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IRELAND'S INNOVATION PERFORMANCE: 1991 TO 2005

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Abstract

In this paper we use data from the five waves of the Irish Innovation Panel (IIP) to profile the innovation performance of manufacturing plants in Ireland and Northern Ireland over the period 1991 to 2005. Despite considerable public sector investment on both sides of the border levels of innovation activity have remained broadly similar throughout this period although somewhat different trends are evident in Ireland and Northern Ireland. In terms of product innovation for example, the proportion of manufacturing plants making product changes has increased 5 per cent in Ireland and just over 7 per cent in Northern Ireland. In terms of process innovation a decline of almost 7 per cent in Ireland has been accompanied by a 7 per cent increase in Northern Ireland. These trends provide some evidence of convergence in innovation performance over the 1991 to 2005 period. This is evident in the narrowing gap between the proportion of product innovators in Ireland and Northern Ireland, convergence in the proportion of plants undertaking process innovation and in terms of the increasingly similar proportions of sales derived from innovative products.

Looking in more detail at the determinants of manufacturing innovation emphasises the importance of R&D and backwards supply chain linkages as sources of new knowledge for innovation. Other external linkages prove less important suggesting the value of policy initiatives designed to promote knowledge sharing. We also find a significant negative innovation effect from legislative restrictions on plants' product innovation. Public support for both product and process innovation are having positive effects on innovation outputs at the level of the individual plant. Future research interest centres on the contrast between this strong positive result at firm level and the more modest increases in innovation among the population of firms in Ireland and Northern Ireland.

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1. Introduction

In this paper we use data from the five waves of the Irish Innovation Panel (IIP) to profile the innovation performance of manufacturing plants in Ireland[1] and Northern Ireland over the period 1991 to 2005. For much of this period promoting innovation and developing innovation capability, particularly among locally-owned firms, has been a priority of industrial policy in both Ireland and Northern Ireland backed by substantial public investment. A key question, therefore, is whether nearly two decades of policy intervention have been effective in improving firms' innovation performance.

In Ireland, the start of our innovation panel data coincides broadly with the publication of the Culliton report (1992). This provided an impetus for the prominence of technology development in industrial policy, being followed in 1995 by a review of science, technology and innovation policy in Ireland (STIAC, 1995), then in 1996 by Ireland's first government White Paper on *Science, Technology and Innovation*, and the subsequent establishment of the Irish Council for Science, Technology and Innovation (ICSTI). ICSTI's mandate was to advise the government on the direction of science and technology policy, including higher education, technology and R&D in industry, financing of innovation and public awareness. More recent policy developments have sought to further strengthen the indigenous innovative capability of Ireland through an upgrading of higher education institution (HEI) investments in R&D and measures designed to leverage higher levels of private R&D spending. For example, initiatives such as R&D tax credits were introduced in 2004 to increase the quantity of R&D performed by companies in Ireland and to encourage foreign companies to undertake R&D activities in Ireland. In relation to the upgrading of research in HEIs the Programme for Research in Third Level Institutions (PRTLI), operated by the Higher Education Authority, was established in 1998 to support high quality basic research in third level institutions and Science Foundation Ireland (SFI) was established in 2001 with a focus on establishing world class research capability in niche areas of ICT and bio-technology.

More recent policy documents such as the Strategy for Science, Technology and Innovation (DETE, 2006) have emphasised the global positioning of Ireland's knowledge based economy with the aspiration that "…Ireland by 2013 will be internationally renowned for the excellence of its research, and will be to the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture" (DETE, 2006, p.21). Achieving this will require a multi-dimensional approach to innovation including enhanced education and skills, higher quality and quantity of research, greater exploitation of research activity for economic and social progress and the building-up of international networks (DETE, 2006).

In Northern Ireland the period we examine spans the formation of the Industrial Research and Technology Unit in 1992, the development of a range of innovation support measures in Northern Ireland through the 1990s, and the amalgamation of IRTU with the other development

[1]In this paper Ireland refers to Republic of Ireland.

agencies to form Invest NI in 2002.[2] Since its establishment Invest NI has emphasised innovation – broadly defined – as a central policy objective, introducing a range of new investment programmes to support this agenda. Pre-competitive research in the universities and research oriented companies has been supported through the Centres of Excellence and START programmes; near market innovation has been supported through the Compete programme; commercialisation of university research has been encouraged through the development of the higher education investment fund (HEIF) and more recently the development of a Proof of Concept Scheme. Alongside these local developments, R&D support measures at UK level have changed with the introduction of R&D tax credits in 2001. Since 2003, these initiatives have been set within the overall framework of Northern Ireland's regional innovation strategy, entitled *Think, Create, Innovate* (DETI, 2003). This had as its key focus the better integration of public, private and higher education R&D efforts as well as the need to increase levels of R&D expenditure throughout the region. Most recently, developments in innovation policy in Northern Ireland have been the focus of a sub-committee of the Economic Development Forum, a social partnership body, which has met regularly to consider aspects of innovation development and performance in Northern Ireland.[3]

It is within the context of active innovation policy development in Ireland and Northern Ireland that our exploration of innovation performance is based. The remainder of this paper is organised as follows. In Section 2 we provide an overview of the Irish Innovation Panel (IIP) from which the data is derived. Section 3 compares innovation performance in Ireland and Northern Ireland over the 1991 to 2005 period both in aggregate and looking more specifically at externally-owned and locally-owned firms. In each case we are primarily concerned with how the level of innovative activity of each group of firms has changed through time and in any change in relative performance. We are less concerned with comparing, say, the innovative performance of externally-owned and locally-owned firms as this comparison will be strongly affected by differences in industrial composition. In Section 4 we focus on the determinants of innovation over the most recent three years covered by the IIP, 2003 to 2005. Section 5 draws some broad conclusions and highlights issues for future policy development.

2. The Irish Innovation Panel

The Irish Innovation Panel (IIP) provides information on manufacturing plants' technology adoption, networking and performance over the period 1991-2005. More specifically, the IIP comprises five surveys or waves conducted using similar survey methodologies and questionnaires with common questions (Roper *et al.*, 1996; Roper and Hewitt-Dundas, 1998; Roper and Anderson, 2000; Roper *et al.*, 2003). Each of the five surveys cover the innovation activities of manufacturing establishments with 10 or more employees over a three year period. For manufacturing each of the five surveys was undertaken by post using a sampling frame provided by the economic development agencies in Ireland and Northern Ireland. In

[2]For example, an Innovation Relay centre was opened in 1993, the Design Directorate was started in 1995 and in 1996 the Manufacturing Technology Partnership was created with the aim of promoting technology transfer between smaller companies and higher education.

[3] See www.edfni.com for committee minutes etc.

each case samples were structured with higher sampling proportions among larger plants with weighting structures being developed to provide representative results for Ireland and Northern Ireland.[4]

The initial wave of the IIP, undertaken between October 1994 and February 1995, related to plants' innovation activity over the 1991 to 1993 period, and achieved a response rate of 38.2 per cent (Roper *et al.*, 1996; Roper and Hewitt-Dundas, 1998, Table A1.3). The second wave, conducted between November 1996 and March 1997, covered plants' innovation activity during the 1994-96 period, and had a response rate of 32.9 per cent (Roper and Hewitt-Dundas, 1998). The third wave covering the 1997 to 1999 period was undertaken between October 1999 and January 2000 and achieved an overall response rate of 32.8 per cent (Roper and Anderson, 2000). The fourth wave was undertaken between November 2002 and May 2003 and achieved an overall response rate of 34.1 per cent. The fifth wave of the IIP, conducted between January and June 2006, had an overall response rate of 28.7 per cent. Taken together the five waves of the IIP comprise an unbalanced panel reflecting firms' non-response but also the closure and opening of manufacturing units over the 15 year period covered by the panel. The panel itself contains 4,525 observations from 2,564 establishments and represents an overall response rate of 33.2 per cent (Northern Ireland, 39.1 per cent; Ireland 30.5 per cent).

