Benchmarking Innovation Performance in Ireland's Three NUTS 2 Regions

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Abstract

The capability of a region to generate advanced technology, information and ultimately knowledge is regarded as the single most important force driving economic growth. This paper provides benchmarks for the innovation performance of manufacturing businesses in the three NUTS 2 regions of Ireland (Border Midlands & West, South & East, Northern Ireland) in 1999, just prior to the start of the current Structural Funds programmes.

Consideration of the regional innovation systems of Ireland's three NUTS 2 regions suggests (a) the knowledge generation and diffusion sub-systems of NI and the S&E are notably stronger and more evenly spread than that in the BMW region; (b) the knowledge application sub-system is notably weaker in NI. The implication is that the S&E region has the strongest RIS, having both a concentration of knowledge generating institutions and a relatively strong company base.

These differentials are reflected in the innovation benchmarks with a clear regional hierarchy emerging topped by the S&E followed by the BMW region and Northern Ireland. In most cases, however, differences in innovation performance between the S&E and the BMW region prove statistically insignificant, while those between NI and the other two regions are stronger and often statistically significant. Indicators of AMT adoption suggest little consistent difference between the S&E and BMW regions and lower adoption rates in NI. As before this reflects both the structural weaknesses of the NI manufacturing sector and lower plant-level AMT usage rates.

Our analysis suggests that in terms of the geography of innovation performance in Ireland there is little clear justification for the BMW/S&E regionalisation and no clear justification for any differentiation in policy or innovation support regimes between S&E and BMW regions. More important is the North-South differential with NI lagging behind the S&E and BMW regions on almost every indicator examined primarily due to innovation performance by plants in the 10-19 employee sizeband.

1. Introduction

The capability of a region to generate advanced technology, information and ultimately knowledge is regarded as the 'single most important force driving the secular process of economic growth' (Breshnahan and Trajtenberg, 1992, p1). Regional investment in R&D, technological development and innovation, in particular, is perceived as being strongly associated with productivity, growth and sustained international competitiveness (Malecki, 1981; Romer, 1990; Eaton and Kortum, 1996). Interest in the potential for technology-led, regional development strategies has also been stimulated by the example of successful regions (e.g. Heidenreich and Krauss, 1998; Yun, 1998), and the search by regional governments for more effective alternatives to traditional regional policy (e.g. Hassink, 1993)[1].

In Ireland[2] this has been reflected in the commitment of substantial resources from the Structural Funds and RIS programmes to the development of innovation capability. Until 1999, both NI and the Republic of Ireland had Objective 1 status, and substantial assistance programmes directed at technological development supported by the Structural Funds. In addition, the Shannon region centred on Limerick benefited from participation in the RIS programme (Dineen, 1995; Andreosso-O'Callaghan, 2000). Since 2000, Ireland has been divided into three NUTS 2 regions: Northern Ireland (NI) which has 'transitional' Objective 1 status; the Objective 1 Border Midlands & West (BMW) region, and the more prosperous South & East (S&E) region of the Republic of Ireland. Although motivated primarily by a desire to maximise Ireland's share of the 2000-2006 Structural Funds allocation (Boyle, 2000), the S&E/BMW split of the Republic of Ireland also reflects long standing concerns about the level and uneven distribution of economic development along the western

[1] Within the EU15 innovation policy has been seen as having both community-wide and regional dimensions. At community level, innovation promotion has been seen as a means of strengthening the competitive base of the European economy as a whole through initiatives such as the Framework programmes. At a regional level, policy has focussed on initiatives designed to stimulate regional technological development, notably through the Structural Funds and more specific initiatives such as the Regional Innovation Strategies (RIS), Regional Technology Partnership (RTP) and Regional Innovation and Technology Transfer Strategies (RITTS) programmes (e.g. ECOTEC, 1999).

[2] The term 'Ireland' is used here to denote the whole island of Ireland. Where more specific geographical references are needed the terms 'NI ' and the 'Republic of Ireland' are used.

seaboard of Ireland. In part this reflects concerns about the competitiveness and lack of technological orientation of many indigenous companies as well as issues related to peripherality, transport and communications infrastructure and uneven development (BMW Regional Assembly, 2000, p. 19).

Reflecting the perceived importance of enhanced technological development capacity, this paper provides benchmarks for the innovation performance of manufacturing businesses in the three NUTS 2 regions of Ireland in 1999, just prior to the start of the 2000-2006 Structural Funding. The benchmarks provide a standard against which the relative effectiveness of the subsequent Structural Funds programmes - and other related technological development programmes - can be measured. They also provide the context for the implementation of some of the specific measures proposed in the three regions' Operational Plans. In the BMW Regional Operational Plan, for example, the Regional Innovation Strategies sub-programme, part of the Local Enterprise Development sub-programme supported by the ERDF, aims 'to improve and enhance the R&D infrastructure and capacity' through the development of technology parks and incubation facilities, support for mentoring and advisory services and support for locally initiated collaborative mechanisms to deliver technology to the region (BMW Regional Assembly, 2000, p52 and 115). Similar priorities are indicated in the S&E Operational Plan (S&E Regional Assembly, 2001, p152), while the NI OP aims 'to achieve a positive impact on business competitiveness and a degree of diversification of the regional economy' (EU Commission, 1999, p49).

Innovation performance cannot, of course, be seen in isolation. In section 2 of the paper we therefore provide an admittedly superficial overview of the regional innovation systems of the three NUTS 2 regions. This provides the context for the specific innovation performance benchmarks outlined in section 3 (product and process development) and section 4 (adoption of advanced manufacturing technology). The innovation performance benchmarks are based on a large-scale survey of manufacturing plants conducted from 1999 to 2000 and reported originally in Roper and Anderson (2000). For this paper a new weighting structure has been developed to allow separate benchmarks to be derived for NI, the S&E and the BMW region (Annex 1).

2. Ireland's Three Regional Innovation Systems

The aim of this section is to provide an overview of the context for innovation and technological development in Ireland's three NUTS 2 regions. The perspective adopted is derived from the literature on regional innovation systems (RIS) which reflects the systemic nature of the innovation process and its dependence on the capabilities of, and linkages between, local organisations (Braczyk et al., 1998; EU, 1998), ‘untraded interdependencies’ (Dosi, 1988), knowledge ‘spillovers’ (Audretsch & Feldman, 1996), knowledge integration through ‘open systems architecture’ (Best, 2000), and the potentially important influence of regional innovation policy (EU, 1998, pp3-6). To paraphrase Metcalfe, (1997, pp461-462) a regional system of innovation is ‘that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technology.

An RIS may be said to comprise two main sub-systems (Autio, 1998):

(a) *The knowledge generation and diffusion sub-system* - comprising universities, FE colleges, other public research organisations, and technology transfer and technology mediating institutions. Most organisations within this sub-system have objectives linked to regional or national development. At best, this sub-system is populated by institutions with strong internal capabilities, dense and evenly distributed network links to other local organisations and 'open' external links to global centres of best practice (EU, 1998; Braczyk, 1998).

(b) *The knowledge application and exploitation sub-system* consisting largely of firms linked through (vertical) local supply-chains and trading relations and (horizontal) collaborative networks. The primary objective of actors within this sub-system is competitiveness measured by enhanced profitability or business value. In the strongest RIS: firms have strong internal innovation capabilities; local supplychain linkages are robust and characterised by strong knowledge flows between trading partners; and, horizontal collaboration networks are ubiquitous (EU, 1998; Braczyk, 1998).

Reflecting this distinction we divide the remainder of this section into two, relating first to the knowledge generation and diffusion sub-system and then to each region's knowledge application and exploitation sub-system[3]. Three general points are worth making in advance, however. First, both elements of each RIS reflect the overlay of national and regional economic conditions and policy. For example, a number of innovation promotion measures operating in NI (e.g. SMART, Link) operate UK-wide. Second, it is important to bear in mind that until the start of the 2000 to 2006 Structural Funds period no serious consideration had been given to BMW/S&E regional split in Republic of Ireland and that the regions do not constitute economically functional areas in any recognised sense[4]. Third, it is important to recognise that marked disparities exist within each region both in terms of economic conditions and technological infrastructure and activity[5]. For example, Andreosso-O'Callaghan et al. (2002) in their 'between' and 'within' region analysis of disparities of R&D and technology transfer activity by multi-national plants in the Republic suggest: 'This shows that each of the NUTS 2 regions in Ireland is far from being homogenous [and lends] support to the fact that there are innovative milieu in the poor region of the country such as the one represented by the Galway agglomeration' (p15).

