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Doran, Justin and Jordan, Declan and O'Leary, Eoin

School of Economics, University College Cork

2013

Effects of R&D spending on Innovation by Irish and Foreign-owned Businesses

By

Justin Doran, Declan Jordan and Eoin O'Leary

School of Economics,

University College Cork

Abstract

This paper estimates the private returns to four different kinds of R&D spending on the probability of Irish and foreign-owned businesses engaging in product, process and organizational innovation. By providing econometric analysis of nearly 2000 businesses in the Community Innovation Survey: 2004 to 2006, it makes an important contribution to our understanding of the effects of Irish innovation policy, which has incentivized businesses to spend on R&D in Ireland. The main findings are that Irish-owned businesses are significantly more likely than foreign-owned to introduce new products as a result of creative R&D work undertaken. Foreign-owned businesses, which spend nearly 6 times more per worker on R&D than Irish-owned, enjoy very high returns mostly from the purchase or licence of patents. This reflects a fundamental difference in the innovation activities of these businesses, which is critical for policymakers' understanding of the Irish innovation system.

Keywords: Innovation Policy; Innovation Output; Research & Development
JEL Codes: O31, R19

1. Introduction

This paper estimates the effect of research and development (R&D) spending on the probability of innovation by Irish and foreign-owned businesses. Since the late 1990s, the Irish government has set an objective, through tax incentives for businesses and public expenditure programmes, to increase total R&D spending to 3% of GDP as part of the so-called Lisbon Strategy. However, to date no econometric analysis has been undertaken on the private return to different forms of R&D spending for Irish-based firms. By using the large scale Community Innovation Survey (CIS): 2004 to 2006 this paper makes an important contribution to assessing Irish innovation policy. Furthermore, recent Irish research has suggested that the importance of external interaction for business innovation has been over-stated, thus pointing to the need to conduct a detailed investigation of the returns on R&D expenditure (Doran and O'Leary, 2011).

Section 2 outlines developments in Irish innovation policy since the late-1990s. This is followed in the next section by a discussion of the conceptual framework used and an identification of a gap in the literature on the analysis of private returns to R&D spending. Section 4 specifies the models tested. This is followed by a description of the CIS: 2004-06 data in Section 5. The next section presents the results of the analysis followed by a discussion of their implications for policymakers in Section 7.

2. The Irish Innovation Policy Context

There has long been a policy consensus on how business-level innovation is to be encouraged in Ireland. Forfás (2000) highlighted the importance of technology linkages and innovation systems for stimulating innovation in Irish businesses. Among the measures recommended by Forfás were the establishment of 'technology intelligence' networks and the development of strategic collaborative partnerships between industry and third-level/state institutions (2000:82). Forfás proposed a science-based industrial policy to "foster clusters of world-class technology based companies" (2003:9).

The Enterprise Strategy Group (2004) identified key sectors with potential for future growth. These include knowledge-based, 'high-technology' sectors, in which Ireland, through innovation, could develop internationally competitive businesses. Through the *Strategy for Science, Technology and Innovation 2006-13*, the Irish government committed €1.9 billion to fund research activity in third–level institutions and supports for research in private and public research centres (Department of Enterprise, Trade and Employment, 2006:13).

More recently, *Building Ireland's Smart Economy* was published by the Irish government in 2008 as its strategy to "reorganize the economy" and generate renewed prosperity and growth (Department of the Taoiseach, 2008:1). The document states that:

> *Ireland has already laid the foundations of the ideas economy by investing heavily in education, skills training and R&D under the National Development Plan [2007-2013], which includes delivery of the Strategy for Science, Technology and Innovation involving major investments in basic research*

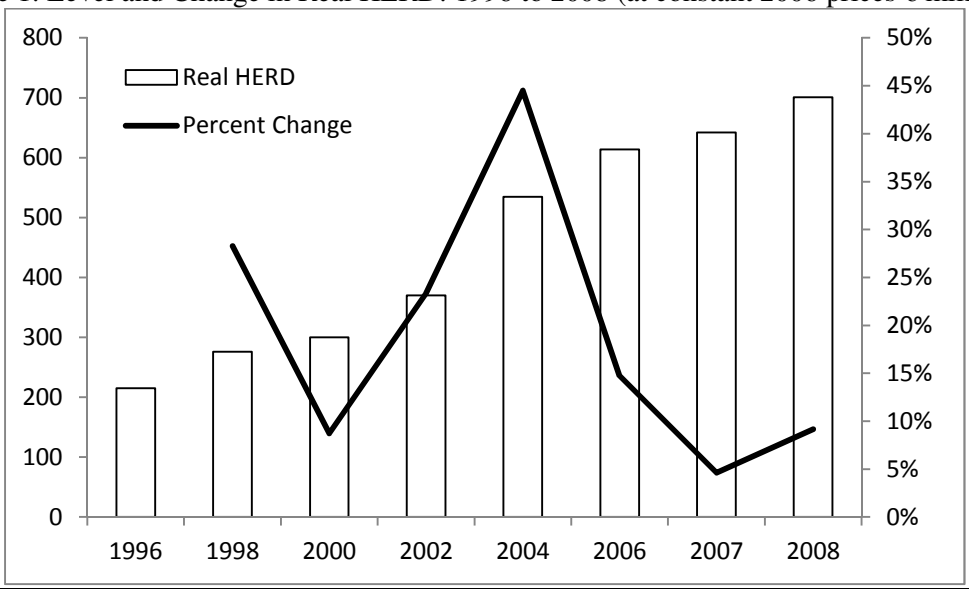
> *through the PRTLI, SFI and other funding programmes. €8.2 billion has been committed to research, technological development and innovation [under the National Development Plan 2007-2013]. Business expenditure on R&D is targeted to grow to about €3.8 billion per annum by 2013.*
>
> *(Department of the Taoiseach, 2008:60)*

Irish policy makers clearly link the "ideas economy" with greater investment in science and technology. The emphasis placed by policymakers on innovation as a key source of future Irish competitiveness has its origin at the beginning of the millennium, when the so-called 'Celtic Tiger' growth spurt looked to have ended. The policy shift towards funding R&D in businesses and Higher Education Institutes (HEIs) was initiated under the National Development Plan, 2000-2006 (2000). This commitment has led to two strands of activity in relation to Irish R&D expenditure; (i) significantly increased funding for Higher Education Research and Development (HERD) and (ii) supports to incentivize Business Expenditure on Research and Development (BERD).

Around the time of the publication of the *National Development Plan 2000-2006*, Science Foundation Ireland was established to undertake and support strategic research of world class status in niche areas of ICT and biotechnology, including the underlying scientific disciplines (Forfas, 2005). Three years earlier the Programmes for Research in Third Level Institutes (PRTLI) were initiated with the aim of achieving a permanent transformation in the Irish research environment. These initiatives represent a significant commitment of State resources to research in higher education by offering HEIs an opportunity to build infrastructure and develop the careers of Ireland's researchers.

Figure 1 shows the level and change in HERD expenditure from 1996 to 2008. There has been a three-fold increase in real terms. This increase has been sourced to a very

Figure 1: Level and Change in Real HERD: 1996 to 2008 (at constant 2006 prices € millions)



Source: Forfás (2007 and 2010a)
Note: Percentage changes are bi-annual.

large extent from public funds. Table 1 shows the composition of funding for HERD from 2002 to 2008. It can be seen that approximately 90% of funding is provided by public sources, with over 80% directly or indirectly from the Irish government and approximately 10% from EU public sources. It is noticeable that the proportion of total funding from Irish and foreign-owned businesses has declined over the period.

Table 1: Composition of HERD by Funding Source (€million)

	2002		2004		2006		2008	
Direct Government	136	*42%*	203	*41%*	265	*44%*	405	*54%*
Indirect Government	128	*40%*	205	*42%*	248	*41%*	219	*29%*
EU Public	24	*7%*	30	*6%*	38	*6%*	46	*6%*
Irish Business	12	*4%*	13	*3%*	11	*2%*	23	*3%*
Foreign Business	7	*2%*	10	*2%*	5	*1%*	6	*1%*
Private/Individual	0	*0%*	0	*0%*	26	*4%*	13	*2%*
Other	15	*5%*	31	*6%*	6	*1%*	37	*5%*
	322		492		599		749	

Source: Forfás (2010a:21)

The second strand of policy in relation to Irish R&D expenditure has been to increase supports for Business Expenditure on Research and Development (BERD). This can clearly be seen in the funding for science and technology from Irish enterprise agencies. Table 2 shows that almost half of total grant funding from Enterprise Ireland and IDA Ireland is attributable to science and technology. It is notable also that the share of IDA Ireland funding for science and technology has increased since 2004, with the funding from Enterprise Ireland declining. In addition, Science Foundation Ireland provides funding for research in science and technology of approximately €170 million annually.

