Innovation, Networks and The Diffusion of Manufacturing Best Practice

A Comparison of Northern Ireland and the Republic of Ireland

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Preface

Successful innovation is of crucial importance to business success and underpins any region's long term economic prosperity. This report compares the level of innovation activity in Northern Ireland to that in the Republic of Ireland. Both regions - through the IRTU in Northern Ireland and Forfas in the Republic of Ireland - have emphasised the promotion of R&D and innovation as a policy objective. The evidence presented here provides an, albeit imperfect, yardstick of their success.

The report has two main objectives. First, it aims to shed light into some previously dark corners. It provides, for example, the first concrete evidence on inter-firm linkages in Northern Ireland and also reports on the diffusion of a range of best practice manufacturing techniques. Secondly, it aims to contribute to the debate on possible changes to industrial development policy in Northern Ireland.

Chapters 1 and 2 of the report introduce the subject matter and provide an overview of the economic and policy context for innovation in Northern Ireland and the Republic of Ireland. Chapters 3 and 4 focus on two of the main building blocks for innovation: R&D and inter-plant linkages. Chapters 5 and 6 relate to the levels of R&D and innovation activity, while Chapter 7 relates innovation to business performance. Chapter 8 summarises the main findings.

The report is based on a survey of over 2,500 manufacturing businesses throughout Ireland. The Royal Irish Academy through its Social Science Grant Scheme provided funding for the direct costs of the survey. The preparation of this report was supported by the Department of Economic Development (Northern Ireland) as part of the NIERC research programme entitled *Innovation and Industrial Change*. The views expressed in the report, however, are those of the authors alone.

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Executive Summary

Key Findings

1. Manufacturing firms in Ireland undertaking product and/or process innovation have faster sales and employment growth, are higher profit margins and higher labour productivity than non-innovators.

2. The proportion of plants undertaking R&D and product and process innovation is higher in the Republic of Ireland than in Northern Ireland.

3. Republic of Ireland plants have been more active in upgrading their production equipment and production methods than Northern Ireland plants. Despite this, the proportion of plants using a range of best practice manufacturing techniques is very similar in Northern Ireland and the Republic of Ireland.

4. Small firms are much less likely to have introduced new products or processes or be using best practice manufacturing methods than larger companies.

5. These are the main findings from the Product and Process Development Survey, and reflect the innovation experiences and performance of over 750 manufacturing businesses in Northern Ireland and the Republic of Ireland.

Contextual Factors

6. Comparisons of the relative level of 'innovativeness' between economies must take into account differences in industrial structure and macro-economic circumstances.

7. Industrial structure in the Republic of Ireland raises aggregate R&D above that in Northern Ireland due to the larger proportion of employment in high R&D intensity sectors. This effect is most pronounced in terms of R&D spending where the structural effect is around a third (Section 2.2).

8. For the chemicals, electronics and engineering, textiles and other manufacturing sectors high levels of external-ownership in the Republic of Ireland reinforce the effect of a positive macro-economic environment on R&D and technical development activity (Section 2.2).

9. Plant-size distributions are relatively similar in Northern Ireland and the Republic of Ireland and are therefore likely to have little effect on aggregate comparisons (Section 2.2).

10. The profile of grant-assistance to plants in the Republic of Ireland and Northern Ireland for R&D and product and process development is generally very similar (Section 2.4).

R&D Activity

11. Taking these factors into account R&D expenditure comparisons between Northern Ireland and the Republic of Ireland suggest broadly similar levels of business R&D spending per employee (Section 3.2).

12. Cohort evidence suggests that an increasing number of plants are engaging in R&D, but that mean levels of expenditure both per employee and per unit of turnover have fallen since 1993.

13. Substantial differences exist between levels of R&D spending and activity in different industries, plant sizebands and ownership categories. R&D activity in both Northern Ireland and the Republic of Ireland increases with plant size.

Innovation Linkages

14. A higher proportion of Republic of Ireland plants has external linkages than Northern Ireland plants (Section 4.2). Linkage activity is also much more common amongst innovating plants in both Northern Ireland and the Republic of Ireland.

15. Larger firms are more likely to have innovation linkages than smaller plants. For example, only 26.2 per cent of plants with between 10 and 19 employees had linkages to other firms and organisations compared to 72.6 per cent of plants with over 500 employees.

16. Innovation linkages were also more common within the chemicals, mechanical engineering, electrical and optical equipment, transport and other manufacturing sectors. This suggests a link between technological sophistication and linkage activity.

17. A slightly higher proportion of externally-owned plants had innovation linkages than indigenously-owned plants. The differential was larger in Northern Ireland than in the Republic of Ireland (Section 4.2).

18. Relationships with clients and or customers and suppliers were the most common form of linkages for all firms, with the least developed linkages being with competitors and research laboratories.

19. The majority of these innovation linkages were formal relationships as opposed to informal relations, however collaboration was used more extensively than formal sub-contractual agreements (Section 4.4).

Product and Process Innovation

20. The larger proportion of Republic of Ireland plants involved in R&D was also reflected in a larger proportion undertaking product and process development over the 1993-96 period.

21. Republic of Ireland plants also tended to be introducing more new or improved products than their Northern Ireland counterparts both in terms of the number of new products and the number of new products per employee. Despite this the breakdown of company sales between new, improved and unchanged products was similar in the two areas (Section 5.2).

22. Evidence from a cohort of firms suggested an increase in levels of technological development activity between 1993 and 1996 in both Northern Ireland and the Republic of Ireland. The proportion of plants undertaking in-house R&D and having an R&D department increased in both areas, as did the proportion of firms undertaking product innovation (Section 5.2).

23. Electrical and optical equipment and food, drink and tobacco were the only sectors to have proportions of innovating plants above the average in terms of both product and process changes.

24. Other sectors having above average shares of product innovators were textiles and clothing, wood and wood products and other manufacturing. Chemicals were the only sector to have above average proportions of process innovators but below average shares of product innovators (Section 5.4).

25. Comparing the proportion of innovating plants in each sector in Northern Ireland and the Republic of Ireland suggests generally higher innovation rates in the Republic of Ireland. Exceptions were paper and printing and metals and fabrication in terms of product innovation and metals and fabrication in terms of process changes.

26. Levels of R&D and innovation activity were greater among larger plants. Larger plants also tended to introduce more new products, but introduced fewer new or improved products per employee.

27. Levels of R&D and innovation activity were higher among externally-owned plants in both Northern Ireland and the Republic of Ireland.

Adoption of Best Practice Manufacturing Methods

28. Republic of Ireland plants have been more active in the introduction of new or modified production equipment than the Northern Ireland plants. In addition, the introduction of new or modified production equipment was associated with greater changes in production methods in the Republic of Ireland than in Northern Ireland (Section 6.2).

29. As plant size increased so too did the proportion of production equipment which was new or modified since 1993. Northern Ireland plants had a smaller proportion

of new or improved production methods resulting from changes in production technology (Section 6.2).

30. Northern Ireland's indigenously-owned plants lagged behind indigenously-owned plants in the Republic of Ireland and externally-owned plants in their introduction of new or modified equipment. It followed that the Northern Ireland indigenously-owned plants were also less likely to have updated their production methods since 1993.

31. Republic of Ireland plants within each of the industrial sectors had a higher proportion of new and modified technology. The only exception was the transportation equipment sector in Northern Ireland. Republic of Ireland plants in each sector were also more likely to have introduced new or modified production methods than their Northern Ireland counterparts.

32. Among those plans making process changes the adoption of best practice techniques was, in most cases, significantly different in Northern Ireland and the Republic of Ireland. With the exception of computer integrated manufacturing and total quality management each of the techniques were more common in the Republic of Ireland plants than among the Northern Ireland plants (Section 6.3).

33. Plant size was found to have a positive effect on the adoption of best practice techniques. Differences in speed of adoption were most marked for managerial/organisational methods.

Innovation and Business Performance

34. Comparisons of the performance of innovating and non-innovating plants suggest a strong positive linkage between innovation and turnover and employment growth. Proportionately smaller but still positive effects are also evident on profit margins (Section 7.2). Comparisons by sector and ownership category indicate the representativeness of these aggregate results.

35. Labour productivity (i.e. value added per employee) and the value added share of sales are also positively related to innovation. No clear difference emerges, however, between the impact of product and process innovation on the value added indicators (Section 7.3).

Chapter 1: Introduction

1.1 Innovation And Competitiveness

Successful innovation is increasingly being regarded as the central issue in economic prosperity. For, just as living standards depend fundamentally on the level of productivity, so

> "*high and rising productivity demands innovation, continuous innovation in the broadest sense of the term, throughout the economy; innovation not only in product or process but in marketing methods and ways of performing a service, in all aspects of business enterprise*[1] *"*.

Recent evidence for UK, German and Irish companies has reinforced earlier studies that have emphasised the link between innovation and business performance (Roper et al, 1996).

Certainty about the importance of innovation to prosperity and business growth contrasts with long-standing doubts about the innovative capability of firms in the peripheral regions of the EU (see the references in Alderman and Thwaites, 1995). For many firms in these areas informational disadvantages linked to peripherality (Oakey, 1984) and relatively unsophisticated local markets (Gudgin, 1995) reinforce weaknesses in national and regional innovation systems (Walker, 1993; STIAC, 1995)[2]. Also there is evidence that deficiency in workforce, technological and management skills may be a widespread barrier to successful innovation[3].

1.2 Innovation Defined

Innovation relates to the *market application of existing knowledge* and has been defined as:

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[1] Professor Michael Porter giving evidence to the House of Lords Select Committee on Science and Technology investigation into Manufacturing Innovation, 1991, Volume 2, para 1184.

[2] In the UK, emphasis has been placed on a lack of co-ordination between the public and private elements of the national innovation system, and a low level of government support for industrial R&D. The latter point has recently been echoed in the Republic of Ireland (see, for example, the discussion in Quinlan, 1995).

[3] For example, evidence presented by a number of major UK companies to the House of Lord's enquiry on Manufacturing Innovation cited '*manpower constraints as a serious obstacle to innovation'*. By contrast, in Germany the committee found that '*the availability of highly-skilled technicians was widely regarded by industry as a strong competitive advantage' (Vol. 1, para* 6.8).