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[3] We make no attempt here to review the historical development of RTD policy in Ireland. On this see O'Connor, 1987; OECD, 1987; Quinlan, 1995; STIAC, 1995; Kane, 1999; Roper and Frenkel, 2000; Calliano and Carprano, 2000; Roper, 2002.

[4] See Boyle (2000) for a lucid account of the political and constitutional processes which led to the 'regionalisation' of the Republic of Ireland and previous regional governance.

[5] From March to May 2002, for example, unemployment rates of those aged 15 plus ranged from 6.8 per cent in the Border area to only 3.9 per cent in the Midlands. Similarly, unemployment rates in the Mid-East were 3.3 per cent compared to 4.7 per cent in the South East. Source: QNHS, 2nd Quarter 2002, Press Release, CSO Dublin.

2.1 Knowledge generation and diffusion

The key capabilities of the knowledge generation and diffusion sub-system for local innovation are fourfold: the ability to generate new knowledge applicable to local firms; the ability to capture knowledge with local applicability; the ability to diffuse knowledge to potential users within the region; and finally, the ability to provide training in R&D and innovation skills which are retained within the region.

Higher and further education institutions play a central role within the knowledge generation and diffusion sub-system both as knowledge generators/attractors and as training providers. This potential was recognised in the development of the higher education network and the expansion of the dispersed Regional Technology College network in the Republic of Ireland in the 1970s and in the North in the expansion of the University of Ulster (Reid and Barrington, 1997; Jones-Evans, 1997). Despite this, it remains the case that the only university campus in the BMW region is NUI Galway with a much stronger concentration of university level training places in Dublin (in particular) and NI. NUI Galway, provides around ten thousand full and part-time student places compared to over 68,000 full and part time student places in seven higher education institutes in the S&E and 46,305 in NI (Table 1). Indeed, within the BMW region, the Institutes of Technology actually provide more higher education places (17,396 places in 1999/00) than NUI Galway alongside their other technology and business related courses (Table 1).

Perhaps more important than the pure number of higher education places they provide, however, is that through their research and other activities the Institutes of Technology provide foci for technology and business development in other parts of BMW region beyond the Galway agglomeration[6]. For example, Dundalk Institute of Technology provides 26 incubator spaces in its Regional Development Centre as does Sligo Institute of Technology in its Business Innovation Centre which housed 22

[6] One such development is the Technology Network established in 1999 with the support of Enterprise Ireland to enable the Institutes to provide firms with R&D, consultancy and technology transfer support.

projects at time of writing. Letterkenny Institute also operates an incubator - its Business Development Centre - and has played a significant role in developing NORWESCO, a cross-border partnership with a focus on improving innovation capability in local firms. Such initiatives by the Institutes of Technology are, of course, not limited to the BMW region. In the S&E, although the ten Institutes of Technology provide marginally fewer student places than the Universities (45,532) they again provide foci for business and technology development in areas lacking a university campus (e.g. Carlow, Tralee, Waterford). Again, the larger Institutes operate incubator facilities and provide consultancy and research support to local firms as well as participating in joint ventures such as the development of the Kerry Technology Park by Tralee Institute of Technology and Shannon Development.

In NI, the Further Education College (FEC) network is also widespread geographically, but is less important in terms of providing higher education places (12,020) than the Institute of Technology network. It is also notable that higher education places in the FEC's are strongly concentrated close to NI 's main university campuses in Belfast and Derry (Table 1). Many of the FEC's do have strong links to local companies through their training programmes, and run bespoke training courses etc, but they do not generally provide R&D or incubation services to local firms. Instead, local enterprise agencies linked to the District Councils exist throughout NI providing managed workspace for start-up companies and the two universities both operate business incubation facilities. The University of Ulster, for example, runs three incubator facilities: the Technology and Software Innovation Centre in Derry, an Innovation Centre on the new Research Park in Coleraine which focuses on bio-technology and bio-sciences companies and Technology, and the Engineering Innovation Centre in Jordanstown focussing on engineering and informatics. Both NI universities also offer a range of technology transfer services to local firms (e.g. QUB Technology Centre) and participate in collaborative research projects with local firms (e.g. Roper, 2002) as well as encouraging spin-out businesses (through UUTECH and QUBIS). Essentially similar activities are offered by NUI Galway alongside its Innovation Centre which provides eight nursery units as well as access to the resources, expertise and amenities of the College. The Galway campus also hosts the

International Services Park established in partnership with the Industrial Development Authority.

Universities in the S&E region also conduct extensive collaborative research with industry and provide business incubation facilities. TCD Innovation Centre for example, was established in 1986 and plays host to six start-ups and two PATs (National Pharmaceutical Biotechnology Centre and Materials Ireland). TCD has also recently worked with the Dept of Education and IDA to develop a larger enterprise centre in Dublin Docklands. Similarly, developments have also been undertaken by the other universities. The concentration of such activity, however, reflects the strong concentration of universities in the Dublin region with the main exceptions being University College Cork and University of Limerick. UL in particular has developed alongside the National Technology Park and the Innovation Centre which was established by Shannon development in 1980 to provide incubation facilities to high-technology companies (Dineen, 1995).

Recent survey work conducted by the Circa Group for InterTradeIreland, however, suggests (a) the relatively low level of commercialisation activity by each of the Irish universities, and (b) the extent of the disparities between the three Irish regions. Twenty-five universities, Institutes of Technology and Research Institutes were questioned about their commercialisation staff, suggesting that a total of 62 people (22 on a full-time equivalent basis) are involved in commercialisation activities across the whole of Ireland. The distribution across the regions - 0.7 FTE in the BMW region, 5.7 FTE in NI and 15.5 FTE in the S&E - again emphasises the concentration of higher education institutions in the main urban agglomerations and the weakness of the knowledge generation and diffusion sub-system of the BMW region's RIS. Also potentially important in terms of technology diffusion are other organisations such as the six Innovation Centres - part of the EC-BIC network - which operate throughout Ireland. These Centres provide a range of training and business services with the aim of contributing to the development of innovative capacity among indigenous enterprises. In the BMW region, WESTBIC, for example, operates through a series of seven local offices providing advisory, training and informational services. In the

S&E, innovation centres are based in Dublin, Cork, Waterford and Limerick, and in NI NORIBIC is based in Derry. Other, more recent, initiatives related to knowledge diffusion include the Technology Transfer Initiative (TTI), a collaborative scheme being operated by UCC, NUI Galway and UL with the aim of encouraging smaller firms to include an element of R&D in their operations (see, for example, www.technologytransfer.ie).

2.2 Knowledge application and exploitation

Key elements in the capability of regions' knowledge application and exploitation sub-system relate to the capabilities of individual firms, the economic structure or sectoral mix in an area; and, the extent of inter-organisational linkages. In terms of the capability of individual firms, perhaps the most important factor relates to in-house R&D which both contributes to in-house knowledge generation and enhances firms' knowledge absorption capability (e.g. Veugelers and Cassiman, 1999).

Little recent data exists on the regional distribution of R&D activity in Ireland but Quinlan (1995) provides an overview of developments in the regional distribution of R&D activity in Republic of Ireland until 1991[7]. She notes the stability of the ranking of the nine IDA regions over the post-1986 period, and comparing the proportion of all firms undertaking R&D, and R&D as percentage of gross output, concludes that: 'In the case of R&D the superior position of the East is not apparent, as the ratio of R&D performing firms to all establishments is quite uniform across all regions, with only the Midlands in particular and the North West lagging behind the national average' (Quinlan, 1995, p76). More marked differences are evident, however, between R&D as a percentage of gross output with the East (1.1 per cent), Mid-West (1.7 per cent) and Midlands (2.2 per cent) having above average (0.8) percentages although as Quinlan (p.86) notes these latter results are vulnerable to large scale

[7] For a more historical perspective see O'Connor (1987) which provides a thorough overview of R&D activity in the Republic of Ireland in the mid to late 1980s. Current Forfas surveys of business R&D provide no regional breakdown due to the 'lack of statistical robustness' of any such regional results.

investments by single firms[8]. One implication is that 'R&D activity in Ireland is far more spatially dispersed than has been observed in other countries. … Ownership of firms therefore appears as the primary issue in the analysis of trends which emerge both in terms of the quality and quantity in the geography of R&D spending in Ireland (Quinlan, 1985, pp100-101).