Table 2: Funding for Research, Development and Innovation (RDI) by State Agencies

	2001 (€m)	2002 (€m)	2003 (€m)	2004 (€m)	2005 (€m)
Enterprise Ireland Total Grant Aid[1]	137	121	111	107	130
of which S&T (% of total)[2]	48 (35%)	63(52%)	63 (57%)	64 (60%)	81 (60%)
IDA Ireland Total Grant Aid	109	118	96	65	87
of which S&T (% of total)[3]	32 (30%)	69 (59%)	29 (30%)	10 (16%)	13 (15%)
Total	**246**	**239**	**207**	**172**	**217**
Total S&T	80 (33%)	132 (55%)	92 (44%)	74 (43%)	94 (43%)
	2006 (€m)	2007 (€m)	2008 (€m)	2009 (€m)	2010 (€m)
Enterprise Ireland Total Grant Aid[1]	132	146	220	250	295
of which S&T (% of total)[2]	83 (58%)	87 (60%)	100 (45%)	102 (41%)	106(36%)
IDA Ireland Total Grant Aid	97	79	80	81	120
of which S&T (% of total)[3]	32 (33%)	44 (56%)	47 (59%)	61(75%)	80 (67%)
Total	**229**	**225**	**300**	**331**	**415**
Total S&T	115 (50%)	131 (58%)	147 (49%)	163 (49%)	186 (45%)

Source: IDA Ireland and Enterprise Ireland Annual Reports 2003 to 2010.
Notes:

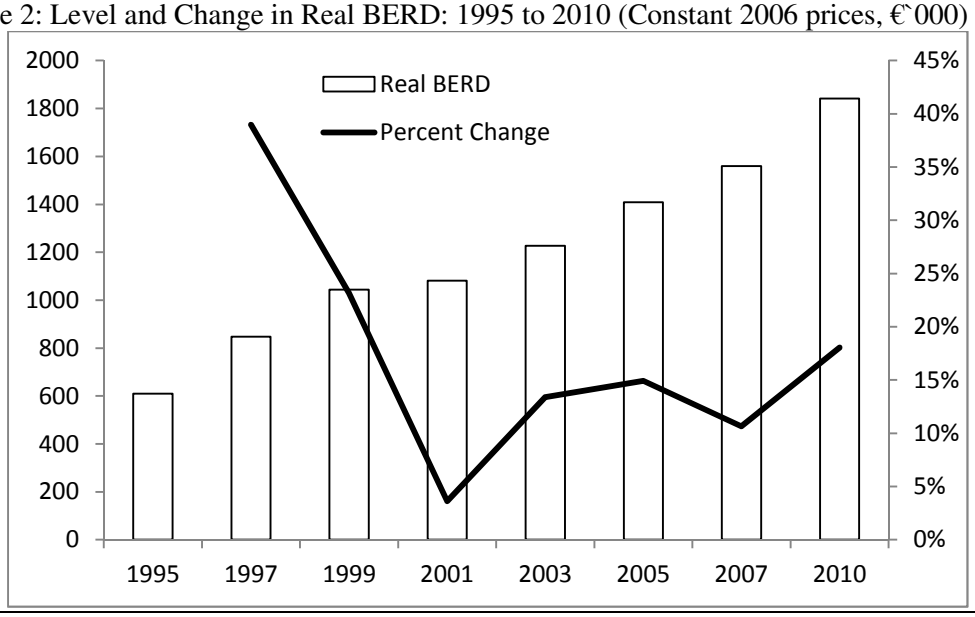
1. Total Financial Support for Industry Charged to Income and Expenditure Account.
2. Financial Support for Science Technology and Development
3. From 2000 to 2005 this includes grants paid for 'New Skills & Technologies' and 'RT&I Initiative' and from 2005 onwards comprises of grants paid for 'R&D Capability' and 'RT&I Initiative'.

The unavoidable conclusion to be drawn is that the Irish government has played a leading role in increasing the level of funding for R&D. A range of supports have been on offer to Irish-owned businesses over the years through Enterprise Ireland. A recent example is the Innovation Voucher scheme aimed at indigenous businesses of less than 50 employees. Vouchers, with a maximum value of €5,000, can be redeemed by businesses for research undertaken by approved third level institutes. Between June 2007 and December 2009, 694 innovation vouchers have been issued (Enterprise Ireland, 2011).

R&D in Irish branches of foreign multinationals has been subsidised through a combination of IDA Ireland grant aid, tax rates, tax credits, tax exemptions and matched funding with the objective of maintaining Ireland as an attractive "value proposition" for foreign direct investment (IDA Ireland, 2011:18). More recently this has included the establishment, through Science Foundation Ireland of Strategic Research Clusters and Centres for Science, Engineering and Technology (CSETs) which provide funding of up to €7.5m and €25m respectively with a 25% cost share for industry. This is targeted at large businesses, typically branches of multinationals, which can benefit from R&D conducted at HEIs at a quarter of the full cost.

Business spending on R&D, which is approximately two thirds of gross expenditure on R&D, has also been increasing, albeit at a slower rate than higher education funding. Figure 2 shows the level and change in BERD between 1995 and 2010.

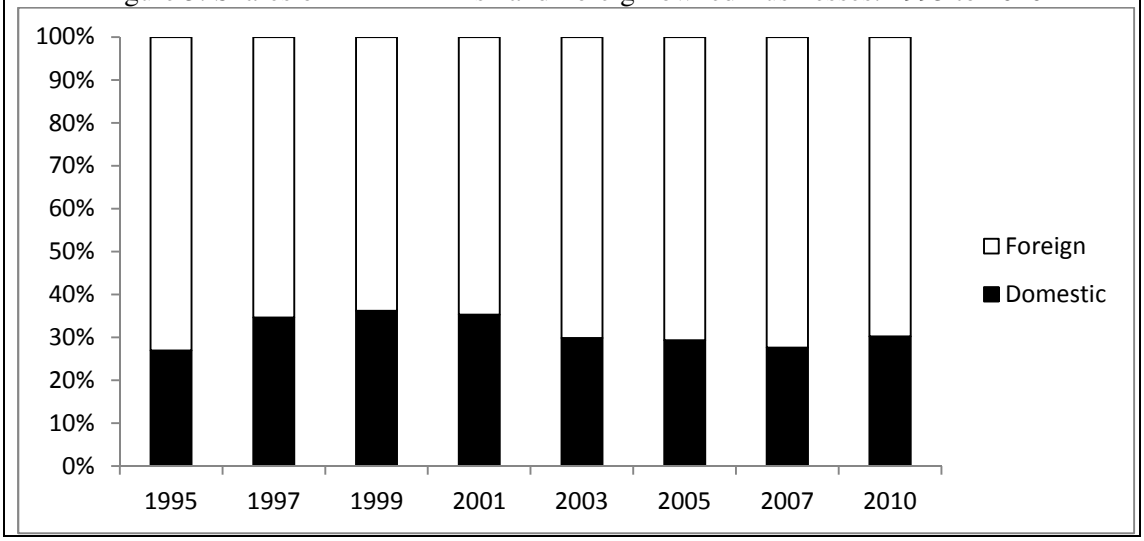
Figure 2: Level and Change in Real BERD: 1995 to 2010 (Constant 2006 prices, €`000)



Source: Department of Enterprise, Trade & Employment (2009) and CSO (2011)
Note: Percentage changes are bi-annual.

The level of BERD has increased throughout the last fifteen years, though in recent years the rate of growth has slowed. The increase in BERD has resulted from increases in R&D spending in domestic and foreign-owned businesses. Figure 3 shows that approximately 70% of BERD in Ireland occurs in the Irish branches of foreign-owned multinationals. This reflects a larger average spend on R&D by foreign-owned businesses. These businesses account for approximately one quarter of all businesses engaged in R&D (CSO, 2011:41).

Figure 3: Shares of BERD in Irish and Foreign-owned Businesses: 1995 to 2010



Source: Forfas (2010b:19) and CSO (2011)

It is worthwhile to explain why Irish branches of foreign-owned multinationals perform R&D, since the relatively low Irish corporate tax rate would appear to act as a deterrent to the location of this activity in Ireland. R&D is a cost to any business. To optimise the benefit of Ireland's low relative corporate tax rate, multinational businesses would benefit from locating revenue generating activities in Ireland and cost generating activities in higher-tax jurisdictions. This would maximise the profit for the multinational business that is taxed at the lower rate.

The R&D tax credit and special tax treatment of royalties on intellectual property are designed to overcome this difficulty. Ireland has had a 25% R&D tax credit scheme since 2004. This tax credit is in addition to the 12.5% corporate tax deduction for R&D expenditure. The credit is available on the incremental cost of qualifying R&D. Incremental cost is calculated using 2003 as the base year. Capital and current expenditure qualifies for the credit, so this includes salaries, related overheads, plant and machinery and buildings. The effect of the tax credit is to eliminate the tax disadvantages associated with locating R&D activity in a low-cost tax jurisdiction such as Ireland.

In addition to the low corporate tax rate and R&D tax credit, the Irish government also exempts income from qualifying patents. These patents are those where "the research, planning, processing, experimenting, testing, devising, designing, developing or other similar activity leading to the invention was carried out in Ireland or the European Economic Area (EEA)" (IDA Ireland, 2011:8). It is unclear how much of any of these activities must have been carried out in Ireland in order to

qualify. In addition the identification of qualifying patents is negotiated between the business and the Irish tax authorities.