" .. *the commercial application of knowledge or techniques in new ways or for new ends. It may involve radical innovation or incremental innovation. In each case the innovator achieves a competitive advantage, at least until another company catches up or goes one better*"[4].

Innovation is a business activity that is stimulated by and affects a firm's market position. As such, innovation may or may not be linked to significant technological advance. This view of innovation as a *business process* with an uncertain technological content differs significantly from the traditional view, which typically stresses a technological impetus and content. This difference is important in terms of the measurement of *innovation activity*. If innovation is regarded as a technologically defined process then technological criteria can be employed in identifying 'innovations'. If innovation is seen instead as a business process with uncertain technological content a less restrictive definition of what constitutes an innovation is appropriate[5].

In either case, the level of *innovative activity* in an area will depend on business opportunities, as they are perceived by firms, as well as the area's *innovation capability*. This, in turn, will reflect all aspects of an area's capacity to develop new or improved products and processes, and will depend on both the capacities of a region's indigenously-owned firms as well as the efficiency of technology transfer. Thus defined, innovation capability will also depend on a wide range of organisational and institutional factors *including* the level of R&D in the region. I*nnovation activity* will depend on *capability*, but will also reflect the attractiveness of innovating at any particular point in time.

1.3 The Product And Process Development Survey

The Product and Process Development Survey (PPDS) was a postal survey of over 2,500 manufacturing businesses (i.e. plants) in Northern Ireland and the Republic of Ireland conducted from November 1996 to April 1997. The aims of the survey were to measure the extent of innovation activity in the two areas and profile certain key elements of each area's innovation capability (specifically R&D and firms' innovation linkages). The survey itself was a follow-up to an earlier study of product innovation in the Republic of Ireland, the UK and Germany conducted in 1994-95 (Roper et al, 1996).

The PPDS was a structured postal survey with extensive telephone follow-up. The overall response rate was 32.9 per cent (752 responses); 43.1 per cent (293 responses) in Northern Ireland and 28.6 per cent (459 responses) in the Republic of Ireland. Telephone follow-up over 200 randomly selected non-respondents suggested that respondents were representative of the entire population (see Appendix 1 for details). The PPDS sought information on six main areas:

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[4] House of Lords, Select Committee on Science and Technology, 1991, para 1.5.

[5] It is, however, recognised that in many cases innovation will have a technological element and that the commercial impact of an innovation may depend on its technological significance.

1. The background to the business including the nationality of ownership status, the skill composition of the workforce and the nature of any government assistance the firm had received for R&D and product and process development.

2. Sales and employment growth over the 1993-96 period, and for the 1995-96 business year employment, sales, material purchases, labour costs, and investment in plant and buildings. Taken together these data items allow us to calculate both trading profit and value added indicators.

3. R&D activity including the question of whether the business had a formal R&D department and whether R&D relevant to the business was conducted elsewhere.

4. Whether the business had any innovation links to other businesses or organisations and the nature of any such links.

5. The nature and extent of any product innovation activity over the 1993-96 period.

6. The nature and extent of any process innovation activity over the 1993-96 period.

The questions included in the PPDS relating to company background, R&D and product innovation were designed to overlap with the earlier Product Development Survey. This overlap is used later in the report to examine changes in the behaviour of the cohort of businesses that responded to both surveys.

1.4 Structure Of The Report

Plants' operating environment is important in determining the level of innovation activity. In Chapter 2 we therefore highlight contrasts between the economic and policy environments in Northern Ireland and the Republic of Ireland during the period covered by the PPDS. We also provide an analysis of the effect of differences in industrial structure on aggregate comparisons of technological development activity. In certain cases - notably with measures of R&D activity - these effects prove substantial.

Chapters 3 and 4 are concerned with two significant determinants of the innovation capability of businesses in Northern Ireland and the Republic of Ireland. Chapter 3 focuses on the level of R&D, while Chapter 4 discusses the extent of inter-plant innovation links.

Chapters 5 and 6 focus on the level of innovation activity itself. Chapter 5 provides a general overview of the introduction of new products and processes and develops a typology of product and process innovators. Chapter 6 deals with the adoption of a range of specific best-practice manufacturing techniques.

Chapter 7 focuses on the downstream effects of innovation on business growth and profitability. Productivity effects are also outlined. Chapter 8 concludes with a brief overview of the main points and some discussion of the policy implications.

Chapter 2: The Economic and Policy Context for Innovation

2.1 Introduction

Comparative studies spanning international borders and national jurisdictions face considerable problems in ensuring the comparability of their results. Structural differences may mean that different industries within each area are of greater or lesser importance, while other short-term or cyclical factors may influence the attractiveness of innovating. In this chapter we review the potential impact of three contextual influences on the results of the PPDS. First, we consider the possible effect of differences in the size, sectoral distribution and ownership of manufacturing firms in Northern Ireland and the Republic of Ireland. This is important because previous studies have shown that the level of innovative activity can differ significantly between industrial sectors (e.g. Geroski, 1991), plant sizebands (e.g. Acs and Audretsch, 1988 and 1993; Roper, 1997) and ownership categories (Ashcroft, Dunlop and Love, 1994). Also, the constraints on innovation activity have been shown to differ significantly between small, medium and large companies (e.g.. Rothwell and Dodgson, 1994). Secondly, we consider the potential effect of macro-economic and regional economic conditions on firms' motivation to innovate. Innovation, like other investments, may, for example, be more attractive in a more buoyant economic environment. Thirdly, we consider briefly the possible impact of technology policy in Northern Ireland and the Republic of Ireland.

2.2 The Potential Impact Of Differences In Industrial Structure

Aggregate comparisons of R&D and innovation activity derived from the PPDS will reflect differences in industrial structure between Northern Ireland and the Republic of Ireland and the effect of individual sectors' technological intensity. Government figures for the UK suggest, for example, that in 1993, 6.7 per cent of the workforce of plants manufacturing electronic equipment were engaged in R&D activity compared to only 0.2 per cent in plants in the textiles and clothing sectors[1].

Table 2.1 summarises the composition of manufacturing employment in Northern Ireland and the Republic of Ireland in 1993. Notable differences exist; in Northern Ireland there was a greater concentration of employment in textiles and clothing and transport equipment; and, in the Republic of Ireland, there was a greater proportion of

[1] Source: Research and Development in UK Businesses, 6th Edn, Central Statistical Office.

manufacturing employment in chemicals, other manufacturing (much of which relates to the processing of rubber and plastics) and electrical and optical equipment. One factor influencing the latter concentration was the relatively high level of foreign direct investment into the Republic of Ireland over the last two decades.

Table 2.1: Employment Structure by Sector and Plant Sizeband: 1993

	Republic of Ireland %	Northern Ireland %
A. By Industrial Sector		
Food, Drink and Tobacco	21.6	20.5
Textiles, Clothing	10.5	25.1
Wood Products	3.8	6.2
Paper and Printing	7.6	6.3
Chemicals	8.1	3.6
Metals and Fabrication	7.2	3.6
Mechanical Eng	4.3	6.6
Electrical and Optical Equip.	20.8	8.2
Transport Equip.	4.2	14.0
Other Manufacturing	12.0	5.9
All Plants	100.0	100.0
B. By Employment Sizeband		
1-19 employees	12.7	14.5
20-99 employees	30.9	21.7
100-499 employees	41.4	41.0
500 plus employees	15.0	22.8
All Plants	100.0	100.0

Notes

1. Sectoral definitions are those used throughout this report and are combinations of NACE (rev 1) categories: 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 Fabrication, 27,28; Mechanical Engineering, 29; Electrical & Optical Equip., 30,31,32,33; Transport Equipment, 34,35; Other Manufacturing, 25,26,36,37.

2. For Ireland the decomposition of employment by plant sizeband relates to 1990.

Sources: NI: Size Analysis of UK Businesses, 1993, Table 10. Republic of Ireland: Statistical Bulletin September 1995, Central Statistical Office, Table 2, p. 426 and Statistical Abstract 1993, Table 4.5, page 126-127.

The potential impact of these differences in industrial composition on aggregate R&D and innovation activity can be illustrated in two ways. First, it is possible to compare the proportions of manufacturing activity (i.e. employment) in low, medium and high

R&D intensity sectors. The standard approach here is that suggested by the OECD which categorises industrial sectors on the basis of R&D spending as a percentage of sales: sectors whose R&D spending accounts for less than 2 per cent of sales are said to have low R&D intensity; 2-4 per cent counts as medium R&D intensity; and, where R&D accounts for more than 4 per cent of sales, a sector is said to be highly R&D intensive. On this basis, 62 per cent of Northern Ireland manufacturing employment in 1993 was in low R&D intensity sectors compared to 51 per cent in the Republic of Ireland. Larger proportions of manufacturing employment in the Republic of Ireland were in medium (24.4 per cent) and high (25.0 per cent) R&D intensive industries than in Northern Ireland (16.1 and 22.0 per cent respectively). This suggests that even if R&D spending was identical in each sector in Northern Ireland and the Republic of Ireland, aggregate spending in the Republic of Ireland would exceed that in Northern Ireland. Conversely, if similar aggregate levels of R&D expenditure were identified this implies that on a like-for-like basis expenditure levels were higher in Northern plants.

Some idea of the extent of the distortion introduced by differences in sectoral composition can be obtained using information on sectoral levels of R&D and innovation activity and expenditure. Table 2.2 gives, for the Republic of Ireland, R&D expenditure per employee and the proportion of manufacturing plants in each sector undertaking in-house R&D and product innovation. Weighting these sectoral figures by the composition of employment given in Table 2.1 allows an approximate aggregate for the Republic of Ireland to be constructed. On the same basis, and using the same sectoral figures, it is possible to estimate aggregate R&D expenditure etc using the Northern Ireland employment structure. The difference between the implied figures for Northern Ireland and the Republic of Ireland measures the structural effect. For R&D expenditure, which differs markedly between industries, the negative effect of Northern Ireland industrial structure is relatively large, reducing aggregate R&D spending by around a third. That is, even if firms in each sector in Northern Ireland were matching the level of R&D spending of their Republic of Ireland counterparts, aggregate spending in Northern Ireland would be only two-thirds of the Republic of Ireland level. Because of the smaller sectoral differences, much more marginal structural effects are evident in terms of the percentage of plants undertaking in-house R&D and the percentage introducing new products.