Innovation in the IIP is represented by a range of indicators reflecting the extent of innovative activity within the overall population of firms as well as the quality and success of firms' innovative activity. Four indicators are discussed here. First, we consider the extent of product innovation activity within the overall population of manufacturing plants in Ireland and Northern Ireland. In the IIP a plant is said to be a product innovator if it introduced any new or improved product over the previous three years.[5] In the most recent wave of the IIP relating to plants' innovative activity over the 2003 to 2005 period (the IIP5), 65 per cent of manufacturing plants were product innovators (Ireland, 68 per cent; Northern Ireland, 59 per cent). The second innovation indicator relates to the extent of process innovation activity within the population of manufacturing plants. Again, a plant is said to be a process innovator if it introduced any new or improved process during the previous three years. In the IIP5 (2003 to 2005), 52 per cent of manufacturing plants were process innovators (Ireland, 51 per cent; Northern Ireland, 53 per cent). The other two innovation indicators discussed here relate to the proportion of plants' sales derived from (a) products newly introduced during the previous three years, and (b) products either improved or newly introduced during the previous three

[4] In fact sampling fractions were high: 100 per cent for firms with more than 100 employees; 75 per cent for firms with 50-100 employees; and 50 per cent for those with 10-50 employees. Non-response telephone surveys were also conducted for each IIP wave until 2002 with no bias evident in terms of the innovativeness of respondent firms. Representativeness is discussed in more detail in the survey reports cited in the text (e.g. Roper and Hewitt-Dundas, 1998).

[5] This definition is considerably less demanding than the definition of technological innovation used in the Community Innovation Survey which requires that an innovation is a 'significant' technological improvement. In the IIP we adopt a less demanding approach to reflect a broader range of innovative activity including more of the incremental innovation typically undertaken by smaller firms.

Table 1: Innovation Activity and Innovation Success, Ireland, Northern Ireland and All Island, 1991-2005

	1991-1993	1994-1996	1997-1999	2000-2002	2003-2005
Ireland					
Product Innovators (% of plants)	62.8	65.9	65.3	56.7	67.9
Process Innovators (% of Plants)	n/a	57.7	65.8	53.9	51.0
Sales from New Products (% sales)	30.2	21.9	27.7	24.3	22.6
Sales from New and Improved Products (% sales)	46.4	40.3	40.4	40.3	34.2
Northern Ireland					
Product Innovators (% of plants)	51.9	56.5	58.5	53.8	59.3
Process Innovators (% of Plants)	n/a	46.0	57.5	50.1	53.0
Sales from New Products (% sales)	27.2	22.7	21.3	25.8	24.1
Sales from New and Improved Products (% sales)	48.7	37.5	39.2	38.6	36.8
All Island					
Product Innovators (% of plants)	59.2	62.9	63.3	55.8	64.7
Process Innovators (% of Plants)	n/a	53.9	63.4	52.7	51.8
Sales from New Products (% sales)	29.3	22.2	25.9	24.7	23.1
Sales from New and Improved Products (% sales)	47.1	39.4	40.1	39.8	35.1

Notes and *Sources:* Observations are weighted to give representative sources. All data from the IIP.

years.[6] Both of these measures reflect not only plants' ability to introduce new products to the market but also their short-term commercial success. On average among product innovators, 23 per cent of plants' sales were derived from new products in the IIP5 with 35 per cent being derived from new and improved products (Table 1).

In addition to the innovation indicators the IIP also provides information on a wide range of variables which previous studies have suggested may contribute to plants' innovation performance. These include a range of indicators relating to the structure and nature of plants' R&D activity, the nature of their production activities, knowledge sourcing behaviour, their resource base, absorptive capacity and plants' receipt of government support. The IIP also includes a range of accounting and business growth information which has been used to examine the relationship between innovation and aspects of business performance[7] as well as information on the barriers to innovation (e.g. Hewitt-Dundas, 2006).

3. Trends in Innovation Performance

Key indicators of Ireland and Northern Ireland's innovation performance over the 1991 to 2005 period are summarised in Table 1. Perhaps the most striking feature of these figures is the relative stability of the proportion of innovating plants in both Ireland and Northern Ireland given the rapid development of the two economies over this period. For example, in Ireland 62.8 per cent of plants stated that they had introduced new or improved products during the 1991 to 1993 period, while by 2005 this proportion had risen only marginally to 67.9 per cent. In Northern Ireland, 51.9 per cent of plants reported introducing new or improved products in the first wave of the IIP covering the 1991 to 1993 period, rising to 59.3 per cent by 2003 to 2005. Two points stand out here. First, the proportion of the population of manufacturing plants introducing product innovations was consistently higher in Ireland than in Northern Ireland over this entire period (Figure 1A). Second, the proportion of product innovating plants in Northern Ireland increased at a faster rate than that in Ireland over the 1991 to 2005 period, narrowing the gap in innovation rates slightly from around 11 pp to less than 9 pp by 2005 (Table 1). A more marked pattern of convergence is seen in process innovation, with the extent of process innovation higher in Ireland from 1994 to 2002, over the 2004 to 2005 period Ireland was surpassed by Northern Ireland (Figure 1B).[8]

During the 1991 to 2005 period, of course, the international economic environment changed radically, with rapid expansion during the later-1990s followed by the high-tech downturn around the millennium, and subsequent recovery. Each of these phases of activity are reflected in the innovation activities of Irish companies. From 1991 to 1999, for example,

[6] By 'new' here we mean that the product was newly introduced by the plant. In the IIP we distinguish between products which are new to the world and those which were previously produced elsewhere but do not make this distinction here.

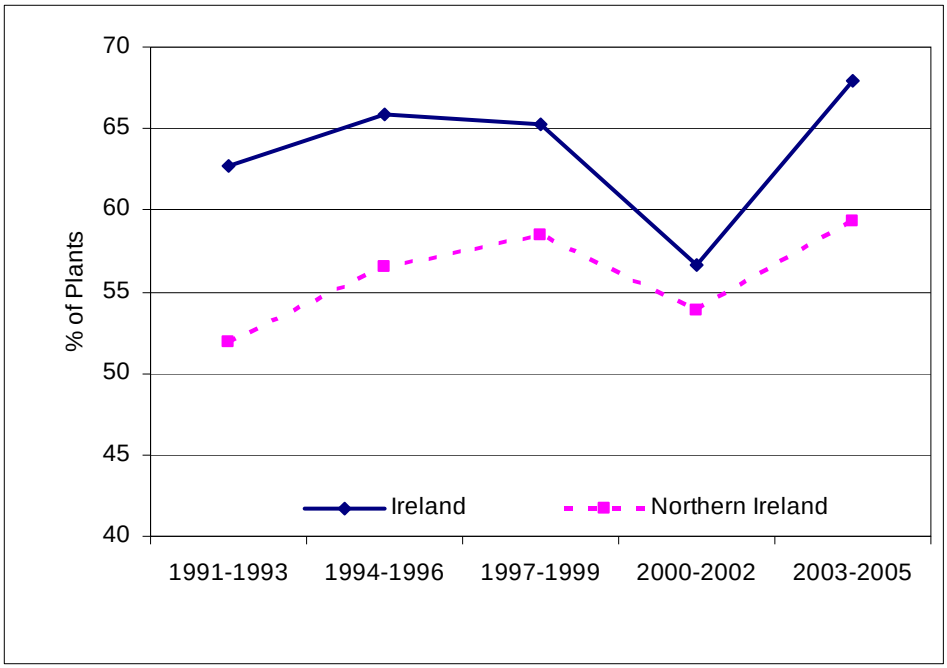
[7] On exporting see Roper *et al.*, 2006; on growth and productivity see Roper *et al.*, 2006; and on profitability see Love *et al.*, 2007.

[8] Over the 1991 to 2005 period around 70 per cent of plants undertaking product innovation in any period also reported process innovation. See Roper and Hewitt-Dundas (1998) for a discussion.