3. Research on Irish Business Innovation.

The previous section has outlined the levels of business and public investment in R&D since the mid-1990s in the context of state supports in the form of taxation and other incentives. This section begins with an outline of a conceptual framework for assessing Irish innovation policy. It proceeds to take stock of what we already know from existing research about Irish business innovation and identifies a gap in our knowledge about the the role of R&D.

According to Roper, Hewitt-Dundas and Love (2003; 2004) the potential benefits of R&D activity are numerous and may be private and social. Businesses engaging in R&D activity may capture benefits through the resulting increments to their private stock of knowledge and commercial gains from the introduction of new products, processes and/or organizational forms. Social benefits refer to other businesses benefitting through increments to the public stock of knowledge resulting from private R&D activity. They may also benefit from rent spillovers through, for example, cost reductions or scale advantages. Finally, other businesses may benefit from pure knowledge spillovers through vertical and horizontal linkages and agglomeration economies.

From an Irish perspective three key issues arise. First is the extent to which Irish-based businesses, both Irish and foreign-owned, benefit privately from R&D activity. This paper addresses this issue. Second, the proportion of the social benefits of R&D activity captured by Ireland is of interest. Third, the extent to which other businesses may benefit depends on whether vertical, horizontal and other forms of linkage are local, regional or national in spatial scale.

In order to comprehensively evaluate Irish innovation policy, it would be necessary to quantify each of the private and social benefits identified by Roper et al (2003; 2004) and compare them to the level of public support for R&D. This is a challenging research programme as many of the benefits are difficult to measure and available data has important limitations. However, there is a growing body of recent econometric research that goes some way to improving our understanding of these key issues.

Jordan and O'Leary (2008) critique Irish innovation policy as well as providing an insight into the innovation performance of a sample of high-technology businesses. Their critique is that Irish policy may be characterized as science-push with its three key tenets being; (i) that high-technology sectors have the greatest potential for innovation and growth, (ii) that public support should be targeted either at HEIs or at businesses interacting with HEIs and (iii) that business and public expenditure on R&D should be increased. Their empirical findings, based on a sample of 184 Irish and foreign-owned high-technology businesses, show that increased frequency of interaction with HEIs lowers the probability of both product and process innovation and that the performance of R&D enhances the likelihood of business innovation.

The availability of the Community Innovation Survey (CIS) has facilitated more broadly-based econometric analyses of innovation in Ireland. Based on a sample of 1,974 businesses from the survey for 2004-06, for the full range of manufacturing and selected service sectors, Doran and O'Leary (2011) investigate the extent of product innovation in Ireland. They show that businesses in *High-technology Manufacturing*, *All Other Manufacturing*, *Wholesale, Transport, Storage and Communication, Financial Intermediation* and *Computer, Architecture and Engineering Services* are equally likely to introduce products that are new to the firm or new to the market. This result questions the view that high-technology sectors have more potential for innovation. Interestingly, that paper finds foreign-owned businesses are more likely to engage in either form of product innovation than Irish-owned.

The absence of a positive effect on Irish innovation performance from interaction with HEI's (Jordan and O'Leary, 2008; Hewitt-Dundas and Roper, 2008) has worrying implications for Irish policy.[1] Doran and O'Leary (2011) investigate how Irish businesses source knowledge for innovation. The results point to a dichotomy in businesses' knowledge sourcing decisions. Businesses can generally be classified into those that source knowledge from market agents, such as suppliers and customers, and those that source knowledge from non-market agents, such as universities and government research institutes. This dichotomy may reflect the science-push focus of Irish innovation policy with its concentration on business-university interaction in high-technology businesses.

To conduct a comprehensive assessment of the contribution of Irish HEIs it is necessary to account for the role played by human capital in Irish business innovation. It has long been recognized that human capital plays a key role in building the absorptive capacity of the business (Cohen and Levinthal, 1990). The traditional role of HEIs as educator clearly has a potentially positive impact on Irish innovation output. The CIS survey is deficient in its treatment of human capital. The proportion of the workforce with educational qualifications, which is a feature of the CIS in other countries, is not included in the Irish case. While the BERD survey (CSO, Various Years) does address this question, there is no published research using matched data from the two surveys. Jordan and O'Leary (2008) find that firms with a higher proportion of the workforce with third level education are more likely to introduce new product and process innovation. However, this is an issue which needs to be addressed using more comprehensive data on human capital to establish the efficacy of public investment in HEIs for Irish innovation.

Doran and O'Leary's (2011) paper questions the importance of learning through interaction with market and non-market agents for innovation performance. After estimating the relationship between innovation and productivity in a simultaneous system, they find external interaction affects the decision to innovate but not the exploitation of innovation for productivity gains. However, they also find that more productive firms have higher levels of innovation output. This important result points to the primacy of cumulative learning built up within the business for innovation and suggests that the importance of external interaction, much heralded in the innovation and regional literature, has been over-emphasized. It serves as a reminder that in-house productive effort is vital. In an Irish policy context Doran and O'Leary (2011) points to the importance of drilling deeper into R&D activity for Irish business innovation.

This paper contributes to the literature and the policy debate by investigating the private returns to R&D activity. Existing research consistently points to the positive role played by R&D for the innovation performance of Irish business (Roper, Du and Love, 2008; Jordan and O'Leary, 2008; Doran and O'Leary, 2011; Doran and Jordan, 2011). This paper takes the analysis further using the more disaggregated measures of R&D in the Irish CIS and investigating their effect on innovation by Irish and foreign-owned businesses.

4. The Private returns to R&D Expenditure

Cohen and Levinthal (1989) assert that R&D plays a crucial role in the development of new knowledge and in enhancing firms' absorptive capacity. They note that firms which invest in R&D gain an increased ability to identify, assimilate and exploit knowledge for the generation of new innovations. This proposition is strongly supported by empirical evidence which shows that R&D has a significant positive effect on the probability and intensity of innovation both in Ireland and internationally (Crépon, Duguest and Mairesse 1998; Lööf and Heshmati 2002; Lööf and Heshmati 2006; Roper, Du and Love 2008; Doran and O'Leary 2011).

In addition, Griliches (1990) has raised the question whether more intensive R&D is more or less efficient as an "engine of innovation" than less intensive R&D activity. Klette and Griliches (2000) develop a model which proposes that R&D expenditure exhibits diminishing returns implying that, at the margin, the benefit in terms of the probability of innovating from each extra unit of R&D expenditure declines. They suggest that, as products become more sophisticated, the costs per efficiency unit of R&D increase. This means that increasing levels of R&D must be undertaken to secure the next innovation. This has obvious implications for policy in that it suggests that, all other things being equal, continuous investment and growth in R&D may have limited private benefits. The model adopted in this paper allows an investigation of whether the returns to R&D are diminishing in the Irish case.

This paper contributes to literature on Irish innovation policy by providing a detailed analysis of (i) the effects of different kinds of R&D expenditure on the likelihood of innovation, (ii) whether R&D expenditure exhibits diminishing returns and (iii) whether differences exist for Irish and foreign owned businesses. In order to test these hypotheses a modified version of the innovation production function is employed (Love and Mansury 2007; Roper et al. 2008; Doran and O'Leary 2011). Equation (1) is the innovation production function to be estimated:

$$IO_i = \alpha_0 + \beta_j R\&D_{ij} + \lambda_j R\&D_{ij}^2 + \phi_k Z_{ik} + \varepsilon_i \qquad (1)$$

Where IO_i is a measure of firms innovation output, $R\&D_{ij}$ is a series of j variables indicating the expenditure of firm i on j different forms of R&D. The paper uses four different types of R&D expenditure; (i) intramural R&D, (ii) the acquisition of capital, (iii) extramural R&D and (iv) the acquisition of external knowledge (see Section 5 for full definitions). Each variable is measured as expenditure per worker and β_j are the associated coefficients. $R\&D_{ij}^2$ is a series of j variables which represent the squared value of firm i's R&D expenditure per worker, with λ_j being the associated coefficients. Z_{ik} is a series of k variables indicating company specific factors for firm i, with ϕ_k being the associated coefficients and ε_i is the error term.

The objective of this paper is to assess the effectiveness of R&D expenditure for firm innovation performance. While the literature typically measures the direct impact of R&D on firm performance, as captured by the coefficients β_j, this paper in addition considers a quadratic relationship between R&D expenditure and innovation (Roper et al. 2008). If the β_j coefficients are significant the rate of return to R&D expenditure at the margin can be derived from the λ_j coefficients. If λ_j coefficients are positive, then it can be concluded that R&D expenditure exhibits increasing returns, a negative coefficient would imply that R&D expenditure exhibits diminishing returns and an insignificant coefficient would imply that R&D expenditure exhibits constant returns.

Three types of innovation output are considered. These are product, process and organizational innovation and are described in more detail in the next section. All variables are expressed as binary indicators of whether a firm has introduced a new innovation or not during the reference period, from 2004 to 2006. As the dependent variable is binary a probit model is used to estimate equation (1).

