{it}$ (see notes to table)	-4.829	1.243	ARD-BERD	1 – 4
AGE	ln age of firm (t minus year opened +1) in years	2.281	0.707	ARD-BERD	1 – 4
Years of R&D	ln years firm involved in R&D in NI	2.614	0.909	Survey	2 – 3
New markets	Dummy coded 1 when main reason for R&D to enter new markets	0.091	0.289	Survey	2 – 3
R&D vital	Dummy coded 1 when R&D has always been vital to business	0.427	0.497	Survey	2 – 3
New product	Dummy coded 1 when main reason for R&D to develop new products	0.373	0.486	Survey	2 – 3
Improve product	Dummy coded 1 when main reason for R&D to improve existing products	0.273	0.447	Survey	2 – 3
Increase share	Dummy coded 1 when main reason for R&D to increase market share in existing market	0.536	0.501	Survey	2 – 3
Support	Dummy coded 1 when in last 4 years received R&D tax allowance, tax credits, capital grant	0.545	0.500	Survey	2 – 3
R&D expected	Dummy coded 1 when R&D likely to be undertaken in next 3 years or not	0.286	0.453	Survey	4
Engaged in R&D	Dummy coded 1 when engaged in R&D sometime in last 5 years	0.114	0.319	Survey	4
Finance	Factor 1 from Table 5 measuring financial obstacles	0.000	-1.000	Survey	4
Risk	Factor 2 from Table 5 measuring risk	0.000	-1.000	Survey	4
No need R&D	Factor 3 from Table 5 measuring need for R&D	0.000	1.000	Survey	4
Lack of skill	Factor 4 from Table 5 measuring lack of skill	0.000	1.000	Survey	4
Industry	Dummy variables coded 1 if firm belongs to 2-digit industry sector	–	–	ARD-BERD	1 – 4

[a] Means (and standard deviations) calculated using n = 209 for model 1, n = 72 for models 2-3, and n = 126 for model 4 (see tables 7-9 below).

[b] All data from the survey refers to Northern Ireland operations in 2005

[c] All data from the ARD-BERD refers to Northern Ireland operations in 2004

[d] Dependent variables for each model are: 1 = R&D; 2 = R&D capital stock; 3 = R&D per worker; 4 = R&D expected.

[e] I.e. $y_{it} - \hat{\beta}_1 k_{it} - \hat{\beta}_2 n_{it} - \hat{\beta}_3 m_{it}$ where *y* log of real gross-output; *k* is log of capital stock; *n* is log of employment; and *m* is log of real spending on intermediate inputs, in firm *i* at year *t*. All variables are from the ARD-BERD merged database.

levels have certain characteristics that are also linked to how much is spent (i.e. the error terms from the probit selection equation and the regression model determining the R&D capital stock are correlated).

The second model estimated is similar, but considers the determinants of R&D intensity (the R&D capital stock per worker), conditional on the firm spending on R&D. The third model estimated is whether those firms that are *not* currently spending on R&D in 2005 expect to undertake any R&D in the next three years. A probit model with sample section (the so-called heckprob model – see Van de Ven and Van Pragg, 1981) is estimated in order to determine which factors might increase the numbers of firms engaged in R&D (and not just the amount of R&D that is undertaken by those currently active in this area).

In choosing the likely determinants of whether R&D spending takes place or not, and subsequently what determines the amount of R&D undertaken and whether any R&D is likely over the next 3 years (for firms not engaged in R&D), we have included those variables that have been shown to be important in the literature and which are available in our matched survey/ARD-BERD database (for a survey of the micro-determinants of R&D spending, see Harris, et. al., 2006, Chapter 2). Thus, firm size (covering scale advantages); industry sector (for technological opportunity); destination of sales (for internationalisation issues); ownership (such as whether a single-plant firm or part of a larger firm, and country of ownership); location (in terms of the travel-to-work areas in Northern Ireland); absorptive capacity (and other firm level characteristics, such as age and total factor productivity); attitudes to and reasons for R&D; and information on the factors that hamper R&D (obtained from questions asked in the survey), are all included.