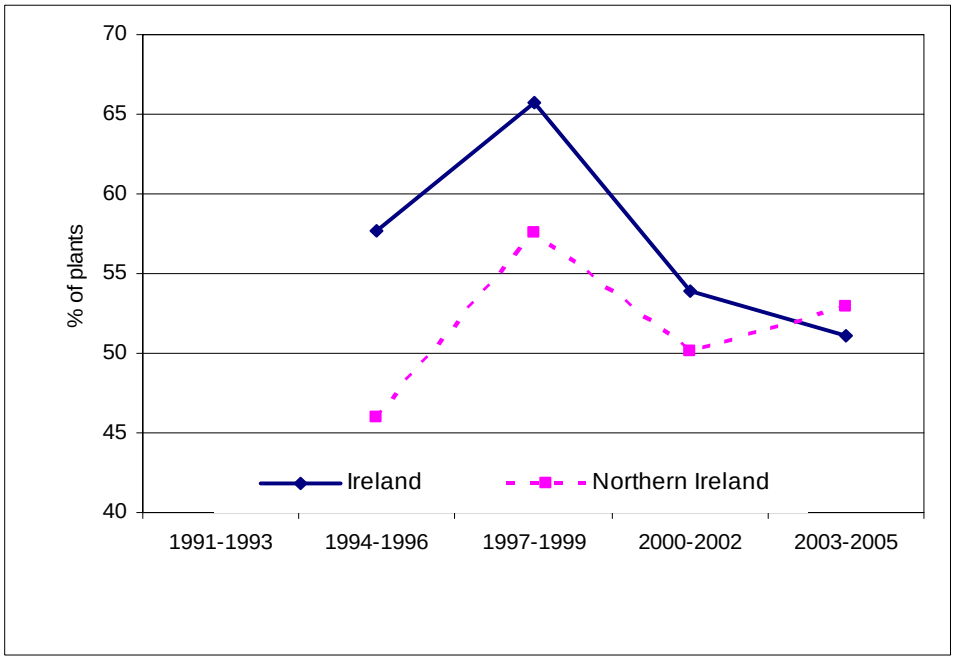
through the first three waves of the IIP we see steady growth in the extent of product and process innovation in relatively benign market conditions. In the 2000 to 2002 period, however, we see a downturn in innovation rates with markedly fewer plants introducing product or process innovations over this period than during the previous three years (Figure 1). This downturn in innovation rates occurred across almost all industrial sectors, all plant size bands and affected both Ireland and Northern Ireland (Roper *et al.*, 2003). The fall in product innovation rates was, however, notably greater in Ireland than in Northern Ireland (Figure 1A) perhaps reflecting the greater exposure of the Irish economy to high-tech sectors over this period.

Figure 1: The Extent of Product and Process Innovation: 1991-2005

A. The Extent of Product Innovation (% of Plants)



B. The Extent of Process Innovation (% of Plants)



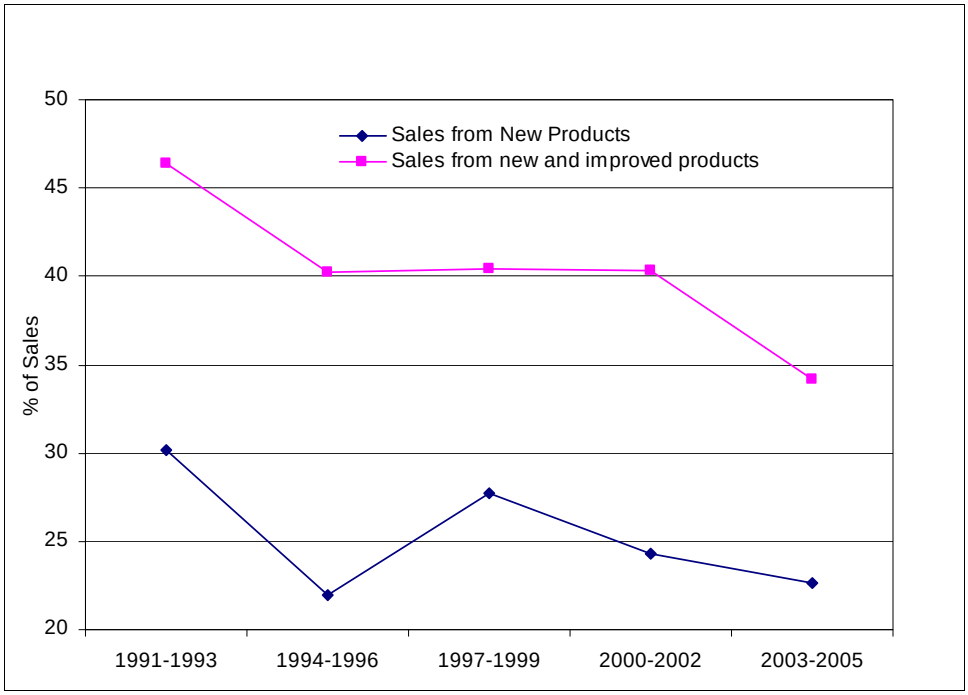
During 2003 to 2005 we then see a sharp recovery in product innovation rates in both Ireland and Northern Ireland with both economies achieving historical highs in terms of the proportion of plants engaged in product innovation (Figure 1A). In terms of process innovation, however, both economies perform less strongly with process innovation rates failing to match those of the late-1990s. In Ireland, in particular, the proportion of plants engaging in process innovation actually continued to fall over this period. This contrasts sharply with increases in process innovation activity in Northern Ireland and Irish plants' renewed enthusiasm for product innovation. One possibility is that this marks something of a change in the nature of product innovation in Ireland with a shift towards more incremental product innovation which does not require related process change. This possibility is also suggested by a slight decline in the proportion of innovating plants' sales – innovation success – coming from new products over the 2002 to 2005 period while the proportion of sales coming from new and improved products remained relatively stable (Figure 2A). In Northern Ireland, a slightly different trend is evident here with sales of new innovative products increasing in importance post-2002, and sales of improved products declining in importance (Figure 2B). This again provides some tentative evidence for convergence over the post-2002 period with Ireland moving towards more incremental product development and Northern Ireland plants increasingly emphasising the development of new products.

Within this general pattern it is also interesting to examine how levels of innovative activity have changed among locally-owned and externally-owned plants over the 1991 to 2005 period. Direct comparison of the innovation performance of the two groups of plants are likely to be misleading, largely due to marked differences in the size and sectoral structure of the two groups. Instead, our focus here is on the temporal profile of innovation within each group and we return to the question of the relative 'innovativeness' of locally-owned and externally-owned plants in the context of the multivariate analysis in Section 4.

Looking first at the proportion of locally-owned plants in Ireland engaging in product innovation, it is clear that trends for this group follow the aggregate pattern with a sharp downturn 2000 to 2002, and recovery during 2003 to 2005 period to reach an all time high (Figure 3A). The proportion of locally-owned plants undertaking product innovation in Northern Ireland also reached an all time high over the 2003 to 2005 period but it is notable that product innovation among this group of plants was relatively unaffected by the downturn during 2000 to 2002 (Figure 3A). Over the whole 1991 to 2005 period, some convergence is evident between the proportions of locally-owned plants engaging in product innovation in Ireland and Northern Ireland, except for the trough of 2000 to 2002. In terms of process innovation, we see clearer evidence of long-term convergence, with small falls in the proportion of locally-owned plants undertaking process innovation in both areas over the 2003 to 2005 period (Figure 3B).