The control variables Z_{ik} include the size of the firm (expressed as the number of people employed), a measure of human capital and the sector the firm operates in. Previous literature on the innovation production function suggests that it is important to control for potential firm heterogeneity arising from these factors (Pavitt 1984; Crépon et al. 1998; Freel 2003).

As already noted, this paper is concerned with whether the returns to R&D expenditure vary between Irish and foreign-owned businesses. In order to test whether the variance in coefficients across ownership is significantly different two different techniques are utilized; (i) likelihood-ratio tests are employed to assess whether the variation across the two ownership types is significantly different (Long and Freese 2001; Greene 2008) and (ii) interaction terms are used to assess whether there is a significant difference across the coefficients of Irish and foreign- owned businesses. The likelihood ratio tests involve comparing the estimation of equation (1) for the full sample to the estimations of equation (1) for the sub-samples of Irish and foreign-owned businesses. The test assesses whether the composite models, comprised of the separate ownership estimations of equation (1), provide a better estimation than the aggregate data estimation of equation (1). The null hypothesis is that the aggregate model applies to each form of ownership meaning there is parameter stability. The use of interaction terms involves the estimation of equation (1) with the equation augmented to include interaction terms of each variable (essentially each variable is multiplied by the dummy variable indicating whether the firm is Irish owned or not). This allows for the testing of hypotheses that specific coefficients are statistically different across Irish and foreign- owned businesses (Powers, 2005). These approaches are alternative ways of testing whether the returns are different.

One final issue which arises in our estimation is that not all businesses in our sample perform R&D. In our estimation we treat these businesses as having zero R&D expenditure in each R&D category. However, some businesses report innovation activity even though they do not engage in R&D (possibly deriving their creative ideas from other sources). This issue has been dealt with in an Irish context, using the same data as this paper, by numerous authors including Doran and O'Leary (2011)

and Doran, Jordan and O'Leary (2012). The general consensus is that, *ceteris paribus*, while businesses which engage in R&D are more likely to innovate than non-R&D active businesses other forms of knowledge sourcing can be used to supplement a lack of R&D activity. While the differing mechanisms through which non-R&D active businesses innovate provides an interesting avenue for future research it is beyond the scope of this paper[2].

5. The CIS: 2004 - 06

This paper uses data from the Irish Community Innovation Survey (CIS), which is conducted jointly by Forfás (Ireland's national policy advisory body) and the Irish Central Statistics Office. The survey sample is 1,974 businesses, representing a 48% response rate, which is high relative to other Irish studies (Roper 2001; Jordan and O'Leary 2008). The survey is directed to companies employing more than 10 persons engaged in selected sectors (see Forfás (2008) for a discussion on the sectoral framework utilised). Consistent with the OECD's Oslo manual, the survey adopts a reference period, which in this case is 2004 to 2006, for innovation inputs and outputs (OECD 2005).

The Irish CIS distinguishes between product, process and organizational innovation. Product innovation is defined as the introduction of a new or improved good or service with respect to its capabilities, user friendliness, components or sub-systems. These innovations must be new to the business, but they do not need to be new to the market. Process innovation is defined as the implementation of a new or improved production process, distribution method, or support activity for goods or services. Again, process innovations must be new to the business but not necessarily the market. Finally, the CIS defines organizational innovation as the implementation of new business practices for organizing procedures, new methods of organizing work responsibilities and decision-making or new methods of organizing external relations with other firms or public institutions. These exclude mergers or acquisitions, even if for the first of such for the business. Firms indicate whether they have performed any of these types of innovation, resulting in a series of binary innovation variables. Table 3 shows that 32% of Irish-owned firms engaged in product innovation, 30% in process innovation and 40% in organizational innovation. These are lower than foreign-owned businesses where the percentages are 53%, 46% and 56% respectively.

The central focus of this paper is the returns from R&D expenditure for innovation performance. The Irish CIS distinguishes between four types of R&D expenditure. The first relates to intramural R&D expenditure by a firm and is defined as creative work undertaken within an enterprise to increase the stock of knowledge and its use to devise new and improved products and processes. The second is the acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes in the enterprise. The third form of R&D is extramural R&D expenditure, which is defined as the same activities as intramural R&D, but performed by other companies or by public or private research organisations and purchased by the enterprise. The final form of R&D is the acquisition of other external knowledge which is defined as the purchase or licensing of patents and non-patented inventions, know-how and other types of knowledge from other organisations. Descriptive statistics for R&D expenditures are displayed in Table 3, disaggregated by ownership.

It is immediately apparent that foreign-owned businesses are considerably more R&D intensive. On average they spend nearly 4 times more per worker than Irish-owned businesses on intramural R&D, 5 times more on the acquisition of capital for innovation, 9 times more on extramural R&D and 33 times more on the acquisition of external knowledge. The large standard deviation on spending by foreign-owned firms on the acquisition of external knowledge is of interest and suggests very large spending by a small number of large firms.

Table 3: Descriptive Statistics from the Irish CIS 2004-06

Variable	Irish-Owned		Foreign-Owned	
	Mean Value	Standard Deviation	Mean Value	Standard Deviation
Innovation				
Product Innovator (1/0)	32.31%	n.a.	53.25%	n.a.
Process Innovator (1/0)	30.13%	n.a.	46.35%	n.a.
Organisational Innovator (1/0)	40.42%	n.a.	56.41%	n.a.
R&D Activity				
Intramural R&D	€ 1,370	€ 7,634	€ 4,881	€ 20,582
Acquisition of Capital for Innovation	€ 1,719	€ 13,030	€ 8,621	€ 60,900
Extramural R&D	€ 108	€ 1,480	€ 981	€ 9,338
Acquisition for External Knowledge	€ 134	€ 1,731	€ 4,366	€ 54,112
Sector				
High Technology Manufacturing	8.86%	n.a.	28.99%	n.a.
All Other Manufacturing	32.38%	n.a.	22.88%	n.a.
Wholesale, Transport, Storage & Communication	39.33%	n.a.	21.89%	n.a.
Financial Intermediation	6.13%	%n.a.	14.99%	n.a.
Computer, Architecture & Engineering Services	13.29%	n.a.	11.24%	n.a.
Business Specific Factors				
Employment	86	524	232	564
Lack of Human Capital				
No Impact	49.9%	n.a.	45.56%	n.a.
Low Impact	21.95%	n.a.	28.8%	n.a.
Medium Impact	19.43%	n.a.	19.92%	n.a.
High Impact	8.73%	n.a.	5.72%	n.a.

The sectors surveyed in the CIS are the complete range of manufacturing sectors and three services sectors: *Wholesale, Transport, Storage and Communication; Financial Intermediation;* and *Computer, Architecture* and *Engineering Services.* This paper classifies manufacturing into *High-Tech Manufacturing* and *All Other Manufacturing*. The services sector *Computer, Architecture and Engineering Services* is also classified as high-technology (National Competitiveness Council, 2009).

Business specific factors also included from the Irish CIS are the number of people employed by the enterprise. The mean size of Irish-owned enterprises is 86 persons while foreign-owned businesses on average employ 232. To proxy absorptive capacity, a variable indicating whether the business perceives a lack of human capital as being prohibitive to innovation is included. This is an ordered variable where businesses indicate the extent to which a lack of human capital influences its ability to innovate. Half of Irish-owned businesses indicate that a lack of human capital had no impact on their innovation performance, while 22%, 19% and 9% reported low, medium and high impacts on their innovation performance respectively. These levels are similar for foreign-owned businesses. As discussed in Section 3, the more typical measure, which is the proportion of the workforce with a third level degree, is not available in the Irish CIS.

6. Econometric Results

Table 4 displays the results of the probit estimations of equation (1), with interaction terms. For ease of interpretation marginal effects are presented. The estimates for the likelihood ratio tests based on equation (1) for Irish and foreign-owned businesses are presented in Appendix 1. It should be noted at this point that both approaches produce identical coefficient results (Stata, 2010), so for brevity the paper just discusses the results for the interaction model (for completeness Appendix 2 contains the original coefficients for the interaction model).

Figures 4 to 6 graphically present the impacts for both Irish and foreign-owned businesses of the different forms of R&D activity for product, process and organizational innovation. Only the variables with significant coefficients on R&D expenditure in Table 4 are used in constructing these Figures.[3]

In 13 of the 24 cases, the value of β_j is positive and significant as expected with the remainder being statistically insignificant (see Appendix 1). This implies that various kinds of R&D expenditure per worker have positive effects on the likelihood of innovation. This generally concurs with the literature (Griffith, Huergo, Mairesse and Peters (2006), Crépon et al. (1998), Doran and O'Leary (2011)). However, by disaggregating R&D spending and investigating the relationship for Irish and foreign-owned businesses and for different types of innovation output, this paper offers more detailed evidence of particular interest to policymakers. The results for product, process and organizational innovation are discussed in turn, followed by a final sub-section on business specific factors.

R&D for Product Innovation

While both Irish and foreign-owned businesses engaging in intramural R&D are more likely to innovate, the marginal effect of the Irish-owned interaction term of +0.47 is 2 times larger than the marginal effect for foreign-owned businesses. This form of R&D relates to creative work undertaken within an enterprise to increase its stock of knowledge. Spending on extramural R&D has no significant effect on the innovation likelihood for both categories of ownership. For the acquisition of capital for innovation, the effects are positive for both with no significant difference between Irish and non-Irish owned businesses, although much lower than for intramural R&D. Perhaps the relatively lower return on capital for innovation may be complemented by the additional benefits of using new capital to enhance productive efficiency of existing products (Doran and O'Leary, 2011).