The dispersion of R&D investment and R&D active businesses across the Republic of Ireland noted by Quinlan (1995) reflects the policy of dispersion of inward investment adopted in Ireland since the mid-1970s (O'Farrell, 1980; Drudy, 1991; Meyler and Strobl, 1997). One other consequence is that the composition of GVA between the BMW and S&E regions is relatively similar with both regions deriving around 41-42 per cent of GVA from manufacturing and construction compared to 25.4 per cent in NI [9]. In addition, also reflecting the more significant inward investment into the Republic of Ireland over the last decade, a significantly smaller proportion of manufacturing employment in NI is in high tech sectors (29.8 per cent) than in the S&E and BMW region (41-45 per cent)[10] (see also NIEC, 2001). Other, more recent studies, also suggest similarities between the activities of industry in the BMW and S&E regions but contrasts between NI and the two Republic of Ireland regions. Andreosso-O'Callaghan et al. (2002), for example, compare the technology development and technology transfer activities of a sample of multi-national plants in the S&E and BMW region and found that that more than half of all MNE plants were conducting some R&D in house and, perhaps contrary to expectations, that MNE plants in the BMW region were more likely to be undertaking basic or pure R&D than those in the S&E. Andreosso-O'Callaghan et al. also found no difference in the technology transfer activities of MNE plants in S&E and BMW regions. Hewitt-Dundas et al (2002), however, do identify marked NI/Republic of Ireland differences,

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[8] Figures for the other IDA regions were: North East and South East 0.3 per cent; South West 0.5 per cent; Donegal and North-West 0.8 per cent. Source, Quinlan, 1985, Table 5.2, p.75.

[9] Figures for the composition of GVA in 1998/99 are taken from Composition of GVA: BMW and S&E, County incomes and regional GDP 1999, CSO, Dublin; NI, Regional Economic Outlook, NIERC/OEF. Figures are for manufacturing and construction: BME, 40.5 per cent; S&E, 42.1 per cent; NI, 25.4 per cent. For market and non-market services: BMW, 51.7 per cent; S&S, 55 per cent; NI, 68.6 per cent. Remaining GVA derives from agriculture, forestry etc.

with lower proportions of NI-based MNE plants using advanced manufacturing technologies (AMTs) and engaging in lower levels of developmental technology transfer activity than their Southern counterparts.

More generally, data from the Product and Process Development Survey or PPDS3 (see Annex 1) provides information on the proportion of plants having 'links to other companies or organisations as part of [their] product or process development activities'. Overall, the proportion of plants with such linkages was highest in the BMW region (47.9 per cent) compared to the S&E (44.9 per cent) with both regions having significantly stronger inter-plant linkages than NI (35.8 per cent). By plant sizeband a slightly more complex picture emerges with no significant difference between innovation linkages between regions for those with 100 plus employees but significantly less common linkages among smaller plants (Table 2).

Considering the type of partners which plants relate to as part of the innovation activity suggests a consistent overall picture with both the BMW region and the S&E having innovation linkages more common with most of types of partners than in NI, with no significant differences between BMW and S&E regions (Table 3). Indeed, in seven out of the ten types of partner, innovation linkages were more common among plants in the BMW region. One notable exception given the weakness of the university sector in the BMW region noted earlier is that 16.9 per cent of plants in the S&E had a university connection compared to 14.5 per cent in the BMW region.

2.3 Overview

Previous analyses of both the NI and Republic of Ireland innovation systems in comparison to 'best practice' within Europe and elsewhere have tended to emphasise the weaknesses of the Irish RIS. In a report produced for the STIAC in 1995, the

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[10] Composition of manufacturing employment: BMW and S&E, Table 4, Census of Industrial Production 1998; NI, ABI 1997.

Circa group, after considering the Republic of Ireland innovation system, summarised the situation by saying:

> *'Overall … the national science and technology system on the product side is now largely based on an under-funded university sector and a much rationalised state sector; it is dispersed, lacks critical mass in many areas and is weakened by historical neglect and drift. On the 'user side' indigenous industry is highly fragmented,, of small scale and has low innovative capability in general'. (STIAC, 1995, p44).*

Similarly, Cooke, Roper and Wylie (2002) have more recently described the NI RIS as 'relatively globalised and non-associative … dominated by a relatively few large firms, with predominantly national and global rather than local and regional linkages, and supported by relatively low levels of regional private and public R&D'. Similar perspectives are reflected in regions' current Regional Operational Plans. The BMW region operational plan, for example, refers to the region's ' limited industrial or services base with GVA across all sectors lower than the national average' and 'few R&D oriented companies' (BMW Regional Assembly, p19). In similar vein, the NI OP acknowledges that 'NI 's industrial structure is characterised by relatively low value per hour worked and has a marked absence of high technology industries … has a low propensity to undertake R&D activities', (EU Commission, 1999, p47).

Our analysis has highlighted the weakness and uneven distribution of the knowledge generation and diffusion sub-system in the BMW region, in particular, and the concentration of knowledge generation capacity in the main urban centres of the S&E and NI. In terms of the knowledge application sub-system, however, no clear differences are evident between the BMW and S&E regions in terms of R&D capability, industrial structure and innovation linkages. More significant differences exist between these two regions and Northern Ireland with lower levels of high-tech employment, lower levels of AMT use by MNE plants and lower levels of innovation linkage particularly among smaller firms.

The key question is to what extent the weaker knowledge generation and diffusion sub-system in the BMW region, and the weaker knowledge application sub-system in NI, influence innovation performance? One possible answer is provided by the innovation performance benchmarks outlined in the next two sections.

3. Innovation Performance Benchmarks

Three indicators are used here to compare product and process innovation performance in the three regions:

(a) *The product innovation rate* - an indicator of the extent of product innovation activity, measured as the proportion of all manufacturing plants with 10 or more employees introducing new or improved products over the previous three years.

(b) *The process innovation rate* - an indicator of the extent of production process innovation activity, measured as the proportion of all manufacturing plants with 10 or more employees introducing new or upgraded production processes over the previous three years.

(c) *Innovation success* - measured by the percentage of plants' sales in 1999 obtained from selling products which had been either newly introduced or improved over the preceding three years.

Each of these three indicators relates to the outputs from the innovation process and each reflects a different aspect of plants' innovation performance. Innovation rates provide an overall guide to the extent of activity but no idea of innovations' commercial impact. This is, however, reflected in the third measure of innovation success.

Across the three regions, 59 per cent of all manufacturing plants undertook product and process innovation in the three years prior to 1999 (Table 4). In each case the proportion of innovating plants was highest in the S&E and lowest in NI, with no statistically significant differences evident between the S&E and BMW regions or the BMW region and NI. A broadly similar pattern was evident in terms of innovation success, with plants in NI having a lower average share of innovative sales (11.5 per cent) than those in both the BMW (16.9 per cent) and S&E region (15.9 per cent). It is possible that these aggregate differences reflect true differences in the innovation performance of plants but they may also reflect the structural differences noted earlier, and in particular the larger share of manufacturing plants in the S&E and BMW in high-tech sectors. Differences in plant size structure may also be important, however, as previous studies using the PPDS3 (e.g. Roper and Anderson, 2000, p4) have pointed to higher innovation rates among larger plants. To assess the potential impact of structural factors on the overall innovation performance we first consider results by plant sizeband and industry before outlining some structurally 'corrected' innovation performance indicators.

In terms of plant sizeband we find, as expected, higher product and process innovation rates among larger plants in each of the three regions (Table 4). Notably, however, no statistically significant differences were evident between regions for plants in either the 20-99 or the 100 plus employee sizebands. Among smaller plants (i.e. 10-19 employees), the product innovation rate in both NI and the BMW region was low relative to the S&E, while in terms of the process innovation rate the only significant performance differential is that between NI and the S&E. As a disproportionately large proportion of manufacturing plants in NI are in the 10-19 employee sizeband, the relatively low innovation rate among this group may be one factor contributing to NI 's lower overall innovation rate[11].