Figure 2: Innovation Success – The Proportion of Sales from Innovative Products

A. Ireland



B. Northern Ireland

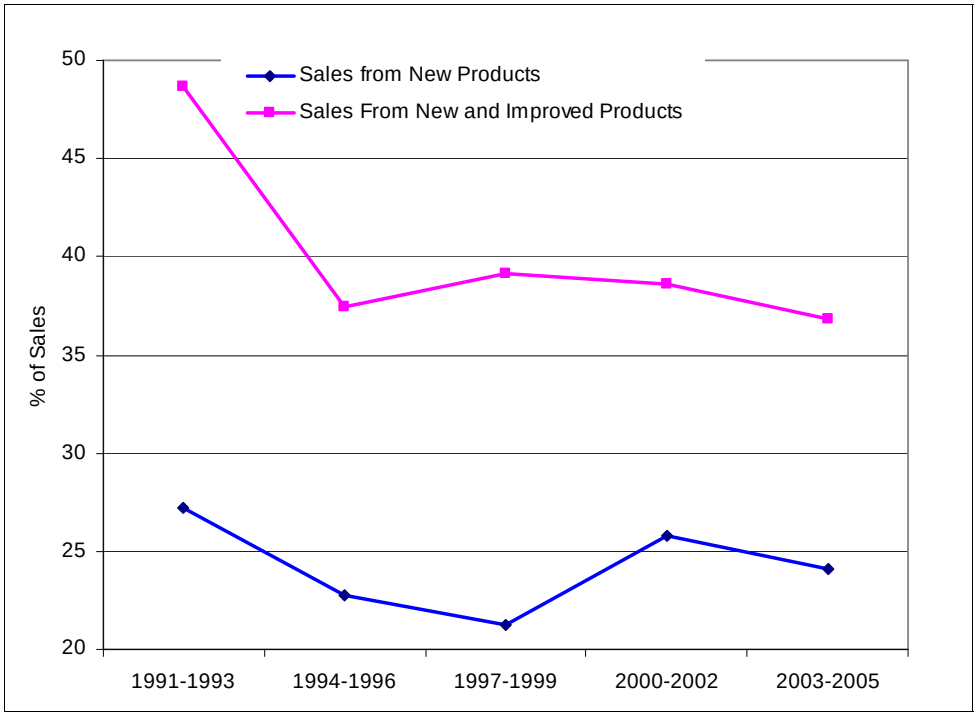
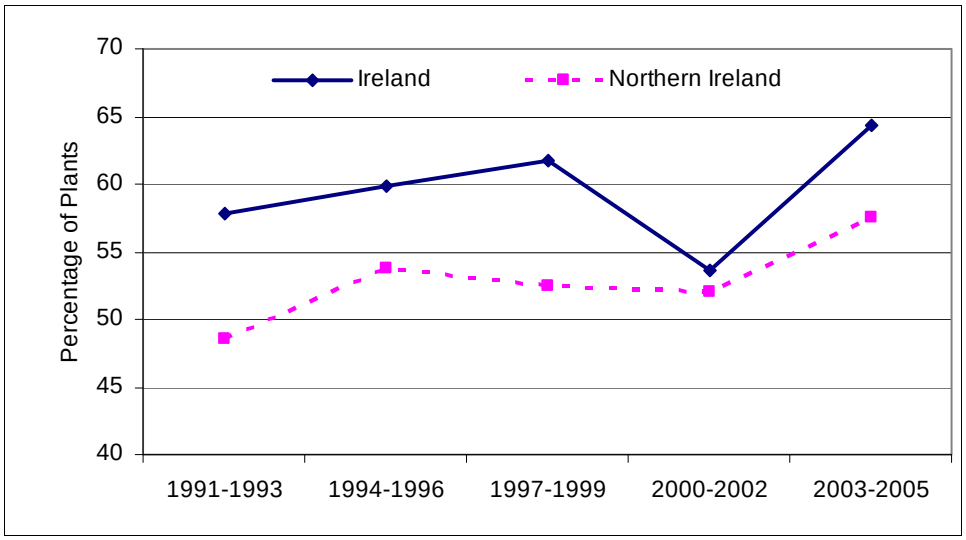
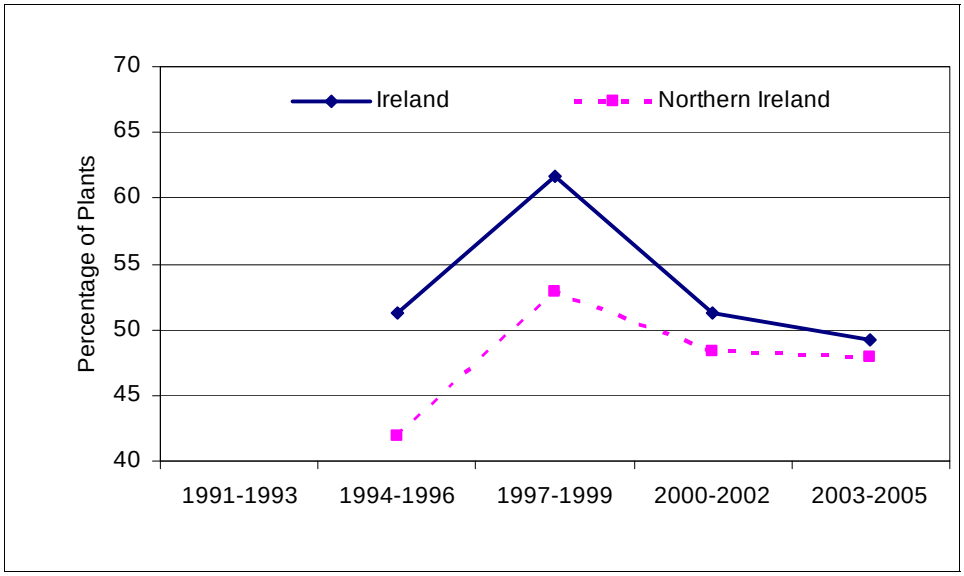


Figure 3: The Extent of Product and Process Innovation: Locally-owned Plants

A. Product Innovation



B. Process Innovation

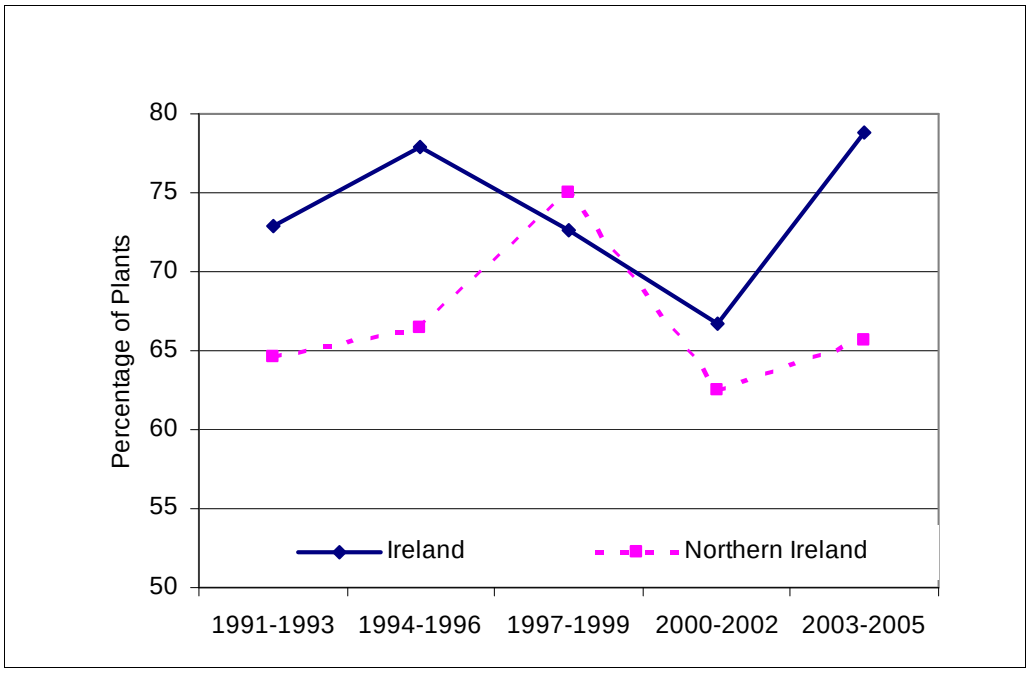


Externally-owned plants exhibit a somewhat more variable picture in terms of innovation rates over the 1991 to 2005 period (Figure 4). In terms of the proportion of externally-owned plants engaging in product innovation, for example, we see falls in both jurisdictions in 2000 to 2002 but a much stronger subsequent 'bounce back' in Ireland (Figure 4A). In terms of process innovation, however, we see a continued weakening among the proportion of externally-owned plants in Ireland in contrast to a sharp increase in Northern Ireland (Figure 4B). As suggested earlier the implication is that an increasing proportion of externally-owned plants in Ireland were undertaking product innovation over this period using existing process technologies rather than upgrading both together. This is likely to result in incremental rather than radical product change and this is reflected

in a decline in the proportion of sales derived from new products by externally-owned plants in Ireland from 2000 to 2005 (Table 2).