Both intramural R&D and the acquisition of capital for innovation exhibit diminishing returns for both Irish and foreign-owned businesses, as indicated by the negative coefficient on the squared terms. This suggests that as businesses increase their R&D expenditure per worker the efficiency of each extra euro spent diminishes. This is consistent with Klette and Griliches's (2000) assertion that R&D expenditure exhibits diminishing returns.

The acquisition of external knowledge, which refers to the purchase or licensing of patents and non-patented inventions, know-how and other types of knowledge from other organisations, has a positive impact on the likelihood of foreign-owned businesses engaging in product innovation. With a marginal effect of 0.21, this is by far the highest return on any form of R&D.[4] Moreover, it is noteworthy that foreign-owned businesses acquisition of these forms of knowledge displays increasing returns. This signifies that the probability of innovation rises at an increasing rate for every extra euro of R&D expenditure. This is represented as a convex curve in Figure 4b. This is the only occurrence of increasing returns observed and runs counter to what is anticipated from Klette and Griliches (2000).

R&D for Process Innovation

Intramural R&D, extramural R&D and the acquisition of capital for innovation have significantly positive effects on the likelihood of process innovation in Irish-owned businesses. Of these the marginal effect of extramural R&D, which relates to the same activities as intramural R&D, but performed by other companies or organisations and purchased by the enterprise, is by far the largest. This can be clearly seen in Figure 5, which also shows strong diminishing returns to this form of R&D for process innovation. Interestingly, the importance of intramural R&D and the acquisition of capital for Irish businesses is reversed from the results for product innovation. Firms which purchase new capital for innovation, such as manufacturing equipment or software, are likely to change their production processes as a result. For foreign-owned businesses only the acquisition of capital for innovation is the only R&D expenditure that exhibits a significantly positive effect on the likelihood of process innovation.

R&D for Organizational Innovation

Results for organizational innovation are very similar to those for process innovation. Again, intramural R&D, extramural R&D the acquisition of capital for innovation have significantly positive effects on the likelihood of organizational innovation for Irish-owned businesses while for foreign-owned businesses only the acquisition of capital for innovation is significantly positive. The returns to R&D also exhibit diminishing returns, regardless of ownership. This similarity in results for process and organizational innovation may reflect how the implementation of new or improved production processes, distribution methods, or support activities and the implementation of new business practices operate in parallel.

Business Specific Factors

In addition to R&D positively impacting on the likelihood of businesses innovating, business-specific variables also suggest that larger businesses are more likely to introduce all types of innovations (regardless of whether they are Irish or foreign-owned). Businesses which report a lack of human capital are also more likely to

innovate. While this human capital finding may appear counterintuitive, Doran and O'Leary (2011) argue this may arise where firms are under pressure to innovate in order to overcome this deficiency or if innovative firms are more likely to perceive a lack of human capital in their firm. Sectoral effects are also observed, with both Irish and foreign-owned businesses in the high-technology sectors of *High-Tech Manufacturing* and *Computer, Architecture and Engineering Services* more likely to introduce product innovation. Irish-owned businesses and foreign-owned businesses in *High-Tech Manufacturing* are more likely to process innovate. The likelihood of organizational innovation appears not to vary much between sectors.

Table 4: Probit Estimation of Equation (1) using Interaction Terms

Variable Names	Product		Process		Organizational	
	Irish[d]	Foreign	Irish[d]	Foreign	Irish[d]	Foreign
R&D Expenditure						
Intramural R&D	0.0473***	0.0250***	0.0148***	0.0017	0.0144***	-0.0034
	(0.0112)	(0.0064)	(0.0053)	(0.0029)	(0.0054)	(0.0030)
Intramural R&D Squared	-0.0004***	-0.0001***	-0.0002***	0.0000	-0.0001***	0.0000
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Acquisition of Capital for Innovation	-0.0077	0.0163***	0.0192***	0.0050***	0.0305***	0.0037***
	(0.0055)	(0.0050)	(0.0034)	(0.0016)	(0.0055)	(0.0019)
Acquisition of Capital for Innovation Squared	0.0001	-0.0002***	-0.0001***	-0.0001***	-0.0004***	-0.0001***
	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
Extramural R&D	0.0390	0.0235	0.1057***	-0.0058	0.1217***	-0.0079
	(0.0447)	(0.0145)	(0.0376)	(0.0076)	(0.0408)	(0.0086)
Extramural R&D Squared	-0.0016	-0.0001	-0.0023***	0.0000	-0.0028***	0.0001
	(0.0012)	(0.0001)	(0.0011)	(0.0001)	(0.0011)	(0.0001)
Acquisition of External Knowledge	-0.2232***	0.2055*	0.0050	0.0005	0.0039	-0.0028
	(0.1213)	(0.1189)	(0.0245)	(0.0079)	(0.0321)	(0.0132)
Acquisition of External Knowledge Squared	-0.0114***	0.0119*	-0.0001	0.0000	0.0000	0.0003
	(0.0061)	(0.0061)	(0.0006)	(0.0000)	(0.0008)	(0.0002)
Sector[c]						
All Other Manufacturing	-0.1640*	-0.1204**	-0.1320	-0.0936*	-0.2190***	-0.1053***
	(0.0859)	(0.0515)	(0.0899)	(0.0523)	(0.0970)	(0.0582)
Wholesale, Transport, Storage & Communication	-0.3339	-0.0199**	-0.0808	-0.1761***	-0.2550***	-0.0268
	(0.0532)	(0.0532)	(0.0542)	(0.0542)	(0.0598)	(0.0598)
Financial Intermediation	-0.1386***	-0.1742***	-0.0625	-0.1568***	-0.1973*	-0.0196
	(0.1010)	(0.0587)	(0.1038)	(0.0592)	(0.1095)	(0.0651)
Computer, Architecture & Engineering Services	-0.2663***	0.0094	-0.1011	-0.1172*	-0.0923	-0.0402
	(0.0941)	(0.0681)	(0.0976)	(0.0662)	(0.1055)	(0.0749)
Business Specific Factors						
Employment	0.0393**	0.0253*	0.0171	0.0496***	0.0355*	0.0298***
	(0.0180)	(0.0145)	(0.0187)	(0.0149)	(0.0204)	(0.0163)
Human Capital	-0.0078	0.0779***	-0.0464**	0.0961***	-0.0583**	0.1338***
	(0.0234)	(0.0205)	(0.0239)	(0.0207)	(0.0266)	(0.0232)
Obs.		1974		1974		1974
Chi2		620.65		382.65		307.77
Prob > Chi2		0.0000		0.0000		0.0000
Likelihood Ratio		-997.50		-1077.91		-1202.55
Pseudo R2		0.2373		0.1507		0.1134

Note a: *** indicates significance at 99%, ** indicates significance at 95% and * indicates significance at 90%.
b: Probit estimation techniques are utilised as the dependent variable is binary in nature. Marginal effects are presented for ease of interpretation.

c: High technology is the sector reference category.
d: The Irish coefficients are interaction terms, which show the differential effects of Irish compared to foreign-owned businesses.