In terms of innovation success, we find a different pattern in the BMW and S&E to that in NI (Table 4). In the Republic of Ireland regions, innovation success is lowest among plants in the 20-99 sizeband. In NI, however, the proportion of innovative sales is lowest for small plants and rises with plant sizeband. No significant differences are evident between the innovation success of plants with 100 plus employees but smaller plants in NI (in both the 10-19 and 20-99 employee sizebands) again under-perform relative to those in the BMW and S&E. Again, lower innovation success among plants in these sizebands is one factor contributing to NI 's lower overall level of innovation success.

[11] In 1998, 39.2 per cent of manufacturing plants with more than 10 employees were in the 10-19 sizeband in NI compared to 30.2 per cent in the BMW region and 31.9 per cent in the S&E. Sources: Annex 1.

Comparison of innovation rates and innovation success by industry also suggests important differences between sectors although relatively few of these prove statistically significant (Annex 2)[12]. Perhaps more interesting, particularly given the very different patterns of inward investment North and South of the border and concerns about the innovative capacity of indigenous firms, are contrasts between the innovation performance of externally-owned and indigenously-owned plants in each region (Table 5). For example, in terms of both product and process innovation rates and innovation success, externally-owned plants consistently outperform their indigenously-owned counterparts (Table 5). This provides some justification for the types of concerns raised in the Regional Operational Plants about the limited technological capability of some indigenously-owned firms in Ireland (e.g. BMW Regional Assembly, 2000, p19).

In terms of each innovation benchmark, there is also no statistically significant regional difference between externally-owned firms. The implication is that wherever they are located externally-owned plants have broadly the same innovation performance, with locational factors having a relatively weak effect on their innovation performance (e.g. Roper, 2000). Roper and Love (2001), in their analysis of the export performance of externally-owned firms in Ireland, offer one possible explanation arguing that such firms are only weakly linked into the domestic RIS, depending instead for their innovation on intra-group technology transfers from outside Ireland.

Finally, product and process innovation rates and innovation success among indigenously-owned plants in NI lagged that in both other regions (Table 5). The impact of location on innovation performance therefore seems more important for indigenously-owned firms, with small plants (with 10-19 employees) under-performing, particularly in NI (Tables 4 and 2). This may reflect the concentration of small plants in the low-tech sectors in NI and underlines the type of results suggested

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[12] A degree of caution is also necessary in interpreting the industry results due to the relatively small sample sizes in some sectors.

by Roper and Love (2001) who highlight the relatively poor export performance of small manufacturing plants in NI compared to their Republic of Ireland counterparts[13].

The previous discussion has highlighted both sectoral and sizeband factors which may be reducing overall innovation performance in NI. In terms of sectoral mix, we have already noted the higher proportion of GVA coming from the more innovative high-tech sectors in the S&E and BMW regions. In terms of plant sizeband, we have also noted that NI has a disproportionately large share of smaller plants within its manufacturing sector. As these plants also tend to be less active and less successful innovators than larger firms, both factors work together to reduce regional innovation performance. To correct for these 'structural' influences it is possible to construct corrected measures of innovation performance based on a common industrial structure/plant sizeband[14]. Suppose that n_{ij} is the number of plants in a region in industry i, sizeband j and that I_{ij} is an indicator of innovation performance in the same sector. Average innovation performance in the region can then be derived as:

$$\bar{I} = \frac{\sum_i \sum_j n_{ij} I_{ij}}{\sum_i \sum_j n_{ij}}$$

Now using a common set of n_{ij} (here for the BMW region) we can derive a set of aggregate innovation performance benchmarks which reflect more closely differences in innovation performance between similar firms (Table 8) and allows us to decompose regional differences in innovation performance into 'structural' and 'plant-level' components (Table 7). Comparison of the aggregate regional innovation rates in Table 4, for example, suggests a 6.4 pp difference in product innovation rates between S&E and NI reflecting the combination of both structural and plant level

[13] In 1999, 84 per cent of plants in the 10-19 employee sizeband in NI were in low-tech sectors compared to 81.5 per cent of 20-99 employee companies and 76.7 per cent of plants in the 100 plus sizeband. Source: Size Analysis of UK Business, 1999, Table 9.1, ONS.

effects. The structurally adjusted difference, reflecting only differences in product innovation rates between similar types of plant, is 5.1 pp. The residual, structural effect, is therefore 1.3 pp (Table 7).

The decomposition suggests that differences in innovation performance between the S&E and NI and BMW region and NI are a combination of reinforcing negative structural and negative plant-level effects. In terms of the S&E-BMW comparison a different picture emerges with the aggregate regional comparisons under-estimating the true differences in plant-level innovation performance as significant gaps in plant-level innovation performance were offset to some extent by the more positive structure of industry in the BMW region.

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[14] An alternative approach uses regression models to standardise for potential sectoral and plant-size effects. See Roper (2001) for this type of approach to Irish regional data.

4. AMT adoption

Another way of looking at plants' process innovation activities is to consider their adoption and use of advanced manufacturing technology or AMT. Advanced manufacturing technology is broadly defined as "an automated production system of people, machines and tools for the planning and control of the production process, including the procurement of raw materials, parts and components and the shipment and service of finished products" (Pennings 1987, p198). The use of advanced manufacturing technologies (AMT) is important because their implicit flexibility can allow small firms, in particular, to overcome the limitations of conventional technology and take advantage of economies of scope based on low volume and low cost production. Specifically, AMT can facilitate customisation and reduced lead times through the production of variety, frequent design changeovers, and rapid processing of design, assembly, materials handling and market information (Parthasarthy and Sethi 1992; Majchrzak 1988; Swamidass 1988).

As part of the PPDS3 plants were asked to indicate whether they currently used a range of different AMTs and at what date these had first been implemented. This provides a guide to the speed with which each AMT has been adopted by plants in each region, the assumption being that more rapid adoption is likely to give plants in any area some competitive advantage. The adoption curves obtained are given in Figure 1 for nine of the main AMTs. For each technique there is clearly a rising level of utilisation in each of the three regions with, perhaps surprisingly, a marked similarity between speed of adoption of each AMT across the three regions. Some exceptions are evident with NI in particular having slower adoption rates of CAD, Robotics, Quality Certification and Just in Time since 1996 than the BMW and S&E regions (Figure 1). This differential pattern of adoption was reflected in the use of each AMT by plants in 1999 (Table 8). In terms of their use of robotics, and Just in Time, NI plants lagged significantly behind both other regions, while for CAD and Quality Certification, NI firms' usage lagged behind that in S&E. No significant differences between the three regions were evident the use of AMH, computer aided production management, TQM and quality circles; and the only significant difference between AMT use in the BMW and S&E regions was for JIT. The picture of AMT adoption and usage suggested here is very similar to that earlier from product and process innovation with little clear difference between the S&E and BMW regions and NI having generally lower levels of adoption/innovation.

Adjusting for industrial structure (again to that of the BMW region) highlights plant-level differences in AMT adoption rates. Again, little consistent difference is evident between the S&E and the BMW region with adjusted adoption rates being higher for five AMTs in the S&E and five AMTs in the BMW region (Table 8). With the exception of quality circles in the BMW region, structurally adjusted AMT adoption rates in Northern Ireland remain below those in the other two regions. The implication is that on a like-for-like basis plants in Northern Ireland remain less likely than their counterparts in the Republic of Ireland to be using each AMT. Again this suggests that in general the overall difference in AMT adoption between NI and the other two regions reflects reinforcing negative plant-level and negative structural effects (Table 9). Between the S&E and the BMW regions the balance of structural and plant-level effects is less clear, although for six of the ten AMTs the BMW region enjoys some structural advantage.