Figure 4: The Extent of Product and Process Innovation: Externally-owned Plants

A. Product Innovation



B. Process Innovation

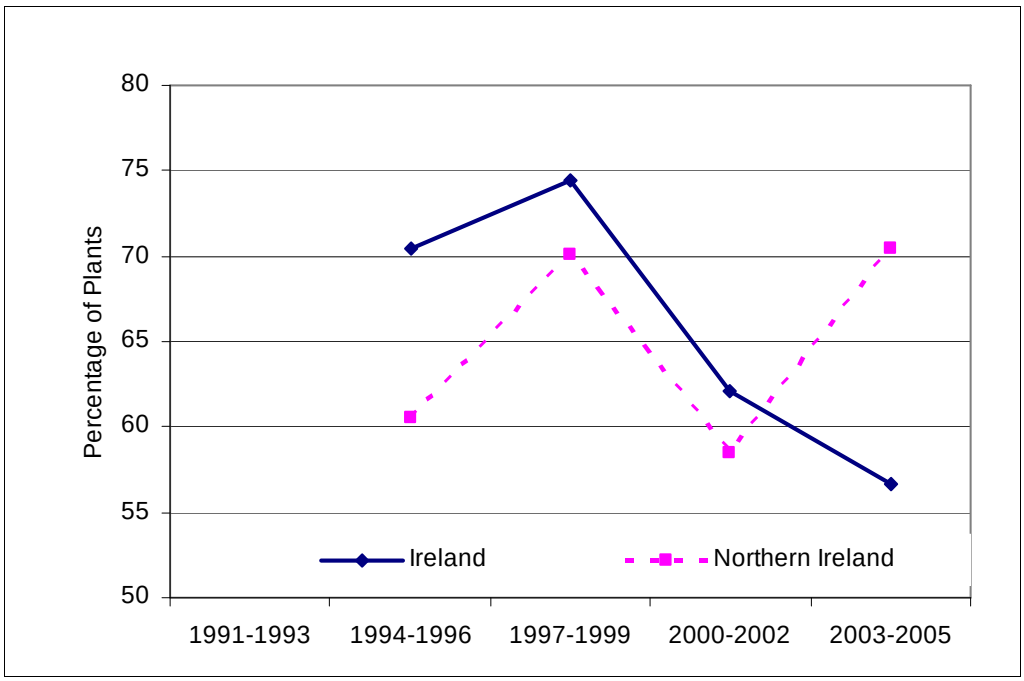


Table 2: Innovation Activity and Innovation Success in Indigenous and Foreign-owned Plants in Ireland and Northern Ireland, 1991-2005

	1991-1993	1994-1996	1997-1999	2000-2002	2003-2005
A. Locally-owned Plants – Ireland					
Product Innovators % of plants)	57.8	59.8	61.8	53.6	64.3
Process Innovators (% of Plants)	n/a	51.3	61.7	51.3	49.2
Sales from New Products (% sales)	29.8	19.3	26.7	23.0	21.8
Sales from New and Improved Products (% sales)	44.5	39.3	39.2	39.4	32.5
B. Locally-owned Plants – Northern Ireland					
Product Innovators (% of plants)	48.5	53.7	52.4	52.0	57.5
Process Innovators (% of Plants)	n/a	41.9	52.9	48.4	47.9
Sales from New Products (% sales)	28.1	22.7	20.8	24.9	23.6
Sales from New and Improved Products (% sales)	49.6	37.6	38.5	38.8	36.6
C. Externally-owned Plants – Ireland					
Product Innovators (% of plants)	72.92	77.96	72.6	66.7	78.8
Process Innovators (% of Plants)	n/a	70.4	74.4	62.1	56.6
Sales from New Products (% sales)	30.7	26.1	29.7	27.9	24.5
Sales from New and Improved Products (% sales)	49.2	41.7	42.6	42.7	38.5
D. Externally-owned Plants – Northern Ireland					
Product Innovators (% of plants)	64.6	66.4	75.0	62.5	65.6
Process Innovators (% of Plants)	n/a	60.5	70.1	58.5	70.4
Sales from New Products (% sales)	25.0	22.9	22.3	29.8	25.4
Sales from New and Improved Products (% sales)	46.3	37.2	40.4	38.1	37.4

Notes and *Sources*: Observations are weighted to give representative sources. All data from the IIP.

4. The Determinants of Manufacturing Innovation: 2003 to 2005

In this section we outline some illustrative models of the determinants of the extent of product and process innovation, and our two indicators of innovation success for the 2003 to 2005 period. We choose to focus here on the most recent cross-section of the IIP as being of most contemporary relevance, with broadly similar results for the IIP as a whole given in Roper *et al.* (2008).

The models reported here are based on the notion of an innovation production function in which knowledge sourced by the enterprise (KS) is translated into innovation outputs (e.g. Geroski, 1990; Harris and Trainor, 1995; Jordan and O'Leary, 2007; Arvanitis and Wörter, 2006), and in which the effectiveness of firms' knowledge transformation activity is influenced by the strength of their resource-base (RI), barriers to innovation (BAR), and receipt of government assistance (GOVT). In general terms where I_i is an innovation output indicator we write the innovation production function as:

$$I_i = \phi_0 \, KS_{ki} + \phi_1 RI_i + \phi_2 BAR_i + \phi_3 GOVT_i + \varepsilon_i \qquad (1)$$

Where plants' internal resources are strong, for example, we would expect this to contribute positively to the efficiency with which plants develop new innovations (e.g. Crépon *et al.*, 1998; Lööf and Heshmati, 2001 and 2002). We would also expect plants' innovation outputs to be negatively related to barriers to innovation and positively related to the receipt of government assistance (e.g. Roper and Hewitt-Dundas, 2005; Link *et al.*, 2005). We also include in the innovation production functions industry measures and a dummy variable indicating whether an establishment is in Northern Ireland. The appropriate estimation method for the innovation production function depends primarily on the nature of the dependent variable. For the extent of product and process innovation bivariate Probit models are appropriate, while for the two innovation success variables (which are percentages) we use a bounded Tobit estimator.[9]

Estimates of Equation (1) based on the fifth wave of the IIP (IIP5, 2003 to 2005) are reported in Table 3 for all manufacturing plants with marginal values reported for each variable. Variable definitions and descriptives are summarised in the data annex. In terms of the extent of innovation, we see strong positive R&D effects on both product and process innovation as well as innovation success. Having in-house R&D increases the probability that a plant is engaging in product innovation by 30 per cent and the probability that a plant will engage in process innovation by 19.4 per cent. It also increases the share of plants' sales accounted for by new products by around 11 per cent and sales of new and improved products by 23.4 per cent (Table 3). These impacts suggest the value of current attempts both in Ireland and Northern Ireland to boost levels of business R&D[10] which are currently only alf that in Denmark

[9] A range of econometric issues arise in estimating this type of innovation production function and we discuss these extensively elsewhere (Roper *et al.*, 2008).

[10] In Ireland increasing the number of R&D active businesses and the level of investment in R&D is reflected in the Government's Strategy for Science, Technology and Innovation 2006-2013. In Northern Ireland a similar emphasis is found in the Regional Innovation Strategy (DETI, 2003).

and a third of that in Finland and Israel.[11]

Our results provide some, more limited, evidence of other positive external linkages as part of plants' innovation activity. Plants having backward linkages to either suppliers or consultants as part of their innovation activity, for example, are 11-12 per cent more likely to engage in product and process innovation and have higher innovation success than plants without such linkages (see also Tan, 1990; Wong, 1992). Other aspects of plants' innovation linkages – to other group companies, customers and public knowledge institutions – prove less important in shaping the extent and success of innovative activity (Table 3). The suggestion is that contrary to the ideal of the open innovation model (Chesborough 2003; 2006) manufacturing innovation in Ireland is driven by a relatively narrow range of external knowledge sources aside from knowledge created within the plant through R&D. This may, in part at least, be a consequence of the low level of business R&D spending in Ireland which may be reducing plants' absorptive capacity and hence their ability to benefit from external knowledge sources (e.g. Griffith, Redding, and Van Reenan, 2003). Of particular importance perhaps given the emphasis of current policy is the lack of any positive link between the extent of innovation activity and links to public knowledge sources (see also Jordan and O'Leary, 2007). This may reflect the fact that engagement with universities takes longer to yield benefits in terms of innovation than other types of external linkages, or that the benefits to plants from university interaction depend on their innovation strategy (Arvanitis and Wörter, 2006). In the context of current increases in investment in higher education R&D in Ireland, however, and in terms of planned increases in higher education R&D in Northern Ireland this result seems worthy of further investigation.