Figure 4: The Impact of R&D on Product Innovation

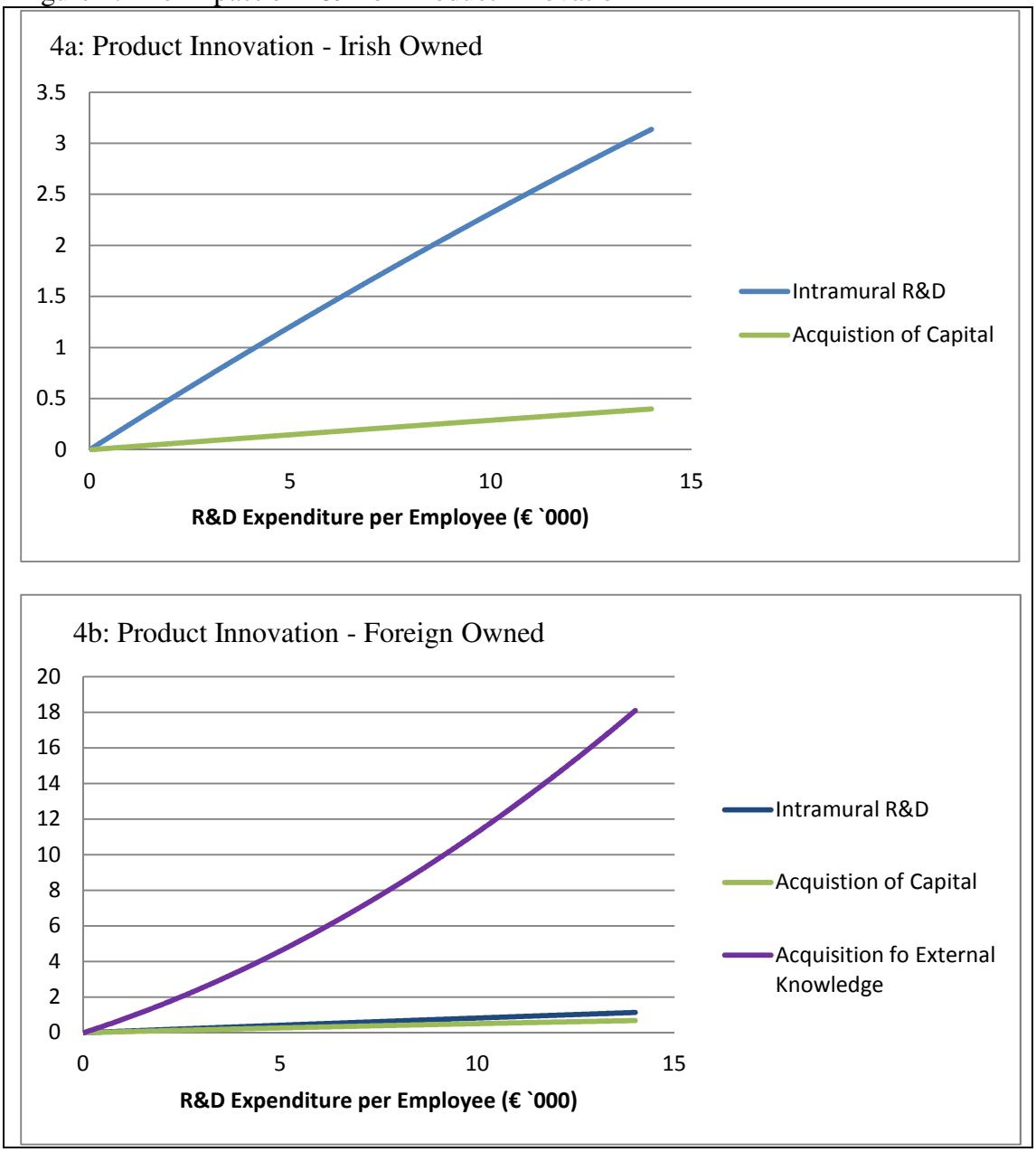


Figure 5: The Impact of R&D on Process Innvoation

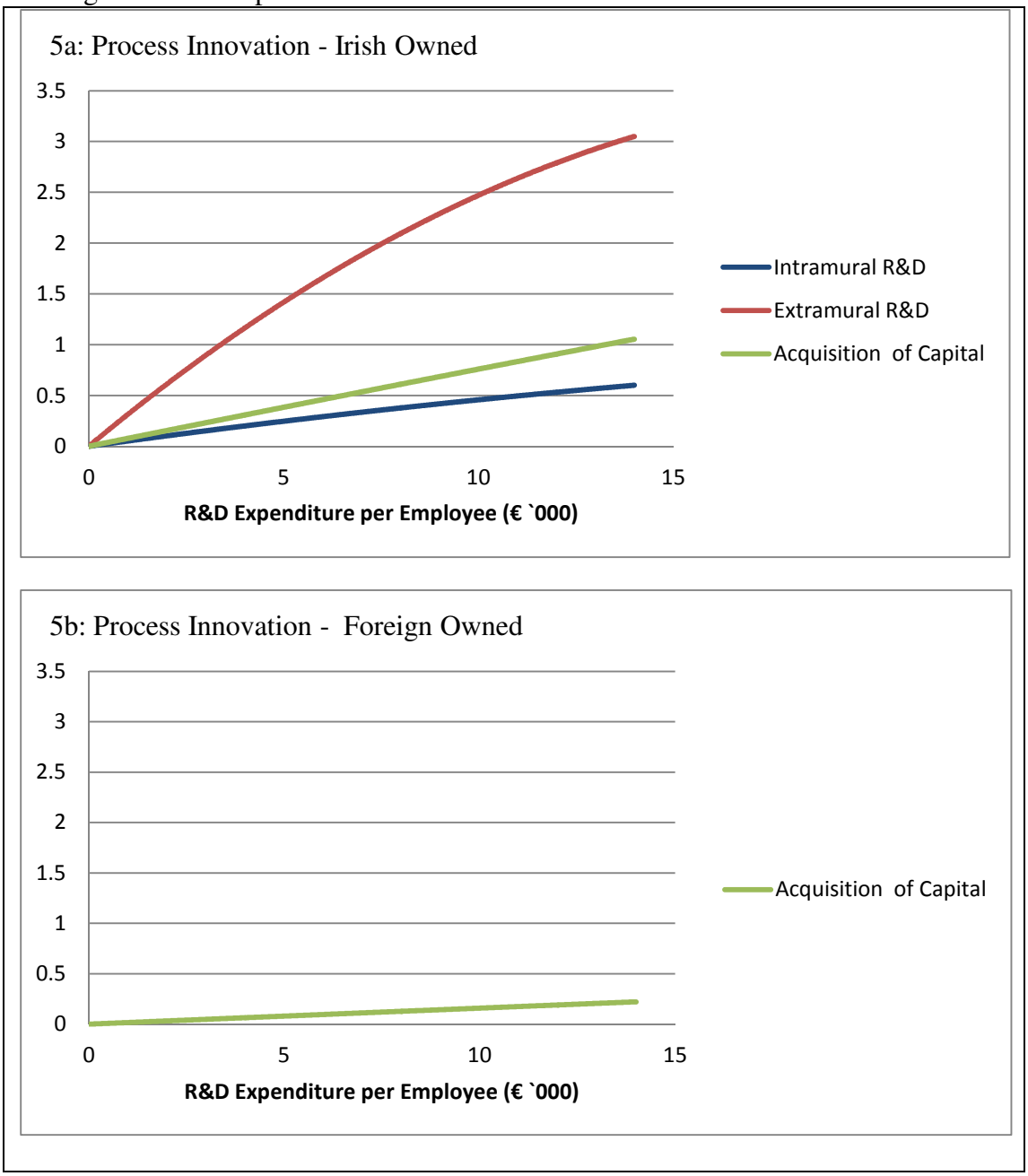
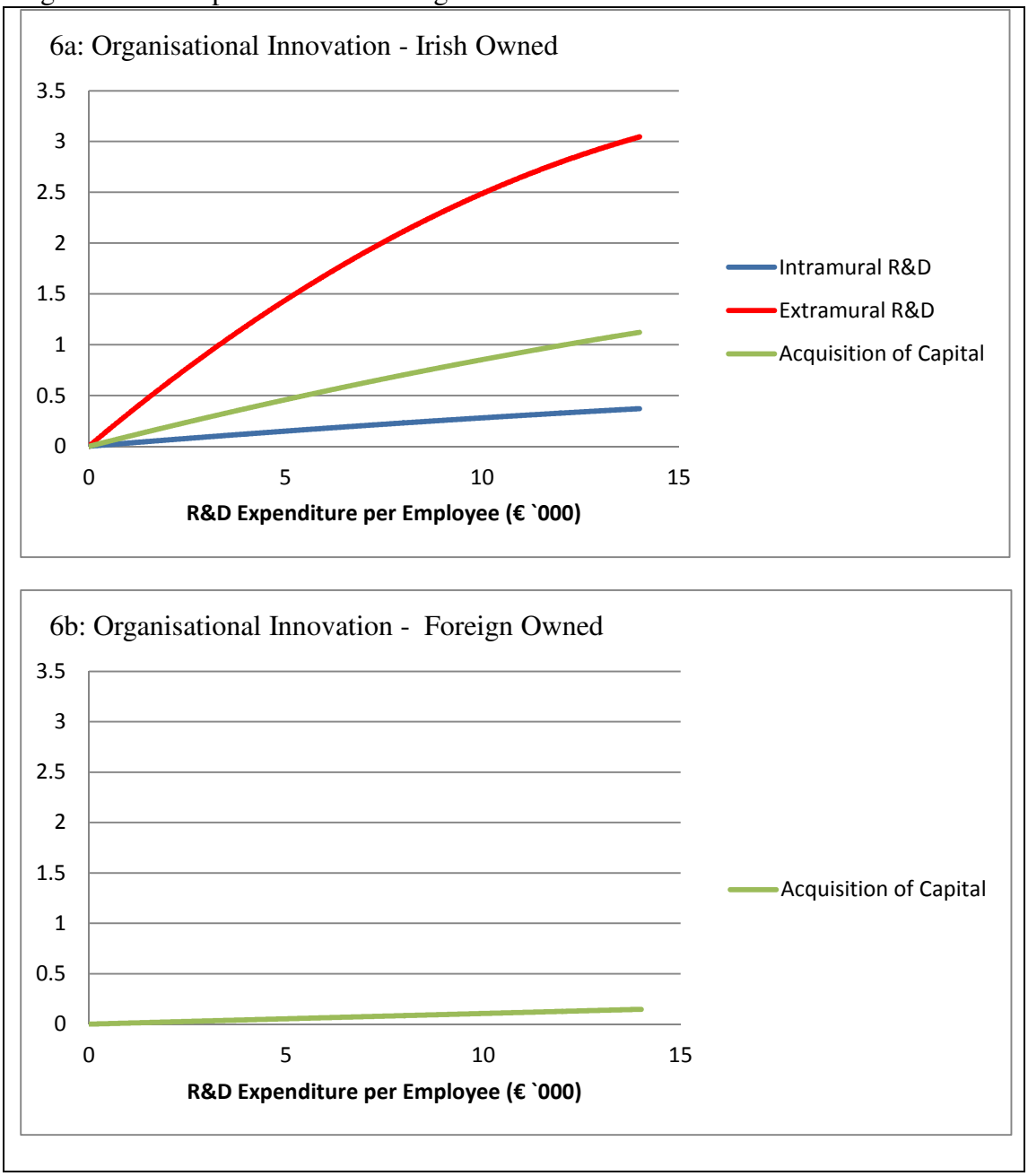


Figure 6: The Impact of R&D on Organisational Innovation



7. Implications for Policymakers

This paper has estimated the effect of R&D spending on the probability of Irish and foreign-owned businesses engaging in product, process and organizational innovation. It makes an important contribution to our understanding of Irish business by providing a detailed econometric analysis of the CIS: 2004 to 2006, on the private returns to four different kinds of R&D spending in Ireland.