The results for the Heckman model determining the size of the R&D capital stock are presented in Table 7. The results relating to whether R&D is undertaken or not are provided in the lower half of the table, with marginal effects reported. Note a stepwise regression procedure was adopted[7] with variables retained in the model that had associated parameter estimates significant at the 15% level or better. The diagnostic tests provided in the lower part of the table also show that the Heckman selection procedure is clearly justified, since the correlation between the error terms of the two equations in the model is clearly large (ρ = 0.750) and statistically significantly different to zero (as tested using the reported likelihood ratio test of the null hypothesis that $\rho = 0$, with a $\chi^2(1)$ = 18.84 that is able to reject the null at better than the 1% significance level).

Looking first at the results for whether R&D takes place or not (the lower half of Table 7), firms in the matched sample that had their headquarters outside the UK were some 25% less likely to engage in R&D (having their HQ in Great Britain was not a significant factor), while selling a greater percentage of their goods and services within Northern Ireland also reduced the likelihood of undertaking R&D (a one standard deviation increase in *ln* sales to NI decreases the likelihood by some 8.8%). The finding that foreign ownership of firms did not encourage

[7] The null hypothesis that the variables dropped had jointly coefficients equal to zero was not rejected at better than the 10% significance level.

participation in R&D activities, which in turn should bring about innovation outputs, is consistent with Harris (1991), Harris and Trainor (1995) and Roper (2000) whilst the estimated relationship between exports and R&D propensity is supported by e.g. Buxton et al. (1991); Ito and Puick (1993); Canto and Gonzalez (1999). In terms of the factors determining the competitive edge for the firm (cf. Table 3), firms that stated that product design was the single most important factor were 18.8% more likely to undertake R&D, which is consistent with e.g. Goddard et al. (1986) and Vega-Jurado et al. (2008). Contrary to expectation, cost effectiveness as a strategic objective was not a significant determinant of whether to undertake R&D or not.

Table 7: Heckman model of determinants of R&D capital stock, 2004

Dependent variable: *ln* R&D capital stock	$\hat{\beta}$	*z*-value
ln Years of R&D	0.535	3.23
ln TFP	1.427	4.79
Single-plant	-1.038	-2.73
AC1	0.858	3.16
AC2	0.477	3.02
200+ workers	1.216	3.02
other non-metallic minerals	-1.480	-3.28
radio, TV, communications equipment	2.156	2.22
motors	2.590	8.36
South	1.263	3.92
Belfast	0.789	2.20
Dependent variable: R&D	$\partial\hat{p}/\partial x$	*z*-value
HQ outside UK	-0.254	-7.29
ln sales to NI	-0.060	-2.50
Product design	0.188	2.45
AC1	0.352	6.63
AC2	0.134	4.40
AC3	-0.221	-4.78
AC4	-0.121	-2.65
50-99 workers	0.340	3.11
100-199 workers	0.550	3.30
200+ workers	0.713	4.36
textiles	0.716	4.57
wood products	-0.163	-2.35
chemicals	0.863	5.96
radio, TV, communications equipment	0.703	3.91
North	-0.174	-2.81
West	-0.097	-1.51
ρ	0.750	3.66
σ	1.368	13.07
λ	1.027	3.97
N	209	
N (R&D>0)	72	
Log pseudo-likelihood	-157.0	
Wald test of independent equations $\chi^2(1)$ =18.84		