Table 2.2: Effect of Industrial Structure on Comparisons of R&D Expenditure per Employee and the Percentage of Plants Undertaking R&D and Product Innovation

	R&D Spending per Employee, 1991	Plants Undertaking R&D	Plants Introducing New/Improved Products
	£ ppe	%	%
A. By Industrial Sector			
Food, Drink and Tobacco	460.2	58.1	69.0
Textiles, Clothing	223.2	58.9	81.6

Wood Products	106.3	60.5	57.2
Paper and Printing	85.1	29.0	10.4
Chemicals	1855.8	66.4	68.7
Metals and Fabrication	381.6	49.6	58.7
Mechanical Eng	1202.8	60.0	73.7
Electrical and Optical Equip.	1764.0	48.0	74.6
Transport Equip.	288.6	46.3	75.8
Other Manufacturing	229.0	67.9	88.6
Total	**769.4**	**54.8**	**68.7**
B. Total with Northern Ireland Industrial Structure	**520.9**	**54.8**	**70.2**
C. Structural Effect (%)	**-32.3**	**0.0**	**2.2**

Sources: Table 2.1, Quinlan (1995), Tables 4.4 and 4.5, pages 59-60; Roper (1996), Tables 5.3, page 27 and Table 3.2, page 14.

Another aspect of industrial structure which also has the potential to cause significant aggregate differences in innovation activity and R&D spending is plant size composition (see, for example, Santarelli and Sterlacchini, 1990). Oakey et al (1988) highlight a number of reasons why small firms are less likely to innovate than larger companies (although, see Roper, 1996). Large firms may experience scale-sensitive advantages in R&D and will also benefit from non-technological, scale-intensive activities which support innovation, such as production, marketing and finance. Such firms may also be more able to finance a range of innovative projects, allowing them to spread risk. These may be characterised as indirect scale effects but Oakey et al (1988) also note a range of more direct scale advantages such as greater division of labour permitting the maintenance of specialist departments for R&D, patenting etc. The ability to maintain contacts with external organisations is also likely to increase with size (Freeman, 1982). Reflecting these advantages, technological development activity, measured both by R&D and innovation tends to be concentrated in larger firms, so a concentration of employment in smaller plants in an area would tend to reduce aggregate levels of innovative activity[2]. In fact, the plant size distribution is relatively similar in Northern Ireland and the Republic of Ireland with both areas having more small plants than the majority of European economies (Table 2.1)[3].

In addition to establishment size and technological activity, previous studies have emphasised the potential importance for levels of innovation activity of plant ownership and group membership. Goddard, Thwaites and Gibb (1986), for example, found higher innovation propensities among multi-plant companies in the UK, a

[2] Roper (1997) indicates that these differences can cause significant distortion in international R&D comparisons. In particular, he argues that the more informal organisation of R&D in UK small firms, and consequent underestimation of R&D activity, may account for up to a half of the difference between UK and German aggregate R&D levels.

[3] For example, in 1993 median plant size in Germany at 338 was substantially above that in the UK (254) and Ireland (162). See Hitchens, Wagner and Birnie (1990) for a discussion of the reasons why German manufacturing plants tend to be larger than those in the UK.

finding supported by evidence from Oakey (1979) for the UK and Brugger and Stuckey (1987) for Switzerland. Thwaites (1978) suggests a number of reasons for expecting a positive relationship between external control and innovation, particularly in the context of branch plants. Such plants, he argues, were at some point established as part of a growing industry and that growth may have been associated with innovation. Branch plants may also be larger than indigenously-owned plants and have access to intra-company technology transfer networks.

Contrary suggestions of a negative relationship between external-ownership and innovation propensity have focused on restrictions placed on the autonomy of group plants, limited access to group and external finance and the centralisation of R&D within multi-plant groups (Malecki, 1980; Howells, 1984; and, Harris, 1991). Two recent studies have, however, attempted to use econometric analysis to separate the effects of R&D-location and ownership. Harris and Trainor (1995), based on evidence for Northern Ireland, concluded that externally-owned establishments were more likely to innovate than indigenously-owned plants because, at least in part, they devoted more resources to R&D than indigenously-owned plants (see Quinlan, 1995, for similar findings for the Republic of Ireland). This was supported by Love et al (1996) who found evidence that foreign-owned manufacturing plants (although not other UK-owned plants) in Scotland were more likely to innovate than their indigenously-owned counterparts.

The impact of ownership differences on any Northern Ireland/ Republic of Ireland comparisons will therefore depend both on the pattern of ownership and the extent to which levels of R&D investment and innovation differ between externally-owned and indigenously-owned companies. In 1992, the extent of external-ownership was greater in the Republic of Ireland both in general and in the chemicals, electronics and engineering, textiles and other manufacturing sectors (Table 2.3). At the regional or national scale therefore, if levels of R&D and innovation activity are higher in externally-owned companies, this would raise aggregate R&D and innovation rates in the Republic of Ireland relative to Northern Ireland. In fact this effect is likely to be disproportionately important because of the concentration of high levels of external-ownership in some high R&D intensity sectors in the Republic of Ireland (in particular, chemicals and electronics).

Table 2.3: Percentage of Manufacturing Employees in Externally-owned Industry

	Nace (Original) Division	Northern Ireland %, 1990	Republic of Ireland %, 1992
Non-Metallic Minerals	1	34.0	21.8
Chemicals, Pharmaceuticals	2	72.5	78.8
Electronics and Engineering	3	50.7	66.5
Food, Drink and Tobacco	4, 5	32.3	22.5
Textiles	6	50.9	70.0
Clothing and Footwear	7	47.8	32.8
Paper and Printing	9	27.0	13.9

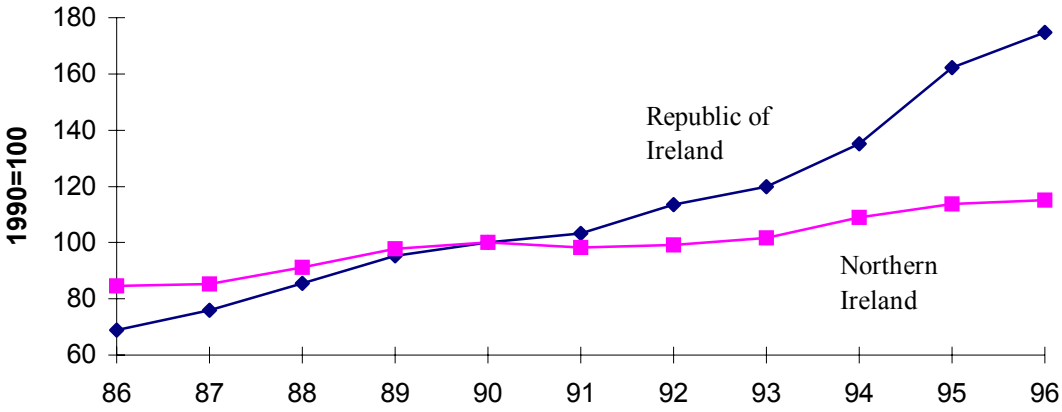
Other Manufacturing	8,10	29.1	40.8
All Sectors	1-10	42.2	48.6

Sources: Northern Ireland: Wilson (1993). Republic of Ireland, Quinlan, 1995, Table 2.1, p. 27.

2.3 The Potential Impact Of The Business Environment

The PPDS relates primarily to plants' innovation activity over the years 1993 to 1995. This period was characterised by very different macro-economic conditions in Northern Ireland and the Republic of Ireland. Figure 2.1, for example, gives indices of manufacturing production for the two economies. In Northern Ireland, over the period 1993-95 manufacturing output rose by around 5 per cent pa, a growth rate significantly in excess of that achieved by the UK economy over the same period. Manufacturing output in the Republic of Ireland, however, grew by some 20 per cent pa over this period.

Figure 2.1: Indices of Manufacturing Production



Sources Northern Ireland Index of Production Press Notice, Eurostat Industrial Trends, Monthly Statistics.

The implication is that domestic economic conditions in the Republic of Ireland were likely to have had a more positive effect on the level of innovation activity that those prevailing in Northern Ireland. The extent of the difference in growth rates between the two areas is, however, likely to overstate the magnitude of any effect for two main reasons. First, firms in both areas, the majority of which export a relatively large proportion of their output, depend on the growth of both domestic and export markets. Secondly, output growth in the Republic of Ireland has been strongly concentrated in certain sectors related primarily to electronics, pharmaceuticals and software development. In other sectors, growth rates have been more like those observed in Northern Ireland.

2.4 Policy Context

Innovation and the potential contribution of science and technology policy to national competitiveness has received much recent attention in both Northern Ireland and the Republic of Ireland (e.g.. IRTU, 1992; STIAC, 1995; HMSO, 1993). In both areas, however, there has been a tendency to view innovation, and perhaps product innovation in particular, as industry's problem. In the Republic of Ireland this is evident from the relatively low level of government support for R&D activity (see Quinlan, 1995, pp 25-26)[4]. In the UK, a similar approach has led to a strong bias towards only supporting basic research, although in Northern Ireland considerable financial assistance is available for near-market developments through the 'Compete' grant scheme[5]. In both areas there has also been a tendency to assist individual company projects, an approach which has contributed to a lack of co-ordination between the elements of the UK's national innovation system (Roper, 1997)[6].

Information from the PPDS provides an indication of the types of plants in Northern Ireland and the Republic of Ireland receiving assistance for R&D, product and process development and other business development activities (Table 2.4). Overall, around a fifth of plants in each area received assistance with product development over the 1993-96 period. Smaller proportions of businesses (10-15 per cent) received assistance for process development or non-specific R&D. Comparing the proportions of plants receiving assistance for these technological development activities to the proportion receiving assistance for other activities (i.e. capital investment and exporting) suggests a similar pattern in Northern Ireland and the Republic of Ireland. In both areas, product development assistance was as widespread as that for exporting but significantly less common than capital grants.

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[4] For example in 1991, the Irish government was financing only 23.1 per cent of total national expenditure on R&D compared to 35.4 per cent in the UK and 37.4 per cent in Germany (STIAC, 1995, Volume 3).