One important finding that is of interest to policymakers is that Irish businesses are significantly more likely than foreign-owned businesses to introduce new products as a result of intramural R&D spending. Also, Irish businesses achieve a return from

intramural spending for process and organizational innovation, which is not experienced by foreign-owned businesses. On average Irish businesses spend nearly 4 times less per worker than foreign-owned businesses on intramural spending, which refers to creative work undertaken by the business. While all Irish-based businesses face the same incentives to engage in R&D, in terms of corporation tax and R&D tax credits, there is one important difference. As part of multi-national enterprises, the parent companies of foreign-owned businesses may make decisions on the location of corporate activities to minimize their group's corporate tax bill. This tax consideration may offset the imperative of developing new products, processes and organisational structures through intramural R&D expenditure. This consideration is not likely to be present for Irish businesses, relatively few of whom are part of multi-national enterprises.

While Irish-owned businesses appear to be superior at directing creative effort to new products, and to a lesser extent, new processes and organizational forms, it remains an open question as to whether these innovations subsequently deliver increased productivity and employment for these businesses. However, the finding is positive for the level of innovation in Irish-owned business driven by the creativity of the businesses themselves, which may contribute to increased national prosperity in the long-term. Foreign-owned businesses, which typically produce high-technology products developed elsewhere in the corporation at the growth or maturity stage of the product life cycle, may not have as strong a need to engage in product innovation as a result of intramural R&D spending. However it should be noted that these large plants have consistently contributed to Irish employment.

Irish businesses enjoy a relatively large positive return from extramural spending, but only for process and organisational innovation. Extramural spending relates to creative work performed by other companies or by public or private research organisations and purchased by the enterprise. This may reflect the tendency for indigenous businesses, which generally are small with an average employment of 86 workers, to rely more on outside sources of knowledge (Freel, 2003). It is not possible to infer, due to limitations of the CIS data, whether these sources are located within the Irish innovation system. Policymakers would clearly be interested in whether the supports available to these businesses to interact with other businesses and HEIs locally, regionally or nationally have had a positive effect. Indeed, it will be worthwhile to investigate whether, in the context of national linkages to HEIs, the introduction by Enterprise Ireland of the Innovation Voucher scheme in 2007 has had a positive effect on the innovation performance of indigenous industry (Enterprise Ireland, 2011).

Turning to the purchase or license of patents and non-patented inventions, know-how and other types of knowledge from other enterprises or organisations, it is particularly noteworthy that foreign-owned businesses, which on average spend €4,366 per worker on this form of R&D (33 times the average level of Irish businesses) enjoy a very high return to product innovation. Indeed, the exceptional finding that this is the only return exhibiting increasing returns is especially noteworthy. The presence of tax exemptions for income from patents, where research, planning, processing, experimenting, testing, devising, designing, developing or other similar activity leading to an invention was carried out in Ireland or elsewhere in the European Economic Area (EEA), is likely to act as a financial inducement to this form of

expenditure, which has a notably strong positive effect on the likelihood that these businesses will introduce new products.

It is significant to note that foreign-owned businesses engaged in product innovation and interacting with HEIs spend nearly 4 times more on collaboration with national HEIs than with HEIs in Northern Ireland and 33 times more than with HEIs in the rest of Europe.[5] Combined with the results in Table 4, this result suggests a difference in the approach to R&D activity in Irish and foreign-owned businesses. Foreign-owned businesses may be in a better position, with access to greater financial resources, to license or purchase patents associated with R&D breakthroughs in Irish HEIs. They may also benefit from collaboration with HEIs by being better placed to identify and evaluate opportunities with greater commercial potential. Foreign-owned businesses may devote more effort to identifying discoveries in HEIs with commercial potential, than in developing new products and processes internally. This sheds light on HEI collaboration which has been a major element of Irish innovation policy (see section 2).

Smaller Irish-owned businesses, on the other hand, may be less able to engage in large collaborative projects due to an inability to provide matched funding and rely more on other sources of knowledge when developing new products and processes. This may explain the variation in the returns to different kinds of R&D effort in Irish and foreign–owned businesses.

Further exploration of the differing nature of R&D efforts in Irish and foreign-owned businesses would be a worthwhile avenue for future research using complementary methods such as longitudinal studies and case analysis. It will also be of interest to policymakers whether the introduction of Strategic Research Clusters and CSETs focussed on foreign-owned businesses and Innovation Vouchers targeted at Irish-owned businesses, have had positive effects on innovation performance.

Apart from the one significant exception mentioned above, the findings indicate that, where they are significant, private returns are positive but diminishing. Thus, all other things being equal, the marginal return in terms of the added effect on the probability of innovation has been found to be diminishing. While this result is consistent with other work (Klette and Griliches, 2000), it should be noted that in practice other factors, such as the capacity of the business's human capital stock and the level and nature of its interaction with outside sources of knowledge, are not likely to be constant. Improvements in these factors, working in tandem with R&D spending, may have the potential to deliver increasing returns for the business. This would be a fruitful line for future research that would be of particular interest to policymakers.

On balance, the results point to significant differences in the relationships between R&D spending and innovation performance in Irish and foreign-owned businesses. The former have significant returns in 8 out of the 12 possible categories investigated, with the largest returns from intramural spending for product innovation and from extramural spending for process and organizational innovation. Foreign-owned businesses have significant returns in only 5 (out of a possible 12 categories) and these are by far the largest in one category, the purchase or licences of patents and

other know-how for product innovation. This may be explained both by obvious differences in relation to size, age and sectoral composition of the businesses but also by the different financial incentives each face in doing innovation in Ireland.

This paper has investigated the private returns to R&D spending by Irish-based businesses. The social return to the Irish taxpayer of offering business incentives to engage in R&D spending has not been addressed. In order to make progress on this important question it is necessary to investigate whether the benefits are captured by the Irish innovation system. In particular to what extent are the suppliers, customers, competitors and other related businesses, that benefit from R&D spending by Irish-based businesses, themselves Irish-based. In addition, how does R&D spending yield benefits in terms of up-skilling the Irish workforce? Unfortunately, as argued in Section 3, these lines of research are currently frustrated in Ireland by data availability problems.

Overall, although a comprehensive evaluation of Irish innovation policy is a substantial research programme, it is becoming increasingly important given the sizeable amounts of public expenditure, which is coming under enhanced scrutiny in the current financial crisis, that have been and are pledged to it in the future. By investigating the relationship between R&D spending and innovation performance, this paper points at important issues to be taken into account in future evaluations of Irish innovation policy.

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Appendix 1 – Likelihood Ratio Estimation of Equation (1)