Different aspects of plants' resource base – reflecting plant size, ownership profile and skills base – prove important for different dimensions of innovation activity. Plant size, for example, only proves significant for the probability of process innovation with no significant effect either on the probability of product innovation or either measure of innovation success (Table 3). As in previous studies (e.g. Roper *et al.*, 2008) we see a non-linear inverted 'U' shape relationship between the probability of process innovation and plant size. Plant age and the proportion of graduates in the workforce prove unimportant for innovation, although other studies have suggested that graduate employment is perhaps more important in exploiting rather than creating product and process innovations (e.g. Roper *et al.*, 2006). Unsurprisingly perhaps given the discussion of Section 3, externally-owned plants, and those with access to group R&D, are also more likely to be undertaking product innovation, although these effects are balanced by a negative impact from being part of a multi-site business. No significant ownership effects are observed in relation to process change, however. These results suggest a marked contrast between the determinants of product and process change: product innovation and innovation success are largely unrelated to plant size but

[11] See for example, Research and Development Performance in the Business Sector Ireland: 2005/06, Figure 5, Forfás, 2007.

Table 3: Determinants of Manufacturing Innovation Performance: 2003-2005

Model	Product Innovation Probit		Process Innovation Probit		New Products as % Sales Success Tobit		New and Improved Products as % Sales Tobit	
	dy/dx	t-stat	dy/dx	t-stat	dy/dx	t-stat	dy/dx	t-stat
Knowledge Sourcing								
Research and development	0.301	6.810	0.194	3.890	11.093	3.230	23.358	5.580
Other group members	-0.083	-1.010	-0.037	-0.460	-4.507	-0.850	-1.230	-0.200
Backwards linkages	0.110	1.800	0.107	1.690	8.793	1.840	8.747	1.560
Forwards linkages	0.076	1.070	0.124	1.820	6.722	1.470	10.539	1.840
Horizontal linkages	-0.045	-0.510	0.076	0.980	0.419	0.080	-1.831	-0.310
Public knowledge sources	-0.062	-0.770	0.040	0.570	-8.894	-2.200	-10.324	-1.940
Resource Base								
Employment (2002)	0.000	0.000	0.002	3.700	0.026	0.620	0.049	0.980
Employment Squared (2002)	0.000	-0.040	-0.003	-2.920	-0.022	-0.460	-0.053	-0.810
Established post 2000	0.014	0.160	-0.019	-0.210	10.664	1.460	10.857	1.320
Externally-owned firm	0.199	2.980	-0.106	-1.080	7.465	1.390	16.030	2.430
Part of multi-plant group	-0.215	-2.450	0.055	0.570	-7.625	-1.410	-15.030	-2.230
Important group R&D	0.170	2.950	0.087	1.040	7.127	1.270	8.617	1.340
Graduates in the workforce (%)	0.000	-0.180	0.000	0.170	0.144	1.300	0.112	0.820
Barriers to Innovation								
Risk of investment	0.024	0.410	-0.005	-0.080	6.946	1.950	4.835	1.030
Low rate of return	0.036	0.620	-0.053	-0.830	-1.032	-0.290	3.520	0.740
Attitudinal barriers in plant	0.105	1.510	0.173	2.290	3.386	0.780	2.793	0.530
Lack financial resources	0.009	0.160	-0.037	-0.620	4.449	1.200	3.166	0.650
Lack information	-0.036	-0.520	-0.036	-0.460	6.546	1.420	4.067	0.710
Regulatory barriers	-0.062	-1.060	-0.051	-0.760	-7.441	-1.920	-6.313	-1.250
Lack partners	-0.122	-1.730	-0.129	-1.640	-10.400	-2.310	-12.457	-2.060
Technical skill barriers	0.003	0.050	0.091	1.160	1.116	0.270	3.167	0.630
Managerial skill barriers	-0.057	-0.790	-0.030	-0.360	-4.090	-0.900	-5.115	-0.910
Government Assistance	0.223	4.680	0.274	4.510	17.956	4.450	16.394	3.460
Industry Dummies								
Food and textiles	-0.018	-0.310	-0.057	-0.880	-4.049	-1.110	-5.268	-1.190
Materials based industry	-0.050	-0.890	0.007	0.120	-10.483	-2.530	-12.164	-2.430
Machinery and equipment	-0.009	-0.140	-0.007	-0.100	-2.692	-0.580	0.098	0.020
Northern Ireland	-0.098	-2.050	0.008	0.150	-3.932	-1.250	-4.990	-1.270
Observations	740		740		689		686	
$Chi^2(20)$	110.97		143.91		5.16		6.09	
Likelihood	-385.50		-424.36		-12,631.98		-13,637.14	
R^2	0.193		0.173		0.037		0.038	

Notes and Sources: Observations are weighted to give representative sources. All data from the IIP. The omitted industry dummy variables relate to chemicals and electronic and electrical engineering (NACE 24, 30-34). Industry dummies reported relate to: food and textiles (Nace 15-19); Materials based industry (Nace 20-26, 36-37); Machinery and equipment (Nace 27-29).

sensitive to ownership and organisational context, while process change is more strongly related to plant size but less sensitive to plants' organisational setting. In policy terms this suggests the type of plant characteristics which might either enhance or negate public support for plants' innovation activity. This is important because public support for innovation proves important in our analysis both in increasing the probability that a plant is engaging in product and process innovation as well as innovation success. Public support for innovation is associated with an increase of around a fifth in the probability that a plant will be innovating and an increase in sales of innovative products of around 17 per cent (Table 3). Some care is necessary in interpreting the policy implications of this result, however, as the coefficients on the policy support – treatment terms – essentially reflect the combination of 'assistance' and 'selection' effects rather than a pure policy effect (see the discussion in (Wooldridge 2002; Greene 2005).[12] Again, given its importance, this is an area where, to date, there has been surprisingly little best practice evaluation of the effectiveness of innovation support being provided by development agencies in either Ireland or Northern Ireland.

We also include in the innovation models a range of indicators intended to identify specific barriers to innovation. These are important as they suggest those aspects of plants' operating environments which may be constraining innovation activity, and therefore may be a useful focus for policy intervention. In the models, we find that generally our 'barriers' variables are largely insignificant suggesting that in general the operating environment in Ireland and Northern Ireland is relatively conducive to innovation. In particular, we find no evidence that either product or process innovation is being significantly constrained by either skill shortages or shortages of finance, a result which may reflect the relatively high level of public support on offer to plants in Ireland and Northern Ireland for innovation. Instead, the most significant barriers to innovation relate to a perceived lack of partners, which has a negative impact both on the extent of innovation and its success, and regulatory impacts which are reducing plants' sales of new products. More specifically, our results suggest that a lack of partners is reducing the extent of innovation by around 12-13 per cent and innovation success by 10-12 per cent (Table 3). Regulatory barriers are reducing plants' sales of new products by around 7.5 per cent but have no significant impact on plants' sales of new and improved products. This suggests that policy intervention to strengthen innovation partnerships and reduce regulation – particularly relating to new products – may both yield significant innovation benefits.