The higher the absorptive capacity of the firm, the more likely it was to undertake R&D (a one standard deviation increase in this variable increased the probability of spending on R&D by over 35%); similarly better external linkages for sourcing technology were associated with overcoming barriers to R&D (firms were 13.4% more likely to engage in R&D with a one standard deviation increase in this variable). The relationship between absorptive capacity and R&D propensity agrees with the findings in the literature (e.g. Cohen and Levinthal, 1990; Mowery and Rosenberg, 1989) while the importance of external linkages along with the capability of the firm to utilize externally acquired knowledge has been extensively documented, for instance, Veugelers (1997); Almeida et al. (2003); Leahy and Neary (2007); Bessant et al. (2005). In contrast, firms that were more committed to strengthening the human capital of their workforce (i.e. internal skills, training, knowledge sharing and specialising in internal R&D), and those with characteristics more associated with the status of a branch-plant, were (*cet. par*.) less likely to spend on R&D. This suggests that these two factors are likely to be associated more with firms that concentrate on exploiting existing technology, rather than developing new technology. This result also suggests that while investing in human capital is associated with increases in productivity, it is not itself likely to increase the propensity of firms to overcome barriers to undertaking R&D. Our finding on human capital and its role as a determinant of expenditure on R&D is contrary to results obtained by others including, Adams et al. (2003) and Kanwar and Evenson (2003) whereas our result regarding investment in firms with branch-plant attributes agrees with Markusen (1985) and Harris (1988). It should be noted that human capital has sometimes been used as a proxy for absorptive capacity in the literature; our results suggest that within this context it is at best a poor proxy, and possibly a misleading one.

The complexity of the relationship between firm size and innovative activity as measured by R&D expenditure has been extensively examined by many academics since the seminal work of Schumpeter (1950) e.g. Cohen et al. (1987); Acs and Audretsch (1991); Holmes et al. (1991); Cohen and Klepper (1996). Our results agree with the findings in this literature; larger firms are significantly more likely to engage in R&D (e.g. those employing 200+ employees were over 71% more likely to do so), and certain industries have a greater/smaller propensity to spend on R&D (vis-à-vis those industries not featuring in the model), with textiles, chemicals and electronic equipment featuring strongly with positive impacts. Like other studies (e.g. Shefer and Frenkel, 2005) we find that location is important, with firms located in the generally more disadvantaged North and West of the region less likely to be R&D orientated (Derry City Council, 2003).

Certain variables were not significant in determining whether R&D takes place (or not); with total factor productivity, single-plant status, and the age of the plant being notable examples.

As to the determinants of the size of the R&D stock, the top half of Table 7 shows that TFP and single-plant status were important, conditional on the firm undertaking R&D. A 10% increase in TFP would increase the R&D capital stock by over 14%, while single plant firms had R&D capital stocks that were on

average 65% smaller.[8] The longer the firm had been involved in R&D in Northern Ireland, the larger the R&D capital stock. Doubling the average value of this variable to just over 5 years would have increased a firm's R&D stock by over 53%, suggesting that undertaking R&D is a slow process (Harris, *et al.*, 2009

Table 8: Heckman model of determinants of R&D per worker, 2004

Dependent variable: *ln* R&D per worker	$\hat{\beta}$	z-value
New markets	0.720	1.33
R&D vital	0.642	1.93
ln TFP	1.008	4.06
AC3	0.339	1.59
AC4	0.322	1.91
50-99 workers	-0.772	-1.86
100-199 workers	-1.448	-2.71
200+ workers	-1.284	-2.03
fabricated metals	0.903	2.41
machinery & equipment	1.002	2.49
electrical machinery	0.388	0.96
radio, TV, communications equipment	1.329	2.00
motors	2.851	5.12
South	1.066	2.46
North	1.082	2.25
Belfast	1.195	2.62
Dependent variable: R&D	$\partial\hat{p}/\partial x$	z-value
HQ outside UK	-0.227	-4.12
ln sales to NI	-0.103	-3.84
Product design	0.225	2.16
AC1	0.351	5.40
AC2	0.164	3.38
AC3	-0.255	-5.37
AC4	-0.124	-3.13
50-99 workers	0.400	3.02
100-199 workers	0.591	4.17
200+ workers	0.675	4.64
textiles	0.680	5.09
wood products	-0.160	-2.71
chemicals	0.699	3.94
radio, TV, communications equipment	0.553	2.90
North	-0.165	-2.70
West	-0.125	-1.63
ρ	0.334	1.85
σ	2.160	25.41
λ	0.361	1.84
N	209	
N (R&D>0)	72	
Log pseudo-likelihood	-159.2	
Wald test of independent equations $\chi^2(1) = 7.84$		

[8] Given the dependent variable is logged, the impact of switching-on the dummy is exp(β)−1.