5. Conclusions

Innovation is now widely appreciated as one of the key drivers of positive economic change, and innovation performance therefore provides a potentially important litmus test of a region or nation's ability to generate and sustain competitiveness. Innovation itself, however, measured in terms of product or process change is the culmination of a process which depends on a wide range of contributory factor sometimes summarised under the general heading of the regional innovation system or RIS. This in turn can be sub-divided into the knowledge generation and diffusion sub-system, in which the primary actors are the universities and colleges, and the knowledge application sub-system dominated by firms themselves.

Consideration of the regional innovation systems of Ireland's three NUTS 2 regions suggests some profound and important differences. First, the knowledge generation and diffusion sub-systems of NI and the S&E are notably stronger and more evenly spread than that in the BMW region. In addition, the absolute scale of the universities/Institutes of Technology network in the BMW region is disproportionately small compared to that in the S&E and NI. This is true both in terms of higher education places and also, for example, in terms of the number of university/college staff involved in commercialisation activities. In terms of the knowledge application sub-system a very different picture emerges with NI lagging on a number of counts: low levels of in-house R&D capability, low levels of inter-company and inter-organisational networks and a particularly high share of employment in low-technology industries particularly in small firms. Few such differences are evident between the S&E and BMW regions, with the latter actually having more extensive inter-organisational linkages.

The implication is that the S&E region has the strongest RIS, having both a concentration of knowledge generating institutions and a relatively strong company base. The BMW region has weaknesses with its knowledge generation and diffusion sub-system but - at least compared to NI - a stronger company base. While in NI a relatively strong knowledge generation capacity combines with a weaker knowledge application sub-system.

These differentials are reflected in the innovation benchmarks with a clear regional hierarchy emerging topped by the S&E followed by the BMW region and Northern Ireland. In most cases, however, differences in innovation performance between the S&E and the BMW region prove statistically insignificant, while those between NI and the other two regions are stronger and often statistically significant. Product and process innovation rates and innovation success, for example, are highest in the S&E for all firms with the majority of the regional differential attributable to under-performance by smaller firms (in the 10-19 employee sizeband) in the BMW region but particularly in Northern Ireland. Correcting for industrial structure suggests that the differential in innovation performance between the S&E and Northern Ireland reflects both structural weaknesses in NI as well as differences in plant-level innovation rates, particularly among smaller firms. These results reflect those of other studies of the distribution of R&D in the Republic of Ireland (e.g. Quinlan, 1995), regional innovation (e.g. Roper, 2001) and the technological development activities of MNE plants in Ireland (e.g. Andreosso-O'Callaghan et al., 2002; Hewitt-Dundas et. al., 2002) which have suggested little significant East-West difference in innovation activity within Ireland but more profound North-South contrasts.

In addition to general indicators of product and process innovation success we also consider indicators relating to the adoption and use of a range of AMTs by plants in each region. Here we see marked similarities in the speed of adoption of each technology between regions but some significant differences in current AMT usage rates. Again our results suggest little consistent difference between the S&E and BMW regions and lower adoption rates in NI. As before this reflects both the structural weaknesses of the NI manufacturing sector and lower plant-level AMT usage rates.

Our analysis suggests that in terms of the geography of innovation performance in Ireland there is little clear justification for the BMW/S&E regionalisation. Clear differences are evident in the two regions' knowledge generation sub-systems but these do not seem to be reflected in any important way in levels of innovation performance or AMT adoption. These may reflect instead the marked similarities in between the structure of the manufacturing sector in the two regions in terms of R&D investments, linkages and sectoral structure. Indeed, if parity in terms of innovation performance is seen as a broad aim of policy our evidence suggests no clear justification for any differentiation in policy or innovation support regimes between S&E and BMW regions.

More important in terms of innovation performance is the North-South differential with NI lagging behind the S&E and BMW regions on almost every indicator examined. It is important, however, to recognise that this is not something endemic to Northern Ireland. Externally-owned firms, for example, are found to have very similar innovation performance across all three of the regions. Also, North-South differentials in innovation performance are less significant for larger plants (100 plus employees). Larger innovation performance differentials are evident for smaller plants, particularly those in the 10-19 employee sizeband. Here, NI lags significantly behind the other two regions suggesting a particular need to improve the innovation capabilities of this group of firms in NI and perhaps the value of looking at the type of support packages being offered in the Republic of Ireland.

In more general terms, the importance of the North-South rather than the East-West differential in innovation performance also suggests that in terms of innovation at least the current regional prioritisation of Structural Funding in Ireland is misplaced.

Although significant regional differences do exist within Ireland it is also important to recognise some more global and common challenges for the future. In particular, despite recent increases in public investment in R&D both in NI and the Republic of Ireland, the overall level of R&D investment throughout Ireland remains well below that of the most successful small economies (e.g. Finland, Israel). Innovation policy within Ireland also remains strongly regional (or at least North- South), with relatively little being known about the nature of the all-Ireland innovation system either from the perspective of institutional capabilities or networks. In an increasingly inter-connected and resource constrained world this seems at best wasteful and at worst irresponsible.