Our final group of variables relate to plants industry, and while these prove largely insignificant in terms of their impact on the probability of innovating, they have stronger effects on the extent of plants' innovative sales (Table 3). Plants in the more traditional materials-based sectors (i.e. paper, printing, non-metallic minerals) have lower levels of innovative sales (minus 10-12 per cent) than plants in the reference sector (electrical and electronic engineering). This is consistent with slower product turnover –

[12] Separately identifying the selection and assistance effects requires a different estimation approach to that adopted here. See Maddala (1973, pp. 257-290) for a general discussion of the issue and Roper and Hewitt-Dundas (2001).

or longer product lifetimes – in the more traditional sectors (see also Love, Roper, and Du, 2007).

5. Conclusions

Our aim in this paper has been to draw on the unique longitudinal aspect of the Irish Innovation Panel (IIP) to track the innovation performance of manufacturing plants in Ireland and Northern Ireland from 1991 to 2005. This period coincides with a growing emphasis on the promotion of innovation by the industrial development agendas of both Ireland and Northern Ireland backed by substantial public sector investments on both sides of the border. Set against this policy background, and significant economic growth, it is perhaps disappointing that levels of innovative activity in both Ireland and Northern Ireland have not increased more rapidly. In terms of product innovation for example, the proportion of manufacturing plants making product changes has increased only 5 per cent in Ireland and just over 7 per cent in Northern Ireland. The trend is even more disappointing for the proportion of plants undertaking process innovation, with a decline of almost 7 per cent in Ireland. In Northern Ireland a somewhat different trend is found with a 7 per cent increase in the proportion of plants undertaking process change. This relatively static level of innovation activity has recently led to a greater emphasis by the business development agencies in both Ireland and Northern Ireland, i.e. Enterprise Ireland and Invest NI, to target assistance at non-innovating businesses and those with limited previous R&D activity.

For example, the introduction of innovation vouchers in Ireland is targeted specifically at small businesses with the hope that this will lead to a culture shift in the business towards innovation and foster the external innovation links with the academic community. In NI, support initiatives that encourage businesses to engage in R&D and innovation such as Compete, Product and Process Development support and SMART awards have now run for a number of years and while programme evaluations have been positive, cumulatively this has not translated into a substantial increase in the proportion of innovative businesses. This raises issues about the persistence of R&D and innovation activity in businesses. However, again awareness within the development agencies of the importance of sustaining innovation activity is evident in initiatives such as the R&D fund in Ireland aimed at increasing the level, quality and commercialisation of R&D in the context of sustained innovation activity in the business. Similarly, in NI innovation support programmes such as the second phase of the Compete programme or the SMART programme are focused on building innovation capability in projects of strategic benefit to business competitiveness.

During the 1991 to 2005 period our analysis also suggests the vulnerability of innovation activity to more general economic conditions. This was most notable around the millennium with the high-tech downturn causing sharp falls in the level of innovation activity (both product and process) in both Ireland and Northern Ireland and across most sectors and plant size bands. The most marked effects, however, were evident in externally-owned plants operating in high-tech, export oriented sectors. In the period immediately following the economic downturn (i.e. 2003 to 2005), however, there was a marked recovery in innovation activity although the nature of this recovery in Ireland and Northern Ireland seems very different. In Ireland, post-2002 while the proportion of plants introducing product innovations increased there was a continued decline in

process innovation activity. In Northern Ireland, both product and process innovation increased in the post-2002 period such that between 2003 and 2005 Northern Ireland had a higher proportion of plants than in Ireland undertaking process innovation. These trends provide some evidence of convergence in innovation performance between Ireland and Northern Ireland over the 1991 to 2005 period. This is evident in the narrowing gap between the proportion of product innovators in Ireland and Northern Ireland, convergence in the proportion of plants undertaking process innovation and in terms of the increasingly similar proportions of sales derived from innovative products.

Looking in more detail at the determinants of manufacturing innovation re-emphasises the importance of business R&D. This provides a strong justification for the Irish Government's Strategy for Science, Technology and Innovation 2006-2013 in seeking to increase the number of R&D active companies and the level of business investment in R&D to that approaching international levels. External linkages to suppliers and external consultants also prove important for innovation, although other types of innovation linkage – to customers, public knowledge sources and competitors – prove less significant. The suggestion is that plants' innovation activities in Ireland and Northern Ireland are drawing on a relatively narrow range of potential knowledge sources, an impression reinforced by the significant negative effect on innovation of a 'lack of partners'.

With a perceived weakness in the innovation knowledge network, it is encouraging to note in recent years, the introduction in Ireland and Northern Ireland of a range of policy initiatives to promote and support research and innovation networks. Since the end of the period covered by our data – to 2005 – a number of new initiatives have been launched in Ireland to promote greater university-business links. These include the Innovation Voucher Scheme, Competence Centres, the Applied Research Enhancement Programme (ARE) and the Technology Transfer Strengthening Initiative. Although other research has suggested a lack of any significant innovation benefits from plants' links to public knowledge sources such as universities (Jordan and O'Leary, 2007), this may be attributable to a number of factors. These include time lags in the exploitation of university research, the misalignment of research with firms' innovation strategy (Arvanitis and Wörter, 2006) or indeed, such findings may relate to a period when intervention to support knowledge transfer activities was much weaker than at present. Clearly, given the increased emphasis by policy on nurturing university-business collaboration, understanding the dynamics and maximising the return from university-business collaboration in the future will be important.

More generally, other initiatives designed to strengthen R&D collaboration and innovation partnerships and increase knowledge sharing and diffusion are to be welcomed as are measures designed to broker more extensive innovation linkages among private sector actors. Both the Enterprise Ireland R&D Fund for collaborative research and the Growth fund for the acquisition of consultancy services will contribute to strengthening such linkages. However, the portfolio of R&D and innovation measures in both Ireland and Northern Ireland remain less strongly oriented towards embedding a collaborative and systemic innovation culture through greater private sector links.

Our results support the findings of programme evaluations in suggesting that public support for both product and process innovation is having significant positive effects on innovation outputs at the level of the individual plant. This is reassuring given the continuing provision of public support for business R&D and innovation activity both in Ireland and Northern Ireland. An interesting question for future research, however, is why these positive plant-level policy effects are not translating into more significant increases in innovation among the population of firms as a whole. A number of possibilities are evident here. First, it may be that innovation policy effects on individual plants are transient and leave little legacy in terms of longer-term commitment to innovation or innovation capability. Second, other factors linked to the business cycle or other elements of plants' operating environment may be undermining a positive policy effect. Our results, for example, suggest the importance of regulatory barriers for new product success. Third, there may be a tendency for plants to seek public support for particularly risky innovation projects which may be reflected in higher levels of innovation but relatively low average levels of innovation success. Future research using the Irish Innovation Panel is planned around each of these issues.

Data Annex

Innovation Indicators	Definition	Northern Ireland n=243		Ireland n=562		All Plants n=805	
		Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
Product innovation	Dummy variable taking value 1 if the plant introduced any new or improved product during the previous three years.	0.591	0.492	0.674	0.469	0.643	0.479
Process innovation	Dummy variable taking value 1 if the plant introduced any new or improved process during the previous three years.	0.516	0.500	0.501	0.500	0.507	0.500
Innovation success (new products)	Percentage sales derived from products newly introduced over the previous three years.	13.531	20.549	14.686	21.929	14.252	21.426
Innovation success (new and improved)	Percentage sales derived from products new or improved products introduced over the previous three years.	20.653	26.840	21.964	27.728	21.469	27.400
Knowledge Sourcing							
Research and development	Dummy variable with value 1 if plant is engaged in R&D	0.442	0.497	0.452	0.498	0.448	0.497
Other group members	Dummy variable if plant has innovation links to other group members/plants.	0.163	0.369	0.177	0.382	0.171	0.377
Backwards linkages	Dummy variable with value 1 if plant has linkages to suppliers or consultants	0.290	0.454	0.307	0.461	0.300	0.458
Forwards linkages	Dummy variable with value 1 if plant has linkages to customers	0.203	0.402	0.200	0.400	0.201	0.401
Horizontal linkages	Dummy if plant has innovation links to competitors or joint ventures	0.064	0.245	0.103	0.304	0.088	0.284
Public knowledge sources	Dummy variable with value 1 if plant has links to universities, public labs.	0.193	0.395	0.162	0.368	0.174	0.379
Resource Base							
Employment (2002)	Employment in 2003	52.338	79.130	60.966	100.984	57.778	93.591
Established post-2000	Dummy variable with value 1 if plant established post 2000	0.033	0.178	0.077	0.267	0.061	0.239
Externally-owned firm	Dummy variable with value 1 if firm owned outside Ireland	0.225	0.418	0.244	0.430	0.237	0.425