[5] Compete was introduced in early 1994. Its predecessor the Product and Process Development Scheme had operated since 1991. Both schemes are almost unique in a UK context in providing support for near market development of new/improved products and processes in firms of all sizes.

[6] This has been highlighted by Walker (1993) as one of the major weaknesses of the UK innovation system. By contrast German technology policy, for example, is widely perceived to have been more systematic and strategically oriented than that in either the UK or Ireland. Also, German policy has been characterised by a stronger emphasis on collaborative initiatives and the creation of technological development than that in either the UK or Republic of Ireland (CEST, 1991).

Table 2.4: Percentage of Plants Receiving Government Assistance: By Plant Sizeband, 1993-96

	Product Develop	Process Develop	Non-Specific R&D	Manuf Licenses	New Plant or Machinery	Exporting
Northern Ireland						
10-19 Employees	7.9	2.4	5.7	0.0	15.4	8.0
20-99 Employees	22.8	9.7	8.4	0.7	30.8	26.7
100-499 Employees	34.4	31.1	12.1	1.4	71.7	29.0
500 plus Employees	49.0	62.8	54.3	0.0	91.5	34.0
All Plants	19.4	10.8	8.4	0.5	32.0	20.3
Republic of Ireland						
10-19 Employees	5.0	5.0	5.6	3.1	14.5	9.7
20-99 Employees	21.6	15.6	10.4	3.2	23.7	22.0
100-499 Employees	37.2	27.4	10.5	4.8	45.4	26.7
500 plus Employees	15.2	38.7	23.9	1.5	46.8	15.5
All Plants	21.2	16.3	10.0	3.4	26.2	20.6

Note: Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

Source: PPDS

Larger plants were also much more likely than smaller business to receive each type of government assistance. For example, in Northern Ireland only 1:5 of manufacturing businesses in the 20-99 employee sizeband received assistance for product development from 1993-96 compared to 1:2 plants with more than 500 employees (Table 2.4). It is also noticeable that lower proportions of Northern Ireland plants received support for R&D, product and process development and the purchase of manufacturing licenses than in the Republic of Ireland. Conversely, slightly higher proportions of Northern Ireland plants received capital grant aid. Export assistance was equally common in the two areas.

2.5 Summary

Levels of innovation activity at either the plant or national level depend on a wide range of institutional and contextual factors. For example, comparisons of the relative level of 'innovativeness' between economies will be influenced by differences in industrial structure and macro-economic circumstances. In terms of aggregate Northern Ireland/ Republic of Ireland comparisons, positive structural effects in the Republic of Ireland (related to both industrial structure and ownership) are likely to be reinforcing the innovation effect of more felicitous national economic conditions. This combined effect is likely to be most pronounced in terms of R&D spending where the structural effect is likely to be around a third. At the level of an industrial

sector or plant sizeband, however, only the ownership and economic environment effects will be important. For the chemicals, electronics and engineering, textiles and other manufacturing sectors, relatively high levels of external-ownership in the Republic of Ireland are likely to reinforce a positive macro-economic environment. For other sectors, a relatively high level of external-ownership in Northern Ireland will offset the effect of the macro-economic environment.

Plant-size distributions are relatively similar in Northern Ireland and the Republic of Ireland and are therefore likely to have little distortionary effect on aggregate comparisons. Similarly, while some differences are evident, the profile of grant-assistance to plants in the Republic of Ireland and Northern Ireland for R&D and product and process development is generally very similar. Again therefore, this is likely to have little effect on any aggregate comparisons.

Chapter 3: Research and Development Activity

3.1 Introduction

R&D, wherever it is carried out, is a potentially important determinant of an area's innovation capability. This Chapter examines, in a comparative context, the level of R&D activity by businesses in Northern Ireland and the Republic of Ireland in 1993 and 1996. Its primary purpose is to set the context for the subsequent discussion of product and process innovation[1]. In considering the results, however, it is important to realise that the presence or absence of R&D in a company or region cannot necessarily be equated with local strengths or weaknesses in innovation. For example, within multi-regional or multi-national companies, R&D activity may be concentrated in a specialist unit based at one location. This means that R&D conducted in one region may lead to product and process innovations elsewhere (Kleinknecht and Poot, 1992; Todling, 1992). In the UK, perhaps the most commonly identified manifestation of this spatial division of R&D and manufacturing capacity is the location of R&D facilities in the South East of England and related production facilities in Northern and peripheral areas.

Evidence for this 'regional hierarchy' in the UK is extensive (see Quinlan, 1995 for a discussion of the situation in the Republic of Ireland). Buswell and Lewis (1970), for example, considered the regional distribution of publicly and privately financed R&D establishments, and found that the South East and West Midlands had a predominant share (58 per cent) of UK research establishments. The South East alone had 48 per cent of the UK total (location quotient 1.43). They argued, however, that even these figures underestimated private sector disparities due to the relatively even national distribution of research activity in higher education. Buswell, Easterbrook and Morphet (1985) provided updated figures for the regional distribution of private sector R&D activity. Over the 15 year period from 1968 to 1983 they again noted the strong concentration of R&D units in the South East of England (the region had over 45 per cent of R&D units throughout the period) and the 'remarkable similarity' of the pattern through time[2]. In 1983 the location quotient of the South East in terms of

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[1] Note, however, that like the innovation data discussed in later chapters the R&D figures reported here are taken from the PPDS. As discussed in Appendix 1 this was a voluntary sample survey unlike the regular and statutory R&D survey conducted by the Department of Economic Development in Northern Ireland. Forfas in the Republic of Ireland also conduct a regular although non-statutory R&D survey. The R&D figures given here are likely to be subject to a wider margin of error than both the Forfas and DED figures.

[2] Howells (1984) provides evidence on the regional distribution of R&D units in the pharmaceutical sector where the concentration of activity in the South East (61.5 per cent of all R&D units) was stronger than average.

private sector R&D units was 1.75[3]. Other studies based on R&D employment rather than the number of R&D units largely confirm this regional pattern. Howells (1984), for example, showed that from 1971 to 1976 over 50 per cent of R&D employment in the UK was in the South East region. More recent evidence suggests little weakening of this effect (Ashcroft, Dunlop and Love, 1995, Table 2.8).

For plants in Northern Ireland this concentration of R&D in the South East of England, and the relatively small size of Northern Ireland, is likely to mean that the majority of developments in new materials, components or equipment will originate outside the region. This emphasises the importance of technology transfer and the difficulty of inferring regional innovation capability from the level of local R&D. In the case of Northern Ireland, in particular, the relatively small size of the region, and the relatively high level of external ownership of manufacturing capacity mean that the local level of R&D activity is likely to *underestimate* the region's innovation capacity.

Although R&D conducted in Northern Ireland may underpin only a proportion of local product and process innovations, it nonetheless plays a potentially crucial role in regional development. A region with little or no independent R&D capacity is entirely dependent on technological developments made elsewhere. With a significant local R&D capacity, a region has the potential to develop or invent its own future, independent of technological development elsewhere. It also has the advantage of being the first to exploit the market advantages of new products or processes.

3.2 R&D Activity

The PPDS contains data on three qualitative indicators of R&D activity. The first is simply whether any R&D was being undertaken at each plant in 1995. The second was whether plants organised their R&D within a formal department or whether the activity was conducted on a more ad hoc basis. The presence of a formal R&D department may suggest that those working within it have a more specialised role than those whose development activities might be more irregular. The third R&D indicator was whether R&D work relevant to the plant was being undertaken elsewhere in the group to which the plant may have belonged. In addition to these qualitative indicators, information was also sought on the number of man-years employed in R&D and R&D expenditure. As indicated in Chapter 2, differences in industrial structure etc are likely to have a significant effect on quantitative indicators of R&D activity (i.e. expenditure or manpower indicators), so some caution is necessary in the interpretation of these figures. Table 3.1 summarises the R&D measures for Northern Ireland and Republic of Ireland manufacturing plants in 1995-96. The qualitative indicators suggest that a significantly higher proportion of manufacturing plants in the Republic of Ireland were undertaking R&D than in

[3] The location quotients reported by Buswell et al (1985) compared the number of private sector R&D units to 1981 manufacturing employment. For the other regions the figures were; Scotland, 0.60; Wales, 0.46; Northern Ireland, 0.30; North, 1.00; North West, 0.93; Yorkshire and Humberside, 0.64; West Midlands, 0.68; East Midlands, 0.57; East Anglia, 0.87; and the South West, 1.00.

Northern Ireland. They also suggest that technology transfers within groups of companies were significantly more important in the Republic of Ireland than in Northern Ireland.

The quantitative measures suggest a slightly different pattern with R&D expenditure per employee significantly higher in plants in the Republic of Ireland but a lower level of R&D expenditure per unit of sales. The contrast between these two indicators is explained primarily by higher turnover per employee in the Republic of Ireland (see Hewitt-Dundas, Roper and McFerran, 1997 for a discussion). The R&D expenditure per employee figures suggest that in 1995 R&D spending in the Republic of Ireland was around 34 per cent above that in Northern Ireland. In Chapter 2, however, we indicated that differences in industrial structure meant that even if plants throughout Ireland had similar R&D spending per employee, aggregate figures in the Republic of Ireland would be around 32 per cent higher than those in Northern Ireland. The implication is that almost all of the difference in per capita R&D spending noted in Table 3.1 is the result of structural differences rather than differences in the R&D investments of similar companies. Put another way on a like-for-like basis plants in Northern Ireland and the Republic of Ireland were making very similar R&D investments in 1995.

Table 3.1: R&D Activity Measures

	Northern Ireland		Republic of Ireland	
	n		n	
Undertaking R&D in plant (% plants)	285	44.0**	451	48.3
R&D Dept in plant (% of plants)	282	13.1**	447	18.6
R&D done by group (% of plants)	105	13.4**	262	26.2
R&D Man Years per 100 employees	245	2.05	407	1.84
R&D Expenditure per Employee (£ pa)	253	428.00**	410	577.00
R&D expenditure (% turnover)	253	0.81	402	0.73

Notes:

1 Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2 For the qualitative indicators ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test. For the quantitative variables ** denotes rejection of the

hypothesis that the Northern Ireland and Republic of Ireland samples come from the same population based on the Wilcoxon test ($\rho = 0.05$).