Table 2, found that when the demand for R&D changes in Northern Ireland it takes on average about 6.5 years for firms to fully adjust to a new equilibrium).

Firms with higher absorptive capacity and better external linkages had larger R&D stocks (an increase of one standard deviation – i.e. 1 – in either variable would increase the R&D capital stock by 86% and 48%, respectively). Larger firms have, *cet. par.*, R&D capital stocks that were 237% larger, with a high concentration of the R&D capital stock concentrated in the electronics and motor vehicle sectors (while firms in other non-metallic minerals had 77% smaller R&D stocks). R&D stocks were also concentrated in the South TTWA or Belfast.

The results for the Heckman model determining R&D per worker are presented in Table 8; again a stepwise regression procedure was adopted and the correlation between the error terms of the two equations in the model is important ($\rho = 0.334$) and statistically significantly different to zero (with a $\chi^2(1) = 7.84$). The lower half of the table presents the determinants of whether R&D takes place or not; these results are very similar to those presented in Table 7. As to the determinants of R&D intensity, conditional on R&D > 0, there are some major differences when compared to the variables that determine the size of the R&D stock. The impact of higher TFP is comparable, and some of the industry and location effects are similar; but the impact of the absorptive capacity variables and firm size has a different role in determining R&D intensity. Firms more committed to strengthening the human capital of their workforce, and those with characteristics more associated with the status of a branch-plant, spend more on R&D per worker; while size is significantly negatively associated with R&D intensity (e.g. firms that employed 200+ workers spent 72% less on R&D per worker compared to firms employing 0 – 9 employees). The latter suggests that there are significant economies of scale when spending on R&D, while the absorptive capacity variables appear to be associated with the quality or type of R&D taking place. Even though these variables are not associated with lowering barriers to undertaking any R&D, conditional on the firm engaging in such activity the more skilled, trained, flexible and diverse are employees, and the stronger are linkages within the organisation, the higher is the commitment to spending relatively more on R&D.

Two additional variables determine R&D intensity that were insignificant in determining the size of the R&D stock: firstly, when the main reason for R&D was to enter new markets, R&D intensity was over 105% higher and, secondly, when the firm stated that R&D has always been vital to their business, R&D intensity was 90% higher.

The final model estimated was the 'heckprob' model determining if firms were likely to do any R&D in the next three years, conditional on their decision not to invest in R&D in 2005. Results are presented in Table 9. The bottom-half of the table has similar results to the earlier models estimated with respect to whether R&D is undertaken or not (although here the dependent variable has been recoded to 1 if R&D was not undertaken in 2005).[9] Thus concentrating on the

[9] There are some differences in the magnitude of the estimates of the marginal effects, since Model 3 has some 12% more observations; however, the overall picture is similar.

top half of Table 9, firms that had been involved in R&D anytime in the preceding 5 years were over 43% more likely to expect to restart investing in the next 3 years; past experience therefore has a large impact on future intention. More efficient firms with higher TFP were also more likely to undertake R&D (a one standard deviation increase in *ln* TFP increases the probability of doing R&D by over 37%); while those that sold all their output outside Northern Ireland were some 25% more likely to start R&D. Thus, the twin effects of greater productivity and exporting have a very large effect on influencing whether a non-R&D firm (with similar characteristics to those doing R&D) participates. Given that Northern Ireland has recently set economic targets of boosting productivity (DETI, 2008) partly through greater exporting, our results suggest that this will also impact positively on R&D levels in the local economy.