Figure 1: AMT Adoption Curves By Region: 1993-1999

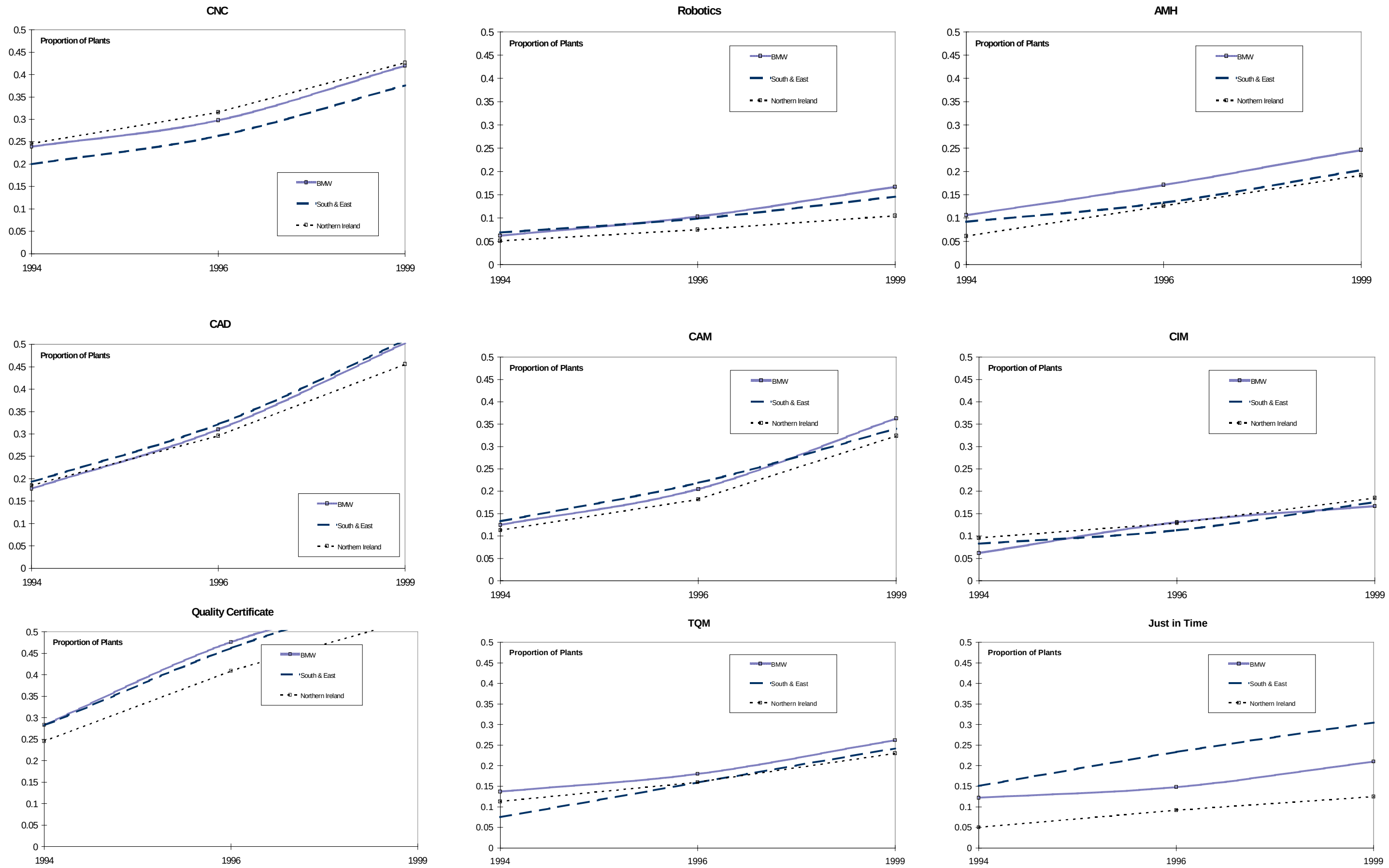

Table 1: Higher Education Enrolments by Region and Institution

Border, Midlands and West			South And East			NI		
	FT	PT		FT	PT		FT	PT
1. Universities etc.	**8655**	**1126**		**58,259**	**10,179**		**29895**	**16410**
NUI, Galway	8,655	1,126	University College Cork	11,122	772	Queen's University Belfast	13635	8490
			University College Dublin,	15,088	3,269	St Mary's University College	745	220
			Trinity College, Dublin	10,896	2,866	Stranmillis University College	825	390
			National University of Ireland, Maynooth	4,028	614	University of Ulster	14690	7310
			Dublin City University	6,998	1,174			
			University of Limerick	9,394	1,476			
			National College of Art & Design	733	8			
2. Institutes of Technology/ Further Education/Other Colleges	**15,050**	**2,346**		**31,374**	**14,158**	**Further Education Colleges**	**3576**	**8444**
Athlone Institute of Technology	3,032	567	Dublin Institute of Technology	9,642	5,426	Armagh		66
Dundalk Institute of Technology	2,583	403	Institute of Technology, Carlow	2,360	429	BIFHE	1,398	2,800
Galway-Mayo Institute of Technology	4,323	806	Cork Institute of Technology	5,395	3,148	Castlereagh		237
Letterkenny Institute of Technology	1,851	285	Limerick Institute of Technology	3,231	1,495	Causeway		154
Institute of Technology, Sligo	2,959	212	Institute of Technology, Tallaght	2,156	1,565	East Antrim	40	449
Hotel Training & Catering College, Killybegs	302	73	Institute of Technology, Tralee	2,229	604	East Down	17	258
			Waterford Institute of Technology	5,280	1,351	East Tyrone		304
			Dun Laoghaire Institute of Art, Design and Technology	696	46	Fermanagh	144	505
			Institute of Technology, Blanchardstown	223	81	Limavady		127
			Tipperary Institute	162	13	Lisburn	60	504
						NEIFHE	180	450

Table 1: Higher Education Enrolments by Region and Institution cont'd

Border, Midlands and West			South And East			NI		
	FT	PT		FT	PT		FT	PT
3. Other Colleges	**289**	**0**		**2069**	**3660**	Newry	212	613
St. Angela's College, Lough Gill, Co. Sligo	289		Coláiste Mhuire, Marino, Dublin	262		NIHCC	201	11
			Church of Ireland College of Education, Rathmines, Dublin	92		North Down and Ards	447	585
			Froebel College of Education, Blackrock, Co. Dublin	180		NWIFHE	686	538
			St. Catherine's College, Sion Hill, Co. Dublin	101		Omagh	6	263
			National College of Ireland	800	3,612	Upper Bann	185	580
			Mater Dei Institute, Clonliffe Road, Dublin	259	23			
			Pontifical College, Maynooth, Co.Kildare	375	25			

Sources: Republic of Ireland, Table 7.4 Statistical Report 1999/2000, Department of Education and Science; NI, Enrolments on Vocational Courses at NI FE Colleges 2000/01 and Higher Education Statistics Press Release 2000/01, Department for Employment and Learning

Table 2: Percentage of Manufacturing Plants With Innovation Linkages by Sizeband

	Plant Size-band							
	10-19		20-99		100+		All Plants	
	%	N	%	n	%	n	%	n
BMW	34.7	37	49.6	117	65.9	52	47.9	206
South & East	28.3	68	48.9	199	62.3	131	44.9	398
Northern Ireland	24.1	78	36.1	225	66.7	100	35.8	403

Notes:

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results (see Annex 1). Sample χ^2 tests were used to determine whether the proportion of plants having linkages in the populations was the same.

2. For all plants the test statistics were as follows: BMW and South & East, $\chi^2 = 0.462$ ($\rho = 0.497$); BMW and Northern Ireland, $\chi^2 = 6.926$ ($\rho = 0.008$); South & East and Northern Ireland, $\chi^2 = 5.547$ ($\rho = 0.019$).

3. For plant size bands statistically significant differences were found in the following cases: BMW and Northern Ireland, 10-19 employees, $\chi^2 = 4.741$ ($\rho = 0.029$); BMW and Northern Ireland, 20-99 employees, $\chi^2 = 4.170$ ($\rho = 0.041$); South & East and Northern Ireland, 20-99 size-band, $\chi^2 = 7.640$ ($\rho = 0.006$).

Table 3: Percentage of Manufacturing Plants With Innovation Linkages

	BMW %	South & East %	Northern Ireland %	All Plants %
n	206	398	402	1006
Other group Companies	20.4	24.2	17.1	21.2
Clients/customers	32.3	28.2	22.8	27.3
Suppliers	31.8	31.7	24.8	29.5
Competitors	7.8	7.1	5.9	6.8
Joint Ventures	9.1	7.5	5.2	7.1
Consultants	24.1	20.2	12.7	18.6
Government research labs	10.9	10.5	5.1	8.9
Universities/higher education	14.5	16.9	12.8	15.1
Industry operated labs	8.1	7.7	5.2	7.0
Private research institutes	5.4	9.6	6.3	7.8

Notes:

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results (see Annex 1).

2. Sample χ^2 tests were used to determine whether the proportion of plants having linkages in the underlying BMW, South & East and NI populations was the same.

3. Statistically significant differences were found in the following cases: BMW and NI, Clients/customers, χ^2= 4.136 (ρ = 0.042); BMW and NI, Joint Ventures, χ^2 = 3.989 (ρ = 0.046); BMW and NI, Consultants, χ^2 = 15.768 (ρ = 0.000); BMW and NI, Government Research Labs, χ^2 = 6.096 (ρ = 0.014); BMW and NI, Industry Operated Labs, χ^2 = 3.017 (ρ = 0.082); South & East and NI, Other Group Companies, χ^2 = 9.237 (ρ = 0.002); South & East and NI, Suppliers, χ^2 = 3.301 (ρ = 0.069); South & East and NI, Joint Ventures, χ^2 = 4.197 (ρ = 0.041); South & East and NI, Consultants, χ^2 = 8.132 (ρ = 0.004); South & East and NI, Government Research Labs, χ^2 = 3.223 (ρ = 0.073); South & East and NI, Private Research Institutes, χ^2 = 2.755 (ρ = 0.097).

Table 4: Percentage of Plants Undertaking Product and Process Innovation Activity: By Plant Size-band

	Plant-size Band			
	10-19 %	20-99 %	100+ %	All Plants %
Product Innovation Rate (%)				
BMW	40.8	62.7	87.0	61.0
S&E	56.2	60.9	70.8	61.3
NI	43.0	57.5	79.2	54.9
Process Innovation Rate (%)				
BMW	40.9	64.5	77.2	60.2
S&E	49.1	65.6	74.8	62.1
NI	40.0	58.2	70.2	52.8
Innovation Success (%)				
BMW	18.5	15.9	17.2	16.9
S&E	16.5	14.2	18.8	15.9
NI	8.9	11.7	17.2	11.5

Notes

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results.

2. Sample χ^2 tests were used to examine whether the innovation rates in the underlying BMW, S&E and NI populations was the same. For product innovation the aggregate test statistics were: BMW and S&E, $\chi^2 = 0.105$ ($\rho = 0.746$); BMW and NI, $\chi^2 = 2.043$ ($\rho = 0.153$); S&E and NI, $\chi^2 = 4.588$ ($\rho = 0.032$). For process innovation the test statistics are: BMW and S&E, $\chi^2 = 0.782$ ($\rho = 0.376$); BMW and NI, $\chi^2 = 0.782$ ($\rho = 0.376$); S&E and NI, $\chi^2 = 8.428$ ($\rho = 0.004$).