Source: PPDS

It is of some interest to examine how the level of R&D activity has changed through time. Such comparisons, however, are complicated by the fact that firms - especially smaller companies - may not undertake R&D on a continuous basis. Perhaps the best way of approaching the issue is therefore to consider changes in the behaviour of a cohort of plants or companies. Table 3.2 reports evidence on the level of R&D activity from such a cohort of manufacturing plants who responded both to the initial PDS and to the PPDS. Two key points emerge:

(a) The proportion of manufacturing plants undertaking R&D and having a formal R&D department increased both in Northern Ireland and the Republic of Ireland over the 1993-95 period.

(b) Real levels of R&D expenditure both per employee and per unit of turnover declined in both areas over the same period.

Table 3.2: R&D Activity In The Same Cohort of Manufacturing Businesses

	Northern Ireland			Republic of Ireland		
	n	1993	1995	n	1993	1995
Undertaking R&D in plant (% plants)	216	41.8**	46.3*	324	45.1	49.0
R&D Dept in plant (% of plants)	216	10.1**	13.1**	326	13.1	19.5
R&D done by group (% of plants)	196	18.1**	10.2**	299	28.5	24.5
R&D Man Years per 100 employees	178	na	2.08	293	na	1.69
R&D Expenditure per Employee	178	592.2**	542.0**	293	790.0	775.5
R&D expenditure (% turnover)	178	0.67	0.48	293	0.68	0.56

Notes

1. Figures in table relate to same group of manufacturing businesses in 1993 and 1995. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. For the qualitative indicators ** denotes a significant difference between sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test. For the quantitative variables ** denotes rejection of the hypothesis that the samples come from the same population based on the Wilcoxon test ($\rho = 0.05$). In each case * indicates a significant difference at the 10 per cent level.

Source: Cohort Data from PDS and PPDS.

Table 3.3 summarises the qualitative R&D indicators by sector, plant sizeband and ownership type. From the sectoral breakdown it is clear that R&D activity is more common in a number of specific sectors. Above average levels of activity are notable in both Northern Ireland and the Republic of Ireland in transport equipment, chemicals and other manufacturing; in textiles and clothing in Northern Ireland; and, in electrical and optical equipment in the Republic of Ireland. In terms of plant size, we observe the expected gradient, with activity levels increasing with size. Also as expected, externally-owned plants were more likely to be conducting R&D and have R&D departments than their indigenously-owned counterparts.

3.3 Summary

Taken together, and allowing for the effects of industrial structure, these results suggest a broad similarity between the level of business R&D spending per employee in Northern Ireland and the Republic of Ireland. The cohort evidence suggests that an increasing number of plants are engaging in R&D, but average levels of expenditure both per employee and per unit of turnover have fallen since 1993. Substantial differences exist between levels of R&D spending and activity in different industries, plant sizebands and ownership categories. Like earlier studies (see the references in Roper, 1997), the PPDS suggests that levels of R&D activity in both Northern Ireland and the Republic of Ireland increase with plant size. Similarly, we also find that R&D activity was more common in externally-owned companies.

Table 3.3: R&D Activity Indicators By Sector, Plant Sizeband and Ownership

	Northern Ireland				Republic of Ireland			
	n	R&D in Plant	R&D Dept in Plant	R&D in Group	n	R&D in Plant	R&D Dept in Plant	R&D in Group
A. By Industrial Sector								
Food, Drink and Tobacco	53	39.6**	13.1**	27.5	85	57.0	23.1	25.9
Textiles and Clothing	46	55.1**	20.5**	12.2	42	43.0	13.7	8.6
Wood and Related Products	23	39.7	3.4**	0.0**	24	41.4	14.6	3.7
Paper and Printing	18	35.5**	4.4**	13.3	33	25.1	1.3	15.5
Chemicals	12	55.8	26.0	16.6**	47	49.9	38.8	56.5
Metals and Metal Fabrication	19	43.6	11.5	5.1**	43	36.7	7.9	17.1
Mechanical Engineering	31	44.3	14.5	3.7**	26	45.7	10.9	25.4
Electrical and Optical Equip	16	44.3	9.5**	14.0**	82	46.0	24.6	45.6
Transport Equipment	9	33.5**	44.6**	22.4	17	64.6	20.2	16.3
Other Manufacturing	42	59.3**	15.1**	8.6**	48	67.8	24.4	37.5
All Plants	16	44.1**	13.1**	13.4**	2	48.3	18.7	26.3
								0.0
B. By Plant Sizeband								0.0
10-19 employees	59	39.6**	3.5**	13.4**	43	33.0	6.4	11.2
20-100 employees	133	43.2**	12.0**	7.0**	236	49.1	17.3	21.8
100-499 employees	68	63.3	35.8	9.3**	123	61.8	35.6	57.4
500 plus employees	6	83.0*	74.5*	41.8**	29	53.5	45.4	41.6
All Plants	266	45.4**	13.2**	14.0**	431	48.5	19.1	26.0

Table 3.3 (Continued)

	Northern Ireland				Republic of Ireland			
	n	R&D in Plant	R&D Dept in Plant	R&D in Group	n	R&D in Plant	R&D Dept in Plant	R&D in Group
C. By Ownership								
Indigenously-Owned	223	42.7**	11.1**	4.8**	283	48.8	16.8	12.8
Externally-Owned	59	51.1	23.7	60.4**	166	46.9	24.8	71.3
All Plants	282	44.1**	13.1**	13.4**	449	48.3	18.7	26.3

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test. * indicates a significant difference at the 10 per cent level.

Source: PPDS

Chapter 4: Inter-plant Innovation Links

4.1 Introduction

Co-operation between firms and organisations enables plants to exploit comparative advantages and

> *'avoid wasteful duplication. Non co-operative firms, on the other hand, compete aggressively and might invest more in R&D relative to the social optima' (Goel 1994:266).*

The links which plants have to other firms and organisations increases their pool of new information, ideas and possibilities. They also facilitate 'inter-organisational interactions of exchange, concerted action and joint production' (Robertson et al 1996:335). It is this 'practical knowledge, communicated amongst firms and agencies that explains the emergence and sustainability of a disaggregated, but nevertheless coherent production system' (Cooke 1996:131).

Inter-plant links or linkages may be formal or informal. Formal linkages are characterised by collaborative agreements between independent partners through licensing, joint ventures, strategic alliances or obligational linkages such as subcontracting and referrals. Informal linkages are most commonly undertaken with customers, professional associations, suppliers and other firms in the same industry. It has been suggested that the acquisition of information, new ideas and possibilities is best attained through informal linkages and weak ties (Rogers 1983), with linkages between highly connected networks often resulting in the pooling of similar information between the members (Robertson et al 1996)[1].

This chapter examines the proportion of both innovating and non-innovating plants that had innovation links to other firms and organisations. Four questions are addressed; What are the characteristics of those plants with innovation linkages? Who are the innovation linkages with? What type of innovation linkages do plants have?

[1] It is suggested that Northern Ireland plants attempt to reduce uncertainty through the formation of long-term relationships with suppliers and customers. These relationships are founded on social links which are influenced by national or cultural contexts (Clulow and Teague 1993). It may be argued that the peripherality of Northern Ireland has constrained the development of social links and subsequently increased the levels of dependence upon the local market for the distribution of goods.

And, how important are these innovation linkages to plants' product and process development activities[2].

4.2 The Extent Of Linkage Activity In Product And Process Development

Links to other organisations are an integral part of the operating environment of every plant and may take a number of forms. For example, linkages with consultants may assist a firm in its marketing activities or the formulation of a corporate plan, but may have little or no impact upon its innovative activities. To overcome any potential ambiguity, plants were asked to indicate whether or not they had links with other firms and/or organisations as part of their *product and process development activities*, i.e. innovation linkages.

Overall, 39.2 per cent of PPDS respondents stated that they had innovation linkages. Such links were, however, more common in the Republic of Ireland (42.7 per cent of plants) than in Northern Ireland plants (31.6 per cent). This may reflect the priority given in industrial policy in the Republic of Ireland to fostering the development of links between the indigenously-owned and externally-owned sectors of the economy. For example, in 1985 the National Linkage Programme was established in recognition that

> *'many Irish companies owe their prosperity to their links with overseas companies based in Ireland. These companies provide sophisticated and demanding markets for Irish sub supply and service companies'* (IDA Annual Review 1992, p. 11).

It was acknowledged that if 'value added partnering' was to be nurtured then relationships would have to be developed between foreign investors and indigenously-owned firms in boosting the price, quality and reliability of indigenously manufactured products. The National Linkage Programme therefore acted as an information provider and facilitator of inter-plant and organisational linkages. In 1995 the Science, Technology and Innovation Council (STIAC, 1995) once again stressed the importance of integration between indigenously-owned and foreign investments[3], in order to allow indigenously-owned firms to overcome the problems of creating, absorbing and applying new technologies in their internal innovative capabilities (STIAC 1995, p. 23).

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[2] The following information on innovation linkages relates specifically to those plants in the PPDS which stated that they had introduced new process innovations between 1993 and 1996.

[3] The interdependence between indigenously-owned and foreign owned investments had previously been alluded to by the Culliton Report, 1992.

Table 4.1: Percentage Of Firms Involved In R&D And Innovative Activities With Innovation Linkages To Other Firms And/Or Organisations.

	Northern Ireland		Republic of Ireland	
	Percentage of Plants with Links			
	n		n	
Firm with R&D in plant	125	48.0**	238	58.2
Firms with R&D Dept. in plant	46	63.2	114	67.0
Firms with R&D being done elsewhere	53	55.4	166	58.1
Product Innovators	163	44.4**	315	54.9
Process Innovators	142	44.9**	285	56.8
Non Innovators	9	10.4	10	9.5

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

For plants in both Northern Ireland and the Republic of Ireland, a positive relationship was found between having innovation links, R&D and product and process innovation (Table 4.1). This supports the view that linkages are a positive source of new ideas and possibilities and suggests that the absence of innovation linkages would significantly reduce the likelihood of firms undertaking R&D, or introducing new products and/or processes.

Just as a clear relationship is evident between the innovative activity of firms and their innovation linkages, a positive relationship is also found between plant size and innovation linkages (Table 4.2). As plant sizeband increases, so too does the proportion of firms having innovation linkages. Among SME's, employing under 500 employees, innovation links to other firms or organisations were more common in the Republic of Ireland. For plants employing over 500 employees, innovation links were more common in Northern Ireland.