Table 9: Heckprob model of determinants of whether firms not spending on R&D in 2005 were likely to undertake R&D in next 3 years

Dependent variable: R&D expected	$\partial\hat{p}/\partial x$	z-value
Engaged in R&D	0.432	4.36
ln TFP	0.619	1.59
No sales to NI	0.249	1.61
No need for R&D (factor 3, Table 5)	-0.250	-4.61
Product design	0.322	2.74
Single-plant firm	0.502	4.73
AC2	0.194	3.39
AC3	0.083	2.31
food & beverages	-0.126	-1.67
rubber & plastics	-0.330	-2.93
Belfast	-0.415	-4.35
Dependent variable: R&D not undertaken (coded 1)	$\partial\hat{p}/\partial x$	z-value
HQ outside UK	0.400	5.23
ln sales to NI	0.116	3.25
Product design	-0.369	-4.36
AC1	-0.376	-5.61
AC2	-0.202	-3.85
AC3	0.307	5.86
AC4	0.182	3.65
50-99 workers	-0.287	-2.96
100-199 workers	-0.470	-4.31
200+ workers	-0.455	-4.33
textiles	-0.478	-11.23
wood products	0.384	3.93
chemicals	-0.351	-2.12
radio, TV, communications equipment	-0.149	-1.72
North	0.333	3.63
West	0.131	1.01
ρ	-0.899	-23.20
N	235	
N (R&D≤0)	126	
Log pseudo-likelihood	-121.7	
Wald test of independent equations $\chi^2(1)$ =4.01		

It is often argued that a major reason for firms not engaging in R&D is the risk involved, as well as problems with raising money in order to finance R&D activities. Table 5 above considered these issues; however here we find that such factors representing constraints linked to finance and risk were not statistically significant in the model; rather a one-standard deviation increase in the factor representing 'no need for R&D' lowers the probability of doing R&D by 25%. When this is combined with the impact of product design as the most important impact on competitiveness (raising the likelihood of R&D by over 32%), it can be seen that there is a culture for some firms whereby they concentrate on minimizing costs (rather than design) and see no role for R&D in boosting their competitiveness.

Single plant enterprises were over 50% more likely to say they could be doing R&D in the future (with this variable being negatively related to outside ownership), and those with higher external linkages and better human capital were also more likely to undertake future R&D (conditional on overcoming actual barriers to undertaking R&D). Lastly, being attached to the food & beverages sector and rubber and plastics (both relatively large in Northern Ireland), and/or being located in Belfast, lowered the probability of undertaking future R&D spending.

4 SUMMARY AND CONCLUSIONS

This paper has analysed the data from a survey of matched firms operating in Northern Ireland (approximately half undertaking R&D and half not), in order to provide a more detailed analysis of attitudes to undertaking R&D in a peripheral region. In the survey we compare similar firms (in terms of certain key characteristics which are known to play a major role in determining the likelihood of undertaking R&D or not), rather than two sub-sets of companies that have very different characteristics which explain why R&D was undertaken by one sub-group and not by the other. Overall, the sample of 250 manufacturing firms covered in the survey were predominately small (employing less than 250) and with their headquarters in Northern Ireland; that is, the type of indigenous firm that needs to be targeted in order to raise R&D activities in the region.

In the preliminary analysis of the survey data it was found that firms undertaking R&D were significantly more likely to: supply markets in Great Britain and the rest of the EU; and concentrate on product design (and to some extent marketing) – i.e. quality (or value-added) aspects of production. In contrast, companies that did no R&D were much more likely to: sell only to the local market; and look to lower costs (and improvements in their process technology) to provide a competitive edge. In all, firms that undertook R&D had greater absorptive capacity based on a wide range of factors. Moreover, the sub-sample of surveyed firms not undertaking R&D were asked if they expected to engage in R&D at any time in the next 3 years: over 70% of firms had no R&D plans, indicating the scale of the task for policy-makers wishing to encourage a greater level of R&D activity in Northern Ireland.