Part of multi-plant group	Dummy variable with value 1 if plant is part of multi-plant group	0.270	0.444	0.341	0.474	0.314	0.464
Important group R&D	Dummy variable with value 1 if R&D relevant to the plant is undertaken elsewhere in the group	0.142	0.349	0.184	0.388	0.168	0.374
Graduates in the workforce (%)	Percentage of the workforce which are graduates	10.514	11.893	11.986	16.131	11.433	14.699
Barriers to Innovation							
Risk of investment	Originally Likert indices. Recoded into dummy variables taking value 1 if the barrier was 'important' or 'very important'.	0.445	0.497	0.481	0.500	0.467	0.499
Low rate of return		0.508	0.500	0.471	0.499	0.485	0.500
Attitudinal barriers in plant		0.406	0.491	0.395	0.489	0.399	0.490
Lack financial resources		0.512	0.500	0.458	0.498	0.478	0.500
Lack information		0.402	0.490	0.388	0.487	0.393	0.489
Regulatory barriers		0.496	0.500	0.411	0.492	0.443	0.497
Lack partners		0.335	0.472	0.337	0.473	0.336	0.472
Technical skill barriers		0.427	0.495	0.414	0.493	0.419	0.493
Managerial skill barriers		0.412	0.492	0.380	0.486	0.392	0.488
Government Assistance	Dummy variable taking value 1 if the plant received government support for product innovation	0.242	0.429	0.170	0.376	0.197	0.398
Industry Dummies							
Food and textiles	Dummy variable for Nace 15-19	0.183	0.387	0.216	0.411	0.203	0.403
Materials based industry	Dummy variable for Nace 20-26, 36-37	0.276	0.447	0.350	0.477	0.322	0.467
Machinery and equipment	Dummy variable for Nace 27-29	0.224	0.417	0.202	0.402	0.210	0.408
Northern Ireland	Dummy variable for Northern Ireland plant	1.000	0.000	0.000	0.000	0.373	0.484

REFERENCES

ARVANITIS, S. and M. WÖRTER, 2006. "Firms' Strategies for Knowledge and Technology Transfer with Public Research Organisations and Their Impact on Firms' Performance: An Empirical Analysis Based on Firm-level Data", KOF Working Paper No. 148, KOF Institute for Business Cycle Research, ETH Zurich.

CHESBOROUGH, H. W., 2003. *Open Innovation*: Harvard University Press.

CHESBOROUGH, H. W., 2006. "Open Innovation: a New Paradigm for Understanding Industrial Innovation" in H. W. Chesbrough, W. Vanhaverbeke and J. West (eds.), *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.

CRÉPON, B., E. DUGUET and J. MAIRESSE, 1998. "Research, Innovation and Productivity: An Econometric Analysis at the Firm Level", *Economics of Innovation and New Technology*, Vol. 7, pp. 115-158.

CULLITON, J., 1992. *A Time for Change: Industrial Policy for the 1990s*, Report of the Industrial Policy Review Group, Dublin: Stationery Office.

DETE, 2006. *Strategy for Science, Technology and Innovation 2006-2013*, Dublin: Department of Enterprise, Trade and Employment.

DETI, 2003. *Think, Create, Innovate: The Regional Innovation Strategy for Northern Ireland*, Belfast: Department of Enterprise, Trade and Investment.

FORFÁS, 2004. *Building Ireland's Knowledge Economy – The Irish Action Plan for Promoting Investment in R&D to 2010*, Dublin: Forfás.

FORFÁS, 2007. *Research and Development Performance in the Business Sector Ireland 2005/6*, Forfás, Dublin.

GEROSKI, P. A., 1990. "Innovation, Technological Opportunities, and Market Structure", *Oxford Econonomic Papers*, Vol. 42, pp. 586-602.

GREENE, W. H., 2005. *Econometric Analysis*, 5th ed. Upper Saddle River, New Jersey: Prentice-Hall.

GRIFFITH, R., S. REDDING and J. VAN REENAN, 2003. "R&D and Absorptive Capacity: Theory and Empirical Evidence", *Scandinavian Journal of Economics,* Vol. 105, No. 1, pp. 99-118.

HARRIS, R. I. D. and M. TRAINOR, 1995. "Innovation and R&D in Northern Ireland Manufacuring: A Schumpeterian Approach", *Regional Studies*, Vol. 29, pp. 593-604.

HEWITT-DUNDAS, N., 2006. "Resource and Capability Constraints to Innovation in Small and Large Plants", *Small Business Economics*, Vol. 26, No. 3, pp. 257-277.

JORDAN, D. and E. O'LEARY, 2007. "Is Irish Innovation Policy Working? Evidence from Irish High-Technology Businesses". Dublin: Statistical and Social Inquiry Society of Ireland, October.

LINK, A. N., D. PATON and D. S. SIEGEL, 2005. "An Econometric Analysis of Trends in Research Joint Venture Activty", *Managerial and Decision Economics*, Vol. 26, No. 2, pp. 149-158.

LÖÖF, H. and A. HESHMATI, 2001. "On the Relationship Between Innovation and Performance: A Sensitivity Analysis", SSE/EFI Working Paper No 446, Stockholm School of Economics.

LÖÖF, H. and A. HESHMATI, 2002. "Knowledge Capital and Performance Heterogeneity: A Firm Level Innovation Study", *International Journal of Production Economics*, Vol. 76, pp. 61-85.

LOVE, J. H., S. ROPER and J. DU, 2007. "Innovation, Ownership and Profitability", Working Paper, Aston Business School (RP0709).

MADDALA, G., 1973. *Limited Dependent and Qualitative Variables in Econometrics,* New York: Cambridge University Press.

ROPER, S. and N. HEWITT-DUNDAS, 1998. *Innovation in Ireland. Lessons for Irish Businesses*, Dublin: Oaktree Press.

ROPER, S. and J. ANDERSON, 2000. "Innovation and E-Commerce – A Cross-Border Comparison of Irish Manufacturing Plants", NIERC Research Report 17, Belfast.

ROPER, S. and N. HEWITT-DUNDAS, 2001. "Grant Assistance and Small Firm Development in Northern Ireland and the Republic of Ireland", *Scottish Journal of Political Economy*, Vol. 48, No. 1, pp. 99-117.

ROPER, S. and N. HEWITT-DUNDAS, 2005. "Measuring the Impact of Grant Support for Innovation: Panel Data Evidence for Irish Firms", European Regional Science Association, Amsterdam.

ROPER, S., J. DU and J.H. LOVE, 2008. "The Innovation Value Chain", Research Policy, forthcoming.

ROPER, S., N. HEWITT-DUNDAS and M. SAVAGE, 2003. "Innovation, Best Practice Adoption and Innovation Networks – A Comparison of Northern Ireland and the Republic of Ireland", (December), InnovationLab (Ireland) Ltd.

ROPER, S., B. ASHCROFT, J. H. LOVE, S. DUNLOP, H. HOFMANN, K. VOGLER-LUDWIG, 1996. "Product Innovation and Development in UK, German and Irish Manufacturing", Queen's University of Belfast/University of Strathclyde/ifo Institut.

STIAC, 1995. *Making Knowledge Work for Us: A Strategic View of Science, Technology and Innovation in Ireland.* Irish Government, Stationery Office, Dublin.

TAN, B. W., 1990. "Using the Supplier Relationship to Develop the Support Industry". *Omega – International Journal of Management Science,* Vol. 18, pp. 151-158.

WONG, P.K., 1992. "Technological Development through Subcontracting Linkages: Evidence from Singapore. *Scandinavian International Business Review*, Vol. 1, No. 3, pp. 28-40.

WOOLDRIDGE, J., 2002. *Econometric Analysis of Cross Section and Panel Data*, MIT Press.