Table 4.2: Innovation Linkages By Plant Size, Sector And Ownership

	Percentage of firms with Linkages			
	Northern Ireland		Republic Of Ireland	
A. By Plant Size	n		n	
10-19	63	19.7**	43	32.2
20-99	128	30.8**	234	42.1
100-499	68	55.7	126	57.3
500+	6	91.5	29	69.3
B. By Industrial Sector				
Food, Drink and Tobacco	50	34.3*	85	41.5
Textiles and Clothing	46	31.1	42	32.5
Wood and Wood Products	23	21.2**	25	35.9
Paper and Printing	19	26.4	34	33.8
Chemicals	12	29.8	46	42.4
Metals and Metal Fabrication	19	29.0	42	33.5
Mechanical Engineering	32	30.3**	25	49.4
Electrical and Optical Equip	16	48.8	84	44.8
Transport Equipment	10	30.1**	17	55.1
Other Manufacturing	42	41.3**	48	63.3
C. By Ownership				
Indigenously Owned	70	29.9**	123	44.1
Externally-owned	31	44.1	88	47.7

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

Innovation linkages were also more common in each sector in the Republic of Ireland, the only exception being the electrical and optical equipment sector. Sectors where the percentage of plants having innovation links was above average were the food, drink and tobacco sector in Northern Ireland; the mechanical engineering and transport equipment sectors in the Republic of Ireland; and, the electrical and optical equipment and other manufacturing sectors in both Northern Ireland and the Republic of Ireland. These results reflect those of Oakey (1984) who noted technologically advanced sectors tend to have the most strongly developed patterns of innovation links.

Plant ownership also makes a significant difference to the probability of having innovation linkages. In both Northern Ireland and the Republic of Ireland a higher proportion of externally-owned plants had innovation linkages that among indigenously-owned plants. The differential between the two groups, however, was smaller in the Republic of Ireland than in Northern Ireland.

Analysis of innovation linkages by sizeband and sector also demonstrates that there is significant variation between sectors in the increase in the relationship between the frequency of innovation linkages and plant size (Table 4.3). For three sectors in particular (wood and wood products, metals and metal fabrication, and transport equipment) a higher than expected proportion of plants with between 10 and 19 employees had innovation linkages. As these are sectors within which it is difficult for plants to adopt 'deep-niche' strategies, small firms may be being forced to co-operate with other plants and/or organisations to derive competitive advantages from innovation (Cooke 1996).

Table 4.3: Percentage Of Firms With Linkages In Their Product And Process Developments By Size And Sector

	Employment Sizeband				
	10-19	**20-99**	**100-499**	**500+**	**All Plants**
Industrial Sector					
Food, Drink and Tobacco	34.6	33.4	55.2	100	**39.4****
Textiles and Clothing	29.9	31.5	42.3	100	**31.9****
Wood and Wood Products	43.1	27.1	10.0	100	**29.8****
Paper and Printing	9.5	32.9	74.3	100	**31.3****
Chemicals	13.4	45.4	49.6	40	**40.5****
Metals and Metal Fabrication	41.3	30.9	67.9	59.9	**32.6****
Mechanical Engineering	13.6	66.3	59.2	-	**40.2****
Electrical and Optical Equip	21.8	40.6	69.6	-	**45.6****
Transport Equipment	58.6	40.6	62.9	100	**45.6****
Other Manufacturing	27.1	62.0	76.9	64.8	**56.3****
All Plants	**26.2**	**39.4**	**56.8**	**72.6**	**39.2****

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

3. Sample sizes are as follows for: 10-19 employees, 91; 20-99 employees, 350; 100-499 employees, 192; 500 plus employees, 35; All plants, 717.

Source: PPDS

To summarise, innovation linkages are more common in the Republic of Ireland plants than Northern Ireland. Innovating firms, and those firms involved in R&D activity, are more likely to have innovation linkages than non-innovators. Further, as the size of plants increases there is an increasing likelihood that plants will have innovation linkages. Deviations from this trend are, however, evident within the wood and wood products, metals and metal fabrication, and transport equipment sectors where a higher than average proportion of the smallest plants had innovation linkages. Finally, ownership influences the likelihood of firms having innovation linkages, with a higher proportion of externally-owned plants having links.

4.3 Nature Of Product And Process Development Linkages

In the PPDS, plants were asked to identify the type of organisations with whom they had innovation linkages. They were also asked to specify whether these links were characterised by collaborative agreements between independent partners through licensing, joint ventures, strategic alliances or were obligational linkages such as subcontracting and referrals (Table 4.4).

Table 4.4: Percentage Of Plants Having Innovation Linkages; Northern Ireland And Republic Of Ireland

	Northern Ireland					Republic Of Ireland				
	n	% of firms	Collaboration	Sub-contract	Other	n	% of firms	Collaboration	Sub-contract	Other
Other Group Comp	42	31.5**	23.3	6.3	1.9	96	39.1	33.5	4.5	1.0
Clients/Customer	66	64.7**	51.7	9.4	3.5	120	56.9	42.3	9.7	4.8
Suppliers	70	66.9**	48.2	14.5	4.3	124	58.7	39.8	11.7	7.1
Competitors	18	16.8**	8.0	5.1	3.5	26	13.2	9.3	0.3	3.5
Joint Ventures	17	19.5**	8.4	9.9	1.1	35	16.1	11.4	2.1	2.5
Consultants	51	46.2**	23.8	16.4	5.9	89	38.8	16.6	17.2	4.9
Govt. Research Labs	21	18.3**	7.7	7.1	3.3	34	13.6	6.6	5.4	1.5
Uni/Higher Labs	30	22.7**	14.9	4.6	3.1	72	30.0	15.1	9.8	5.0
Industry Labs	23	20.2**	9.6	6.3	4.2	47	18.6	4.9	10.9	2.7

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

Given the emphasis placed upon linkages by industrial policy in the Republic of Ireland, in particular through the National Linkage Programme, it is perhaps surprising to find that a higher proportion of Northern Ireland plants had innovation linkages with suppliers and clients or customers than in the Republic of Ireland. According to von Hippel (1982) contact between producers and users is a vital source of information with close and frequent contact between these groups reducing the risk of an innovation failing to meet a customer's needs (Rothwell 1991). Market awareness is therefore strengthened through such relationships and this has important implications for the success of product and process innovations (see Roper 1997, forthcoming). Despite a lower overall proportion of Northern Ireland plants having linkages, the orientation of these linkages suggests that innovative activity among Northern Ireland plants may be more market driven than that of Republic of Ireland plants.

For both the Northern Ireland and the Republic of Ireland plants, linkages with competitors were the least well developed, with this being closely followed by the use of government research laboratories. A broadly similar pattern is therefore found between the two regions in the relative importance of innovation links to different

types of organisations. The forms which these innovation linkages take is also similar in Northern Ireland and the Republic of Ireland (Table 4.4). For each of the organisations with which the Northern Ireland and Republic of Ireland manufacturing plants had linkages, a similar weight was attached to collaboration and sub-contract relationships.

It has previously been suggested that small firms tend to have informal linkages whereas larger, more bureaucratic, firms will tend to engage in formal strategic alliances and subcontracting arrangements (Malecki and Veldhoen 1993, p. 136). Analysis of the pattern of innovation links by plant sizeband suggests that as size increases so too does the proportion of plants having innovation linkages with most types of organisations (Table 4.5). Those plants with between 10 and 19 employees were, however, much more likely to have links with competitors than larger plants. The relationships that these small plants had with their competitors were predominantly collaborative, while larger plants tended to have sub-contract arrangements with their competitors. Almost without exception, collaborative arrangements were used more widely as a linkage mechanism than sub-contracting. Only in a few cases were sub-contracting linkages more prominent; e.g.. between larger firms and consultancies and government labs, and links to industry labs by all types of plant.

Table 4.5: Network Characteristics By Employment Sizeband Of Plant

Links To:		Employment Sizeband 10-19	20-99	100-499	500+	
other group companies	**% of firms**	18.9	32.0	55.7	68.3	**
	Collaboration	10.6	25.3	51.8	57.9	
	Sub-Contract	8.3	4.7	3.9	8.6	
	Other	0	2.0	0	1.7	
clients/ customers	**% of firms**	44.4	58.3	67.4	68.3	**
	Collaboration	38.8	41.3	57.8	64.8	
	Sub-Contract	0	12.2	5.0	1.7	
	Other	5.6	4.7	4.5	1.7	
suppliers						
	% of firms	60.0	57.3	63.4	76.2	**
	Collaboration	43.5	40.7	45.3	64.8	
	Sub-Contract	16.4	6.9	16.5	9.6	
	Other	0	9.6	1.4	1.7	
competitors						
	% of firms	21.0	11.8	14.1	39.1	**
	Collaboration	18.2	6.9	10.6	15.3	
	Sub-Contract	0	1.7	2.2	1.7	
	Other	2.8	3.1	1.3	22.0	
joint ventures						
	% of firms	14.2	17.3	12.0	17.0	**
	Collaboration	9.8	12.2	7.9	5.8	
	Sub-Contract	4.3	2.1	2.1	9.4	
	Other	0	3.0	1.8	1.7	
consultants						
	% of firms	26.9	38.9	51.6	61.7	**
	Collaboration	26.9	16.3	19.3	19.8	
	Sub-Contract	0	17.1	25.4	31.6	
	Other	0	5.49	6.9	10.13	
government labs	**% of firms**	0	12.2	28.3	40.1	**
	Collaboration	0	5.9	14.2	13.7	
	Sub-Contract	0	3.4	13.3	26.4	
	Other	0	2.8	0.7	0	
universities						
	% of firms	20.7	22.6	44.9	51.2	**
	Collaboration	4.9	12.3	26.0	35.6	
	Sub-Contract	4.8	6.0	16.8	15.6	
	Other	10.9	4.1	2.0	0	
Industry Labs						
	% of firms	16.0	12.4	36.4	40.2	**
	Collaboration	6.3	3.5	12.0	13.0	
	Sub-Contract	9.7	5.1	21.1	24.6	
	Other	0	3.7	3.2	2.5	

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

3. Sample sizes are as follows: 10-19, 24; 20-99, 140; 100-499, 100; 500 plus, 24.

Source: PPDS

Differences were also identified in the type of innovation links of indigenously-owned and externally-owned plants (Table 4.2). In the Republic of Ireland, indigenously-owned plants had more innovation linkages with clients and/or customers, suppliers, competitors, joint ventures, consultants and government laboratories than externally-owned plants. In Northern Ireland, however, externally-owned plants were more involved than indigenously-owned plants in innovation linkages with each type of potential partner.