We then modelled the determinants of R&D expenditure using three separate models that take into account potential self-selection effects. The first model

estimated was concerned with the determinants of the R&D capital stock, using a two-stage Heckman (1979) approach; the second model estimated was similar, but considered the determinants of R&D intensity (the R&D capital stock per worker), conditional on the firm spending on R&D. The third model estimated was a probit model with sample selection to determine whether those firms that are *not* currently spending on R&D in 2005 expected to undertake any R&D in the next three years.

Concentrating on the relevance of our results in terms of their main policy implications, and emphasising more the barriers to undertaking R&D (rather than the amount spent once barriers to R&D are overcome), we found that firms with their headquarters outside the UK, or who sold mostly to local (Northern Ireland) markets, were significantly less likely to engage in R&D. Firms that concentrated on product design (as opposed to cost factors) were significantly more likely to invest in R&D. Absorptive capacity and better external linkages for sourcing technology were also associated with overcoming barriers to R&D, while those that concentrated on strengthening the human capital of their workforce, and those most closely associated with having the status of a branch-plant, were less likely to spend anything on R&D. Firm size also had a positive impact on R&D, as well as industry and location (the latter suggesting that encouraging R&D in the less well-off regions of Northern Ireland faces an additional barrier).

As to those factors that encourage non-R&D firms to start investing, a key factor is whether there has been any previous experience of doing R&D in the preceding period. Greater efficiency and selling overseas is also very important. However, we found that financial barriers and perceived risk (the most common factors presented for justifying government invention to help firms) did not act as substantive barriers to starting R&D (in the matched set of firms considered here), although a perception that R&D is not needed did have a major negative effect. When these results are combined with the further result that firms who concentrated on product design were much more likely to say they would start doing R&D, it can be seen that a fundamental problem for firms in Northern Ireland is not a *resource*-gap but a *capabilities*-gap. Hence, to encourage more firms to take-up R&D, there is a need to increase the level of internationalisation of locally-owned firms (rather than relying on inward FDI), which is also associated with a need to increase absorptive capacity. That is, overall the lack of a 'culture' of undertaking R&D (and the over-emphasis on producing goods and services that compete more on costs than quality) has to be tackled. Stating the obvious, this is by no means an easy task.

Vis á vis other more entrepreneurial and technologically advanced regions (such as South East England, and Bavaria), Northern Ireland has a lot to catch-up. The necessary impact to fundamentally change (firm-based) capabilities has to be large and will likely take a long time to achieve. Moreover, the uncertainties - and time lags - involved in policies designed to develop innovation and enterprise capability suggest the value of a progressive shift towards a portfolio of policy instruments (rather than reliance on just one or two) designed to develop enterprise and systemic innovation capabilities in Northern Ireland.

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UNPUBLISHED APPENDIX

Matched Sample Survey of Firms

The methods used to obtain a sample for the survey are outlined here. Firstly, a stepwise logit regression was undertaken using 2004 plant-level data from the BERD-ARD.[10] With the dependent variable coded as 1 if the plant had a non-zero R&D capital stock in 2004 (coded 0 otherwise), the set of right-hand-side regressors comprised the age of the plant, size, the capital-labour and intermediate-inputs to labour ratios, labour costs per employee, and ownership, sub-region and industry dummy variables.