Table A1: Estimations of Equation (1) with LR Test

Variable Names	Product		Process		Organizational	
	Irish	Foreign	Irish	Foreign	Irish	Foreign
Constant	-1.3225	-0.6269	-1.3514	-0.8372	-1.2228	-0.4350
	(0.1871)	(0.2767)	(0.1790)	(0.2643)	(0.1779)	(0.2588)
R&D Expenditure						
Intramural R&D	0.2503***	0.0865***	0.0528***	0.0054	0.0318***	-0.0097
	(0.0319)	(0.0225)	(0.0142)	(0.0091)	(0.0128)	(0.0087)
Intramural R&D Squared	-0.0019***	-0.0003***	-0.0007***	0.0000	-0.0004***	0.0000
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Acquisition of Capital for Innovation	0.0299***	0.0567***	0.0776***	0.0161***	0.0982***	0.0108**
	(0.0079)	(0.0173)	(0.0098)	(0.0051)	(0.0150)	(0.0055)
Acquisition of Capital for Innovation Squared	-0.0001***	-0.0006***	-0.0002***	-0.0001***	-0.0013***	-0.0001**
	(0.0000)	(0.0002)	(0.0000)	(0.0000)	(0.0003)	(0.0000)
Extramural R&D	0.2167	0.0815	0.3201***	-0.0186	0.3267***	-0.0227
	(0.1466)	(0.0503)	(0.1186)	(0.0244)	(0.1152)	(0.0247)
Extramural R&D Squared	-0.0061	-0.0005	-0.0073**	0.0001	-0.0078***	0.0002
	(0.0042)	(0.0003)	(0.0036)	(0.0002)	(0.0031)	(0.0002)
Acquisition of External Knowledge	-0.0611	0.7126*	0.0176	0.0015	0.0032	-0.0079
	(0.0857)	(0.4136)	(0.0742)	(0.0254)	(0.0840)	(0.0379)
Acquisition of External Knowledge Squared	0.0018	0.0414*	-0.0003	0.0000	0.0008	0.0008
	(0.0022)	(0.0253)	(0.0018)	(0.0001)	(0.0023)	(0.0007)
Sector						
All Other Manufacturing	-0.2899**	-0.4172**	-0.2085	-0.2998*	-0.1439	-0.3026*
	(0.1442)	(0.1795)	(0.1350)	(0.1678)	(0.1335)	(0.1676)
Wholesale, Transport, Storage & Communication	-0.5306***	-0.0691	-0.3090**	-0.5644***	-0.0218	-0.0770
	(0.1447)	(0.1842)	(0.1354)	(0.1750)	(0.1331)	(0.1719)
Financial Intermediation	-0.3883**	-0.6038***	-0.1885	-0.5025***	0.1649	-0.0562
	(0.2016)	(0.2051)	(0.1911)	(0.1906)	(0.1841)	(0.1869)
Computer, Architecture & Engineering Services	-0.1944	0.0327	-0.1854	-0.3757**	0.4073***	-0.1154
	(0.1658)	(0.2361)	(0.1535)	(0.2126)	(0.1505)	(0.2151)
Business Specific Factors						
Employment	0.2239***	0.0876*	0.2138***	0.1590***	0.1876***	0.0856*
	(0.0369)	(0.0503)	(0.0359)	(0.0481)	(0.0352)	(0.0469)
Human Capital	0.2430***	0.2701***	0.1593***	0.3079***	0.2169***	0.3844***
	(0.0374)	(0.0719)	(0.0367)	(0.0673)	(0.0350)	(0.0682)
Obs.	1467	507	1467	507	1467	507
Chi2	402.00	149.75	248.74	91.07	213.16	55.77
Prob > Chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Likelihood Ratio	-722.02	-275.47	-773.37	-304.54	-883.18	-319.36
Pseudo R2	0.2178	0.2137	0.1385	0.1301	0.1077	0.0803

Note a: *** indicates significance at 99%, ** indicates significance at 95% and * indicates significance at 90%.

b: Probit estimation techniques are utilised as the dependent variable is binary in nature.

c: High technology is the sector reference category.

d: The Likelihood ratio tests for product, process and organisational innovation have Chi2 values of 61.85, 65.26 and 77.70 respectively resulting in and a p-value of 0.0000 for each type of innovation. This suggests that there is a statistically significant difference in the coefficients for Irish and foreign-owned firms.

Appendix 2 – Coefficient Estimates of Equation (1) Interaction Model

	Product		Process		Organizational	
	Irish	Foreign	Irish	Foreign	Irish	Foreign
R&D Expenditure						
Intramural R&D	0.1639***	0.0865***	0.0474***	0.0054	0.0415***	-0.0097
	(0.0390)	(0.0225)	(0.0169)	(0.0091)	(0.0155)	(0.0087)
Intramural R&D Squared	-0.0016***	-0.0003***	-0.0007***	0.0000	-0.0004***	0.0000
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Acquisition of Capital for Innovation	-0.0268*	0.0567***	0.0615***	0.0161***	0.0875***	0.0108**
	(0.0190)	(0.0173)	(0.0111)	(0.0051)	(0.0160)	(0.0055)
Acquisition of Capital for Innovation Squared	0.0005**	-0.0006***	-0.0001***	-0.0001***	-0.0013***	-0.0001*
	(0.0002)	(0.0002)	(0.0000)	(0.0000)	(0.0003)	(0.0000)
Extramural R&D	0.1352	0.0815	0.3387***	-0.0186	0.3495***	-0.0227
	(0.1550)	(0.0503)	(0.1211)	(0.0244)	(0.1178)	(0.0247)
Extramural R&D Squared	-0.0056	-0.0005	-0.0074**	0.0001	-0.0080***	0.0002
	(0.0042)	(0.0003)	(0.0036)	(0.0002)	(0.0031)	(0.0002)
Acquisition of External Knowledge	-0.7734	0.7123*	0.0161	0.0015	0.0111	-0.0079
	(0.4216)	(0.4128)	(0.0784)	(0.0254)	(0.0922)	(0.0379)
Acquisition of External Knowledge Squared	-0.0395	0.0414**	-0.0003	0.0000	0.0000	0.0008
	(0.0212)	(0.0211)	(0.0018)	(0.0001)	(0.0024)	(0.0007)
Sector						
All Other Manufacturing	-0.5684**	-0.4172**	-0.4230	-0.2998*	-0.6291**	-0.3026*
	(0.2982)	(0.1795)	(0.2883)	(0.1678)	(0.2797)	(0.1676)
Wholesale, Transport, Storage & Communication	-1.1572*	-0.0691	-0.2589	-0.5644***	-0.7326***	-0.0770
	(0.2775)	(0.1842)	(0.2749)	(0.1750)	(0.2603)	(0.1719)
Financial Intermediation	-0.4802***	-0.6038***	-0.2002	-0.5025***	-0.5666*	-0.0562
	(0.3504)	(0.2051)	(0.3326)	(0.1906)	(0.3154)	(0.1869)
Computer, Architecture & Engineering Services	-0.9228	0.0326	-0.3240	-0.3757*	-0.2650	-0.1154
	(0.3276)	(0.2361)	(0.3129)	(0.2126)	(0.3031)	(0.2151)
Business Specific Factors						
Employment	0.1363**	0.0876*	0.0547	0.1590***	0.1020*	0.0856*
	(0.0624)	(0.0503)	(0.0600)	(0.0481)	(0.0586)	(0.0469)
Human Capital	-0.0271	0.2701***	-0.1486*	0.3079***	-0.1675**	0.3844***
	(0.0810)	(0.0719)	(0.0767)	(0.0673)	(0.0767)	(0.0682)
Constant		-0.6269**		-0.8372***		-0.4350*
		(0.2767)		(0.2643)		(0.2588)
Obs.		1974		1974		1974
Chi2		620.65		382.65		307.77
Prob > Chi2		0.0000		0.0000		0.0000
Likelihood Ratio		-997.50		-1077.91		-1202.55
Pseudo R2		0.2373		0.1507		0.1134

Note a: *** indicates significance at 99%, ** indicates significance at 95% and * indicates significance at 90%.

b: Probit estimation techniques are utilised as the dependent variable is binary in nature.

c: High technology is the sector reference category.

Endnotes

[1] In fact there is little evidence of a positive effect in other countries (Roper, Youtie, Shapira and Fernandes-Ribas, 2010).

[2] The inclusion of zero values as indicators of a lack of R&D activity is consistent with the international literature such as Roper et al (2010). As an alternative to entering zeros it is possible to use a two-step model which firstly models whether firms engage in R&D activity and subsequently whether R&D expenditure (for those firms who actually engage in R&D activity) has a positive effect on innovation. This is essentially the method used by Crepon et al. (1998). However, the application of this approach to this paper is not viable due to the fact that it would result in a large reduction in our degrees of freedom, possibly reducing the efficiency of our estimates. This is due to the fact that the second stage of the estimation is run on only the subsample of firms which perform R&D, substantially reducing our degrees of freedom. Also as our dependent variable is a binary indicator of innovation activity, and as approximately 97% of firms who perform R&D innovate, restricting our sample to only R&D performing firms means that our binary dependent variable is mainly dominated by 1s. This can have implications for the accuracy of estimates. For this reason we follow Roper et al. (2010) approach as oppose to the CDM method.

[3] It is assumed that all other variables are held constant and that the business operates in the *High-Technology Manufacturing* sector. Changing these assumptions merely result in a shift of the R&D curve and have no impact on the slope or relative magnitude of the estimated returns.

[4] The marginal effect of -0.2232 for Irish-owned is added to that for foreign-owned. It is therefore approximately zero and insignificant. This is confirmed in Appendix 1.

[5] The CIS survey question on R&D spending does not indicate where the recipient of the expenditure comes from. However, the CIS does include a separate question on whether or not businesses collaborate with HEIs and if so where the HEI is located. On the assumption that collaboration with HEIs coincides with the purchase of patents or other know-how, a cross-tabulation reveals that product innovating foreign-owned businesses spend €1,002 per worker interacting with Irish HEIs, €272 per worker with Northern Irish HEIs, and €30 per worker with HEIs in the rest of Europe. Interestingly they spend zero euro interacting with HEIs outside Europe. While these levels are noteworthy they are considerably lower than the average spend on this form of R&D. Table 3 showed this to be €4,366 per worker with an extremely large standard deviation. The difference can be explained by a small number of foreign-owned businesses not engaged in product innovation who have very large spending on patents.