Table 4.6: Linkage Activity By Ownership

	Northern Ireland			Republic Of Ireland		
% of firms	**N**	**Indigenously Owned**	**Externally-owned**	**n**	**Indigenously Owned**	**Externally-owned**
Other group plants	42	20.4**	71.5*	98	30.7	62.0
Clients/Customers	69	60.2	81.0**	123	58.5	53.2
Suppliers	71	63.9	77.6**	127	62.9	47.7
Competitors	19	14.5	25.3**	27	14.5	10.1
Joint Ventures	18	18.6	23.3**	35	16.8	14.3
Consultants	51	42.2	61.0**	90	40.9	33.2
Govt. Labs	21	12.7	38.6**	34	14.7	10.8
University Labs	30	13.7**	55.2**	72	28.6	33.1
Industry Labs	23	11.6**	50.7**	49	16.9	23.2

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

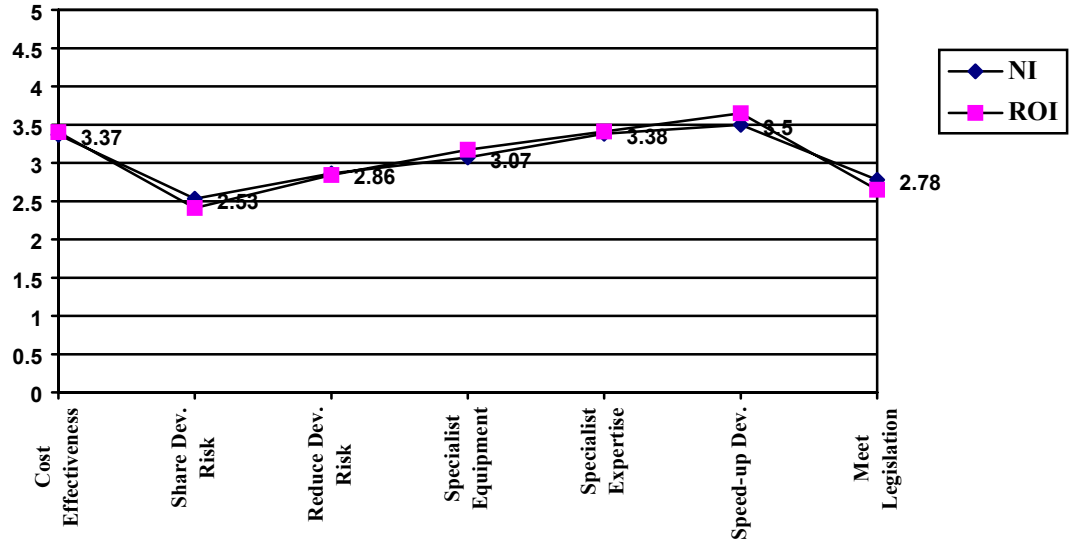
The relative importance of each group of potential partners is very similar for indigenously-owned and externally-owned plants. Linkages with clients and/or customers, suppliers and other group plants are most common. Among externally-owned plants in Northern Ireland, linkages with clients and/or customers and suppliers were, however, more common than in the Republic of Ireland. Indigenously-owned plants in Northern Ireland were , however, less likely than their

counterparts in the Republic of Ireland to have links to university and industry laboratories[4].

4.4 The Importance Of Linkages In Product And Process Development

While it is useful to understand which firms had innovation linkages, the most important question concerns the effect of the linkages on the ability of plants to undertake product and process developments. Using a scale from 1 (unimportant) to 5 (very important) respondents to the PPDS were asked to identify how linkages contributed to their ability to innovate. Considerable similarity was evident between the Northern Ireland and Republic of Ireland responses (Figure 4.1). For both the Northern Ireland and Republic of Ireland plants, linkages were most important in speeding-up product and process developments. Linkages were also important for accessing specialist expertise and making development activity more cost-effective. Of least importance to both Northern Ireland and Republic of Ireland plants was the sharing of development risk.

Figure 4.1: Average Importance Of Linkages On Factors Affecting Plants' Product And Process Development Capability

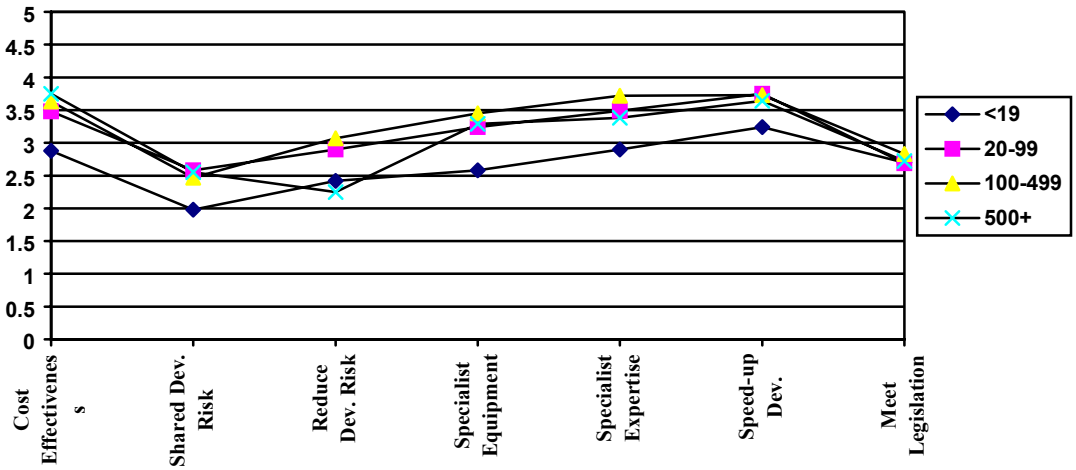


Source: PPDS

[4] It should be noted that there is a strong positive correlation between the use of government laboratories and university laboratories (.417**) and industry laboratories (.413**). With ** denoting significance at the 1 per cent level. If plants are involved in linkages with laboratories in their product and process developments, this will be reflected in each of the different laboratories. For both indigenously-owned and externally-owned plants in Northern Ireland and the Republic of Ireland university and higher education laboratories were more widely used than government laboratories and industry laboratories.

It was anticipated that for larger plants reducing risk through innovation linkages would have been less important than for smaller firms. As Figure 4.2 indicates, however, shared and reduced development risk were the least important outcome of linkage activity for all the firms, irrespective of size. Rather, plants with fewer than 500 employees gave most weight to the ability of innovation linkages to speed-up development; increasing cost-effectiveness was the most important factor for larger plants.

Figure 4.2: Average Importance Of Linkages On Factors Affecting Plants' Product And Process Development Capability By Plant Sizeband



Source: PPDS

The importance of innovation linkages on product and process development within indigenously-owned and externally-owned plants was again very similar. For both indigenously-owned and externally-owned plants, innovation linkages were most important in facilitating a speeding-up of the development process, with the least important impact factor being the sharing of development risk.

4.5 Summary

The acquisition of information or new ideas and possibilities is vital if plants are to increase their innovative capabilities. Product and process development does not take place in a vacuum within the plant, but is conceived and nurtured in a changing competitive environment. The PPDS suggests that a higher proportion of Republic of Ireland plants are involved in innovation linkages than that in Northern Ireland. Linkage activity is also much more common amongst innovating plants, supporting previous suggestions of a positive link between external links and innovative activity. Larger firms are also more likely to be involved in innovation linkages than smaller plants. For example, 26.2 per cent of plants with between 10 and 19 employees had innovation linkages to other firms and organisations as compared to 72.6 per cent of plants with over 500 employees. Linkage activity was also more important within the chemicals, mechanical engineering, electrical and optical equipment, transport and

other manufacturing sectors, suggesting that there may be a link between technological sophistication and linkage activity (Oakey 1984). Further, a slightly higher proportion of externally-owned plants had innovation linkages than the indigenously-owned plants, although this differential was much larger in Northern Ireland than in the Republic of Ireland.

Relationships with customers and suppliers were the most common form of innovation linkages for all firms, with the least developed linkages being with competitors and research laboratories. The majority of these linkages were formal relationships with collaboration being more common than sub-contract type agreements.

The innovation linkages which the plants pursued were found to be similar in the effect which they were said to have on product and process development. The ability of innovation linkages to speed-up development was the most important factor, followed by the ability to access specialist expertise and increase the cost effectiveness of development activity. Of least importance was the potential for innovation linkages to reduce the risk associated with product and process developments.

Chapter 5: Product and Process Development Activity

5.1 Introduction

Past attempts to measure the level of innovative activity in the UK have taken two main forms; studies of the adoption of specific technologies and more generic studies which have attempted to count or measure the number of 'innovations'. A number of UK studies, for example, have considered disparities in the diffusion of specific technologies such as CNC machinery, or micro-processor based product innovations (e.g.. Goddard, Thwaites and Gibb, 1986; Northcott et al, 1984, 1986; Gibbs and Edwards, 1985; Alderman and Davis, 1990). These studies have emphasised the more widespread adoption of best practice manufacturing methods in the South East of England and lower levels in more Northern and peripheral areas.

Other UK studies of innovation activity have been based wholly or partially on the SPRU database of significant innovations. This derived from an expert survey to identify innovating firms, followed by a company survey to obtain details of the innovator and innovation (Pavitt et al, 1987). Harris (1988) notes that the resulting profile of innovations in the UK is 'closely correlated with that of official figures on patenting activity' (and to a lesser extent, R&D activity). Moreover the SPRU database suggests that, at least until the early 1980s significant innovations were also heavily concentrated in the South East of England with peripheral and northern regions (Harris, 1988) and assisted and development areas (Townsend et al, 1981) having a less than proportionate share[1]. Oakey, Thwaites and Nash (1980) extended the original SPRU database to include those companies that had received the Queen's Award to Industry. Using their combined database they too indicated that 30-40 per cent of UK innovation activity was concentrated in the South East of England.