Table A1: Logit regression model of determinants of plant level R&D capital stock (>0 coded 1), Northern Ireland, 2004

RHS regressors	$\hat{\beta}$	$\partial\hat{p}/\partial x$	z-value	$\overline{X}$
ln capital-labour ratio	0.284	0.017	3.88	9.800
ln labour costs per employee	0.563	0.035	2.78	9.903
3 - 9 employees	0.843	0.058	2.73	0.359
10-19 employees	2.008	0.236	5.03	0.129
20-49 employees	3.202	0.514	9.40	0.089
50-99 employees	4.128	0.729	16.63	0.044
100-299 employees	4.605	0.804	21.12	0.023
300+ employees	5.560	0.883	32.61	0.011
Belfast	-0.541	-0.031	-3.04	0.331
North/North East	-0.744	-0.036	-3.75	0.117
South	-0.353	-0.020	-1.91	0.192
West	-0.655	-0.034	-3.36	0.169
GB-owned	-0.924	-0.039	-3.44	0.018
Food & drink (15)	0.611	0.046	2.31	0.118
Textiles (17)	1.059	0.099	2.44	0.040
Clothing (18)	1.030	0.097	1.46	0.016
Printing & publishing (22)	-1.053	-0.045	-3.91	0.085
Chemicals (24)	1.586	0.186	2.75	0.020
Iron & Steel (27)	1.230	0.127	1.30	0.009
Metals (28)	0.623	0.046	2.26	0.157
Machinery & equipment (29)	1.193	0.114	3.44	0.082
Electrical (31)	0.839	0.073	1.42	0.016
Radio & communications (32)	1.648	0.199	2.13	0.010
Instruments (33)	2.171	0.309	3.56	0.018
Motor vehicles (34)	0.989	0.091	1.96	0.026
Furniture & other manufacturing (36)	-0.696	-0.034	-2.36	0.117
constant	-12.050			

N = 4,373; pseudo R^2 = 0.40

The results from the logit model are given in Table A1. Higher capital intensity per employee is associated with a plant having a non-zero R&D capital stock (an

[10] See Harris *et al.* (2006) for details of the BERD-ARD database.

increase of just over £18k per employee – in 1980 prices – increases the probability of having a non-negative R&D stock by nearly 2%), as is paying the workforce higher wages (an increases in labour costs per employee of £20k in 1990 prices increases the probability of having a non-negative R&D stock by nearly 3.5%).

The single most important factor determining whether R&D is undertaken is the size of the plant; vis-à-vis the benchmark group of plants that employee 1 – 2 employees, those that have 3 – 9 employees are *cet. par*. 5.8% more likely to have a non-zero R&D capital stock. This increases with size thus plants with 300 or more employees are about 88% more likely to undertake R&D.

Having controlled for other covariates such as size, sector and ownership, plants that were located in Belfast were some 3.1% less likely to undertake R&D (vis-à-vis the benchmark sub-region of mid-Ulster). Being located in the North/North East, South and West of the Province also had negative impacts, *cet. par*. GB-owned plants (compared to other ownership groups), were nearly 4% less likely to undertake R&D, but there was no statistically significant effect associated with any other ownership group.

Lastly, vis-à-vis those industries omitted from Table A1, plants operating in certain industries were more likely to have non-zero R&D capital stocks (e.g. belonging to the instruments sector was associated with a 31% higher probability of undertaking R&D, with a nearly 20% higher likelihood in radio & communications and nearly 19% higher in chemicals), while operating in printing & publishing or the furniture & other manufacturing sub-groups was associated with lower probabilities of undertaking R&D (–4.5% and –3.4%, respectively).

Having estimated this model, those plants with high predicted probabilities[11] of having an non-zero R&D capital stock were selected to form the basis of the sample from which to undertake the necessary surveys required for this project. The reason for selecting a sample in this way is to insure that those firms contacted have similar characteristics to those firms that undertake R&D. Including firms with dissimilar characteristics (e.g. those with low levels of employment and/or those operating in sectors where R&D is much less likely to occur) would mean that such characteristics dominate any analysis and therefore we could not investigate as fully why firms that should be undertaking R&D (based on their characteristics that make them similar to firms that undertake R&D) in fact do not. The sub-group of firms that have a zero R&D capital stock – because they possess certain well-specified characteristics that place them into such a sub-group – are not the relevant comparator when trying to obtain additional in-depth information through surveys on the reasons for the low level of R&D spending in Northern Ireland.