3. Sample sizes are as follows for BMW; 10-19 employees, 35; 20-99 employees, 116; 100 plus employees, 50; all plants, 201. S&E ; 10-19 employees, 66; 20-99 employees, 198; 100 plus employees, 129; all plants, 393. NI ; 10-19 employees, 74; 20-99 employees, 226; 100 plus employees, 100; all plants, 400.

4. Sample χ^2 tests were used to examine whether the innovation rates in the underlying BMW, S&E and NI populations was the same. Statistically significant differences were found in the following cases: product innovation: BMW and S&E, 10-19 employees, $\chi^2 = 4.256$ ($\rho = 0.039$); S&E and NI, 10-19 employees, $\chi^2 = 7.004$ ($\rho = 0.008$); process innovation: S&E and NI, 10-19 employees, $\chi^2 = 3.631$ ($\rho = 0.057$)

5. Sample t tests were used to examine whether innovation success in underlying BMW, S&E and NI populations was the same. Statistically significant differences were found in the following cases: BMW and NI, 10-19 employees, t = 1.931 ($\rho = 0.006$); BMW and NI, 20-99 employees, t = 1.745 ($\rho = 0.083$); S&E and NI, 10-19 employees, t = 2.440 ($\rho = 0.016$); S&E and NI, 20-99 employees, t = 1.755 ($\rho = 0.080$)

Table 5: Innovation Performance Benchmarks by Ownership

	BMW	S&E	NI
Product Innovation Rate (%)			
Indigenously-owned	58.2	58.6	50.2
Externally-owned	69.5	67.9	73.6
Process Innovation Rate (%)			
Indigenously-owned	58.9	57.6	48.3
Externally-owned	72.3	73.9	71.4
Innovation Success (%)			
Indigenously Owned	16.4	13.8	9.5
Externally Owned	17.3	21.6	21.5

Notes:

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results.

2. Sample χ^2 tests were used to examine whether the innovation rates in the underlying BMW, S&E and NI populations was the same. Product innovation rates: BMW and NI, indigenously-owned, $\chi^2 = 3.581$ ($\rho = 0.058$); S&E and NI, indigenously-owned, $\chi^2 = 4.777$ ($\rho = 0.029$).

3. Sample χ^2 tests were used to examine whether the innovation rates in the underlying BMW, S&E and NI populations was the same. Process innovation rates**:** BMW and NI, Indigenously Owned, $\chi^2 = 3.953$ ($\rho = 0.047$); S&E and NI, indigenously-owned, $\chi^2 = 4.553$ ($\rho = 0.033$).

4. Sample t tests were used to examine whether innovation success in the underlying populations were the same: BMW and NI, indigenously-owned, $t = 2.656$ ($\rho = 0.009$); S&E and NI, indigenously-owned, $t = 2.475$ ($\rho = 0.014$).

Table 6: Structurally Adjusted Innovation Indicators

	BMW	S&E	NI
Product Innovation (%)	60.6	65.0	59.9
Process Innovation (%)	60.3	63.9	56.2
Average New Products (%)	16.8	16.3	12.3

Table 7: Decomposition of Regional Differences in Innovation Performance

	S&E and BMW	S&E and NI	BMW and NI
Total Performance Gap (i.e. Unadjusted - Adjusted, pp)			
Product Innovation (%)	1.0	6.4	6.1
Process Innovation (%)	1.9	9.3	7.4
Average New Products (%)	-1.0	4.4	5.4
Plant Level Performance Gap (i.e. Adjusted, pp)			
Product Innovation (%)	4.6	5.1	0.7
Process Innovation (%)	3.6	7.7	4.1
Average New Products (%)	-0.5	4.0	4.5
Structural Component of Performance Gap (i.e. Residual, pp)			
Product Innovation (%)	-3.6	1.3	5.4
Process Innovation (%)	-2.7	2.1	3.3
Average New Products (%)	-0.5	0.4	0.9

Table 8: Percentage of Plants using AMT

				Structurally Adjusted		
	BMW %	South & East %	Northern Ireland %	BMW %	South & East %	Northern Ireland %
n	185	364	339	185	364	339
Production Techniques:						
CNC	45.2	39.1	42.7	45.2	39.8	45.1
Robotics	17.5	15.1	11.5	17.5	15.9	12.4
Automated Materials Handling	25.7	21.0	20.6	25.7	22.5	22.3
Computer Aided Design	51.2	53.2	46.5	51.2	52.2	47.9
Computer Aided Production Management	37.1	35.5	34.0	37.1	35.2	34.7
Computer Integrated Manufacture	17.9	19.4	17.3	17.9	19.6	17.9
Organisational Techniques:						
Quality Certification	59.7	61.2	54.5	59.7	60.7	55.6
Total Quality Management	27.4	26.1	24.3	27.4	25.9	25.4
Quality Circles	7.9	11.5	9.2	7.9	12.3	9.2
Just in Time	22.7	31.8	13.9	22.7	32.9	14.9

Notes:

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results (see Annex 1). Sample χ^2 tests were used to determine whether the proportion of plants using AMT in the underlying BMW, S&E and NI populations was the same.

2. Statistically significant differences were found in the following cases: BMW and NI, Robotics, χ^2 = 5.130 (ρ = 0.024); S&E and NI, Robotics, χ^2 = 7.838 (ρ = 0.005); S&E and NI, Computer Aided Design, χ^2 = 3.575 (ρ = 0.059); S&E and NI, Computer Integrated Manufacture, χ^2 = 4.737 (ρ = 0.030); S&E and NI, Quality Certification, χ^2 = 3.952 (ρ = 0.047); S&E and NI, Quality Circles, χ^2 = 3.295 (ρ = 0.070); BMW and S&E, Just in Time, χ^2 = 4.625 (ρ = 0.032); BMW and NI, Just in Time, χ^2 = 5.222 (ρ = 0.022); S&E and NI, Just in Time, χ^2= 27.506 (ρ = 0.000).

Table 9: Decomposition of Regional AMT Use

	S&E - BMW	S&E - NI	BMW-NI	S&E - BMW	S&E - NI	BMW-NI	S&E - BMW	S&E - NI	BMW-NI
	Total Performance Gap (i.e. Unadjusted – Adjusted, pp)			Plant Level Performance Gap (i.e. Adjusted, pp)			Structural component of Performance Gap (i.e. Residual, pp)		
Production Techniques									
CNC	-6.1	-3.6	2.5	-5.4	-5.3	0.1	-0.7	1.7	2.4
Robotics	-2.4	3.6	6	-1.6	3.5	5.1	-0.8	0.1	0.9
AMH	-4.7	0.4	5.1	-3.2	0.2	3.4	-1.5	0.2	1.7
CAD	2	6.7	4.7	1	4.3	3.3	1	2.4	1.4
CAPM	-1.6	1.5	3.1	-1.9	0.5	2.4	0.3	1	0.7
CIM	1.5	2.1	0.6	1.7	1.7	0	-0.2	0.4	0.6
Organisational Techniques									
Quality Certification	1.5	6.7	5.2	1	5.1	4.1	0.5	1.6	1.1
TQM	-1.3	1.8	3.1	-1.5	0.5	2	0.2	1.3	1.1
Quality Circles	3.6	2.3	-1.3	4.4	3.1	-1.3	-0.8	-0.8	0
Just in Time	9.1	17.9	8.8	10.2	18	7.8	-1.1	-0.1	1

Table 10: Percentage of Plants in 10-19 Size-band using AMT

	BMW %	S&E %	NI %	All Plants %
n	24	56	48	128
Production Techniques:				
CNC	34.88	37.53	34.88	36.22
Robotics	10.21	1.42	7.57	4.86
Automated Materials Handling	11.17	10.09	9.70	10.12
Computer Aided Design	37.06	48.22	37.09	42.73
Computer Aided Production Management	9.64	21.33	25.91	21.13
Computer Integrated Manufacture	7.60	11.86	19.83	13.77
Organisational Techniques:				
Quality Certification	52.44	38.76	44.21	42.70
Total Quality Management	13.25	13.39	20.56	15.79
Quality Circles	3.49	5.52	8.65	6.27
Just in Time	26.62	22.12	4.80	16.96
Investors in People		9.24	12.76	9.00

Notes:

1. Table relates to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results (see Annex 1). Sample χ^2 tests were used to determine whether the proportion of plants using AMT in the underlying BMW, S&E and NI populations was the same.