[11] To ensure an adequate sample for the survey, we chose a predicted probability of 0.25 or above as the cut-off point.

Table A2: Certain Characteristics of those 2004 plants[a] chosen for survey sample

	R&D stock=0	R&D stock>0	*t*-test
$\hat{p}$ (probability that R&D stock > 0)	0.438	0.600	-10.31
AGE (in years)	9.7	12.3	-3.01
Employment	71	167	-4.56
ln labour productivity	10.189	10.279	-1.50
ln capital stock per employee	8.719	9.048	-3.07
ln intermediate inputs per employee	10.814	10.947	-1.82
ln labour cost per employee	9.817	9.940	-4.34

[a] There are 292 in the R&D stock > 0 sub-group, and 276 in the R&D = 0 sub-group.

Table A2 compares various characteristics for those plants that have been chosen for inclusion in the sample for the survey work. As can be seen, they have similar characteristics although those with a zero R&D capital stock were smaller (in employment terms), were younger, and had lower labour costs per employee. All these differences are statistically significant at better than the 1% significance level (see the last column in Table A2). They also had a significantly lower probability of a non-zero R&D capital stock.

Table A3: Industrial sectors of those 2004 plants[a] chosen for survey sample (figures are column percentages)

Industry (SIC92)	R&D stock=0	R&D stock>0
Quarrying and mining (14)	4.3	1.4
Food & drink (15)	20.7	20.5
Tobacco (16)	0.4	0.3
Textiles (17)	6.2	8.6
Clothing (18)	2.5	3.1
Wood (20)	3.6	3.4
Paper (21)	1.8	1.7
Printing & publishing (22)	0.7	0.3
Chemicals (24)	3.6	6.8
Rubber & plastics (25)	5.8	7.5
Non-metallic minerals (26)	9.4	5.1
Iron & Steel (27)	1.1	0.7
Metals (28)	11.2	6.8
Machinery & equipment (29)	13.0	11.0
Office machinery & computers (30)	0.4	1.4
Electrical (31)	1.4	3.4
Radio & communications (32)	2.2	4.1
Instruments (33)	3.6	5.1
Motor vehicles (34)	3.3	5.1
Other transport (35)	0.4	2.4
Furniture & other manufacturing (36)	2.5	0.3
Recycling (37)	1.8	0.7

[a] There are 292 in the R&D stock > 0 sub-group, and 276 in the R&D = 0 sub-group.

Table A3 shows that the plants chosen for inclusion in the survey have a similar distribution across industrial sectors. Tables A4 and A5 indicate that the two sub-groups are comparable in terms of the distribution by ownership and spatial location.

Table A4: Country of ownership of those 2004 plants[a] chosen for survey sample (figures are column percentages)

Country of ownership	R&D stock=0	R&D stock>0
Northern Ireland	86.2	76.2
Commonwealth	0.4	2.1
Ireland	2.9	4.1
SE Asia	0.0	2.1
US	2.9	7.6
Europe	1.8	3.1
Great Britain	5.8	4.8

[a] There are 292 in the R&D stock > 0 sub-group, and 276 in the R&D = 0 sub-group.

Table A5: Sub-region of those 2004 plants[a] chosen for survey sample (figures are column percentages)

Country of ownership	R&D stock=0	R&D stock>0
Belfast	33.3	32.5
North/NE	12.3	10.6
South	18.1	22.3
West	11.2	12.3
Mid-Ulster	25.0	22.3

[a] There are 292 in the R&D stock > 0 sub-group, and 276 in the R&D = 0 sub-group.

Finally, of the sample of 568 plants chosen from the 2004 survey for their similar characteristics in terms of the probability of undertaking R&D, when plants are aggregated to the level of the firm (some 5.4% of the plant level sample comprised more than one plant belonging to a firm), and when these firms are then matched to the 2004 IDBR, the result is a sample of 445 firms for the telephone survey.

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