2. Statistically significant differences were found in the following cases: BMW and S&E, Robotics, $\chi^2 = 3.726$ ($\rho = 0.054$); BMW and S&E, Computer Aided Design, $\chi^2 = 2.759$ ($\rho = 0.097$); BMW and S&E, Quality Certification, $\chi^2 = 3.131$ ($\rho = 0.077$); BMW and NI, Just in Time, $\chi^2 = 6.553$ ($\rho = 0.010$); S&E and NI, Just in Time, $\chi^2 = 5.916$ ($\rho = 0.015$); BMW and S&E, Investors in People, $\chi^2 = 2.950$ ($\rho = 0.086$); BMW and NI, Investors in People, $\chi^2 = 4.009$ ($\rho = 0.045$).

Annex 1: Data Sources and Methods

The benchmarks reported in the text are based on data taken from a postal survey of plants' innovation activity (called the PPDS3) conducted in 1999-2000 and reported in Roper and Anderson (2000). The original survey was based on a structured sample and was designed - after weighting - to produce representative results for NI and the Republic of Ireland. Samples were drawn from lists of businesses drawn from the IDBR in NI and from Forfas in the Republic of Ireland. Overall survey response rates were 41 per cent (419 responses) in NI and 29.4 per cent (624 responses) in the Republic of Ireland.

As the PPDS3 was based on a structured sample weighting is necessary to obtain results which are representative of the underlying population. In the original survey report weights were constructed to give representative results for NI and the Republic of Ireland as a whole (see Roper and Anderson, 2000, p50). For this paper a new weighting structure was developed to allow representative results to be obtained for the BMW and S&E regions separately. Figures for the underlying population of manufacturing plants in the BMW and the S&E regions were obtained from the 'Census of Industrial Production', 1998, Table 4, CSO, Ireland. Similar, population figures for NI were obtained from 'Size Analysis of United Kingdom Business' 1999, Table 9.1, Office for National Statistics, UK. Ten industrial sectors and three plant sizebands were distinguished in the weighting exercise. The industrial sectors were combinations of 2-digit groupings from SIC92: Food, Drink and Tobacco, 15, 16; Textiles and Clothing, 17, 18, 19; Wood and Wood Products, 20; Paper and Printing, 21, 22; Chemicals, 24; Metals and Metal Fabrication, 27, 28; Mechanical Engineering, 29; Electrical and Optical Equipment, 30, 31, 32, 33; Transport Equipment, 34, 35; Other Manufacturing, 25, 26, 36, 37. Plants were excluded from the survey if they were in Nuclear, Coal, Coke etc, 23. The plant sizebands were: 10-19 employees, 20-99 employees, 100 plus employees. Due to confidentiality restrictions, some figures were not available for the total population in 100 plus employee sizeband. In these cases the sample from the 20-99 and 100 plus sizebands were pooled and combined weights were derived for the entire 20 plus employee group.

Annex 2: Industry Tables

Table A2.1: Percentage of Plants Undertaking Product Innovation by Industry and Ownership

	BMW		S&E		NI	
	n	%	*n*	%	*N*	%
High/ Medium-High Technology Sectors:						
Chemicals	*9*	85.2	*39*	64.7	*12*	75.2
Mechanical Engineering	*11*	78.0	*36*	71.0	*27*	69.4
Electrical and Optical Equipment	*35*	68.6	*66*	85.5	*30*	87.1
Transport Equipment	*5*	80.0	*12*	72.4	*16*	51.1
Low Technology Sectors:						
Food, Drink and Tobacco	*36*	60.6	*59*	67.4	*71*	60.8
Textiles and Clothing	*24*	68.8	*22*	54.8	*60*	65.1
Wood and Wood Products	*10*	36.6	*12*	100.0	*21*	45.0
Paper and Printing	*9*	33.3	*31*	22.8	*29*	16.8
Metals and Metal Fabrication	*22*	56.9	*45*	55.1	*41*	44.8
Other Manufacturing	*43*	60.3	*71*	61.8	*80*	59.8

Notes:

Tables relate to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results. Sample χ^2 tests were used to determine whether the proportion of innovating plants in the underlying BMW, S&E and NI populations was the same. Statistically significant differences were found in the following cases: BMW and S&E, Wood and Wood Products, $\chi^2 = 10.553$ ($\rho = 0.001$); BMW and S&E, Electrical and Optical Equipment, $\chi^2 = 4.037$ ($\rho = 0.045$); S&E and NI, Wood and Wood Products, $\chi^2 = 8.770$ ($\rho = 0.003$).

Table A2.2: Percentage of Plants Undertaking Process Innovation by Industry and Ownership

	BMW		S&E		NI	
	n	%	*n*	%	*N*	%
High/ Medium-High Technology Sectors:						
Chemicals	*9*	63.9	*39*	75.3	*12*	57.9
Mechanical Engineering	*11*	45.4	*36*	73.1	*27*	65.1
Electrical and Optical Equipment	*35*	75.4	*66*	65.0	*30*	51.9
Transport Equipment	*5*	80.0	*12*	59.7	*16*	68.5
Low Technology Sectors:						
Food, Drink and Tobacco	*36*	54.5	*59*	65.1	*71*	46.7
Textiles and Clothing	*24*	50.2	*22*	35.4	*60*	50.1
Wood and Wood Products	*10*	77.5	*12*	67.2	*21*	47.5
Paper and Printing	*9*	63.5	*31*	48.5	*29*	57.2
Metals and Metal Fabrication	*22*	44.8	*45*	59.0	*41*	43.8
Other Manufacturing	*43*	67.9	*71*	69.5	*80*	59.6

Notes:

Tables relate to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results. Sample χ^2 tests were used to determine whether the proportion of innovating plants in the underlying BMW, S&E and NI populations was the same. Statistically significant differences were found in the following cases: BMW and S&E, Mechanical Engineering, $\chi^2 = 4.500$ ($\rho = 0.034$); BMW and NI, Mechanical Engineering, $\chi^2 = 2.892$ ($\rho = 0.089$); S&E and NI, Food, Drink and Tobacco, $\chi^2 = 4.459$ ($\rho = 0.035$).

Table A2.3: Average Percentage of Sales Derived from New Products by Sector and Ownership

	BMW		S&E		NI	
	n	%	*n*	%	*N*	%
High/Medium-High Technology Sectors:						
Chemicals	*9*	15.5	*40*	16.1	*9*	10.8
Mechanical Engineering	*11*	27.3	*32*	16.8	*25*	15.3
Electrical and Optical Equipment	*33*	30.8	*55*	35.3	*29*	19.0
Transport Equipment	*5*	26.0	*12*	22.8	*15*	11.0
Low Technology Sectors:						
Food, Drink and Tobacco	*33*	9.2	*54*	12.9	*70*	12.9
Textiles and Clothing	*20*	28.2	*21*	7.0	*56*	19.1
Wood and Wood Products	*10*	5.5	*8*	18.9	*20*	5.5
Paper and Printing	*9*	7.3	*29*	3.7	*29*	1.4
Metals and Metal Fabrication	*20*	15.6	*45*	15.4	*39*	9.3
Other Manufacturing	*39*	14.5	*60*	18.7	*72*	11.9

Notes:

Tables relate to manufacturing plants with 10 or more employees. Survey responses were weighted to give representative results.
Sample χ^2 tests were used to determine whether the proportion of innovating plants in the underlying BMW, S&E and NI populations was the same. Statistically significant differences were found in the following cases: BMW and S&E, Textiles and Clothing, t = 1.779 (ρ = 0.086); BMW and S&E, Wood and Wood Products, t = -1.942 (ρ = 0.071); S&E and NI, Textiles and Clothing, t = -2.084 (ρ = 0.041); S&E and NI, Wood and Wood Products, t = 1.928 (ρ = 0.075); S&E and NI, Metals and Metal Fabrication, t = 1.908 (ρ = 0.060); S&E and NI, Electrical and Optical Equipment, t = 1.712 (ρ = 0.092).

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