Implicit in the studies based on the SPRU database, and others based on patent data and documentary sources, is the notion of innovation as a narrowly defined technologically deterministic process. In the PPDS, while taking account of the potential contribution of new technology to stimulating innovation, we adopt a broader approach and argue that innovation should be regarded as a business rather than *technological* process. More specifically, innovation is identified as the *market application of existing knowledge*. Viewed in this way, it is clear that innovation is a business process, stimulated by and subsequently influencing a plant's market position. As such, innovation may or may not be linked to significant technological

[1] Scotland, for example, had a significantly lower share of national significant innovations (5 per cent) than of either UK population (8.9 per cent) or net output (8.4 per cent; Ashcroft, Dunlop and Love, 1995).

advance. In the PPDS this is reflected in use of a range of indicators to reflect the technological content of product and process innovation. Specifically, four different types of product changes are identified:

(a) *New products*, i.e. new products introduced to the market for the first time by the plant in question

(b) *Transfer products*, i.e. new products introduced by the plant from 1991-93 but previously made elsewhere

(c) *Technically improved products*, i.e. technically improved products which were being made by the plant in 1991.

(d) *Design improved products*, i.e. aesthetically improved products which were being made by the plant in 1991.

The first three types of product change are included within the standard OECD definition of a 'significant' or 'incremental' product innovation. The notion of *design improved products* is added to reflect the fact that commercially important product changes may relate to improvements in product appearance and design while product performance remains unchanged. This type of product change is excluded from the standard definitions of innovation that, as indicated earlier, interpret product innovation as a technological rather than business process.

The PPDS also collected information on a wide range of indicators of process innovation. A number of these measures related to the adoption of specific managerial and production techniques are discussed in Chapter 6. Two other types of more generic indicator were also used. First, respondents were asked to indicate whether the process changes they made over the 1993-96 period led to 'significant changes in the organisation of production'. Secondly, respondents who had made some process changes over the 1993-96 period were asked to indicate the proportion of their production equipment (in terms of replacement cost) which fell into the following categories:

(a) *New Processes* - new or improved equipment associated with production methods first introduced since 1993;

(b) *Improved Processes* - new or improved equipment associated with production methods which were being used in 1993 but since been modified or improved significantly;

(c) *Replacement Processes* - new or improved equipment associated with slightly improved or unchanged production methods since 1993;

(d) *Unchanged Processes* - equipment operating in 1993 and still operating unchanged and unmodified.

Conventional, technologically based definitions of process innovation would recognise categories (a) and (b) of this hierarchy. The exclusion from such definitions

of category (c), relating primarily to like-for-like replacement equipment, is perhaps less important, however, than the limitations of the conventional product innovation definition.

5.2 Product And Process Development Activity

As a precursor to a more detailed examination of the nature of product and process development in Northern Ireland and the Republic of Ireland it is useful to consider the proportions of plants introducing new or improved products or processes over the 1993-96 period. Table 5.1 indicates that a higher proportion of plants in the Republic of Ireland made both product and process changes over this period. In terms of process changes, the innovations made by Republic of Ireland plants also involved significant organisational changes in a larger proportion of cases. As indicated in Chapter 2 (see in particular Table 2.2) structural differences between Northern Ireland and the Republic of Ireland had relatively little effect on aggregate comparisons of the proportion of innovating plants. The relativities suggested by Table 5.1 are therefore representative of similar plants in the two areas. That is, on a like-for-like basis plants in the Republic of Ireland were more likely to introduce new or improved products or processes than their Northern Ireland counterparts.

Table 5.1: Product and Process Innovation Activity: 1993-96

	Northern Ireland		Republic of Ireland	
	n		n	
Product Innovation (% of plants)	286	56.5**	451	65.9
Process Innovation (% of plants)	288	45.9**	447	57.8
Of which:				
With significant organisational change (%)	288	26.9	447	33.8
No significant organisational change (%)	288	19.0	447	24.0

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test.

Source: PPDS

Information on changes in the level of product innovation activity in Northern Ireland and the Republic of Ireland is available from a comparison of information from the PDS (which relates to innovation over the 1991-93 period) and the PPDS (which

relates to the 1993-96 period). As in the case of R&D, however, perhaps the best indication of any changes in activity levels comes from cohort information (see also Table 3.2). From the cohort of plants which responded to both surveys, it is clear that in both Northern Ireland and the Republic of Ireland there was an increase in the level of product and process development activity. In Northern Ireland, the proportion of this cohort of plants introducing new or improved products rose from 52.4 per cent from 1991-93 to 60.4 per cent over the 1993-96 period (Table 5.1). In the Republic of Ireland, a similar increase was evident from 57.3 per cent to 66.2 per cent[2]. This increase in the level of product innovation activity reflects the increase noted earlier in the proportion of plants undertaking some in-house R&D, and the proportion of plants having an R&D department.

Table 5.2: Product and Process Innovation Activity: By Plant Sizeband

	Employment Sizeband				
	10-19	20-99	100-499	500 plus	All Plants
Northern Ireland					
Product Innovation 1993-96 (%)	45.5	57.9**	80.9	100.0*	57.3**
Process Innovation 1993-96 (%)	30.3**	50.5**	67.2*	100.0*	46.0**
Of which:					
With Significant Organisational Change	*10.2*	*35.0*	*33.3*	*91.5*	*26.4*
No Significant Organisational Change	*20.1*	*15.6*	*33.8*	*8.5*	*19.6*
Republic of Ireland					
Product Innovation 1993-96 (%)	49.4	66.5	77.9	81.3	65.9
Process Innovation 1993-96 (%)	50.6	55.4	73.5	79.5	58.1
of which					
With Significant Organisational Change	*32.5*	*31.1*	*44.8*	*53.5*	*34.0*
No Significant Organisational Change	*18.2*	*24.3*	*28.6*	*26.0*	*24.1*

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test. * denotes a significant difference at the 10 per cent level.

[2] These figures are based on a weighted analysis of the cohort of plants which responded both to the PDS and PPDS. Sample sizes were 227 in Northern Ireland and 330 in the Republic of Ireland. The representativeness of this cohort of plants is discussed in Appendix 1.

3. Sample sizes are as follows for Northern Ireland (the Republic of Ireland): 10-19 employees, 60 (42); 20-99 employees, 133 (233); 100-499 employees, 68 (123); 500 plus employees, 6 (28); All plants, 267 (429).

Source: PPDS

Analysis of the main product and process innovation indicators by plant sizeband suggests the expected pattern; the proportion of plants introducing new or improved products and processes increases with plant size (Table 5.2)[3]. In terms of process innovation, the majority of this increase is associated with the introduction of new or improved production methods that required significant organisational change. This pattern is clearest in the Republic of Ireland data, where around a quarter of plants in each sizeband were introducing new or improved production methods that required no significant changes in the organisation of production. Over and above this, a proportion of plants - which increased with plant sizeband - were making process changes that had more significant organisational implications.

On an industry-by-industry basis there were also differences in the proportion of plants which introduced new or improved products or processes over the 1993-96 period, although as indicated earlier these sectoral differences were significantly less marked than differences in levels of R&D spending. In only two sectors - electrical and optical equipment and food, drink and tobacco - were the proportions of innovating plants above average in both areas and in terms of product and process changes (Table 5.3). Other sectors having above average shares of product innovators were textiles and clothing, wood and wood products and other manufacturing. Chemicals were the only sector to have above average proportions of process innovators but below average shares of product innovators. Comparing the proportion of innovating plants in Northern Ireland and the Republic of Ireland suggests generally higher innovation rates in the Republic of Ireland. Exceptions, i.e. where the proportion of innovating plants was higher in Northern Ireland were; paper and printing and metals and fabrication in terms of product innovation, and metals and fabrication in terms of process changes.

Table 5.3: Product and Process Innovation By Industry And Ownership: 1993-96

	Northern Ireland			Republic of Ireland		
	n	Product Innovation %	Process Innovation %	n	Product Innovation %	Process Innovation %
A. By Industrial Sector						
Food, Drink and Tobacco	52	57.9**	53.7*	85	71.2	60.2
Textiles and Clothing	48	63.8**	46.5	42	77.6	47.7
Wood and Related Products	23	60.8**	46.5	25	78.7	51.8

[3] Roper et al (1996) provides similar evidence for the UK and Germany. ENSF (1995) reports evidence from other national innovation surveys of a similar positive relationship between the plantsize and the probability of innovating.

Paper and Printing	18	57.8**	45.9	32	15.8	52.0
Chemicals	12	55.8**	51.7	47	73.9	64.7
Metals and Metal Fabrication	19	68.6**	48.5	42	53.2	41.8
Mechanical Engineering	30	41.2**	45.7**	26	67.4	63.8
Electrical and Optical Equip	16	59.0**	54.3**	82	70.6	66.1
Transport Equipment	9	50.1	55.1	17	53.5	59.4
Other Manufacturing	42	61.1**	40.4**	48	75.3	69.8
All Plants	286	56.5**	46.0**	449	65.9	57.7
C. By Ownership						
Indigenously-Owned	224	53.6**	42.6**	283	62.5	55.2
Externally-Owned	59	72.4	64.3	166	76.6	65.6
All Plants	283	56.5**	46.0**	449	65.9	57.7

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a $\chi^2(1)$ test. * denotes a significant difference at the 10 per cent level.

Source: PPDS

Table 5.3 also gives the proportion of indigenously-owned and externally-owned firms making product and process changes over the 1993-96 period. Consistent with the earlier R&D figures, the proportion of externally-owned plants introducing new and improved products and processes was highest in both areas. The proportions of innovating plants were also higher in both categories in the Republic of Ireland.

5.3 Qualitative Analysis Of Product And Process Development

Given the differences in the proportion of innovating plants in Northern Ireland and the Republic of Ireland it is of some interest to examine the nature of the innovations that were being made in each area. One possibility, for example, is that Northern Ireland plants may be introducing fewer innovations but of higher quality (measured, for example, but technological complexity) than those in the Republic of Ireland. Two issues are involved here; first, the relative extent or intensity of innovation activity in the two areas and secondly the quality of those innovations.

5.3.1 Innovation Intensity

Measures of innovation intensity have been discussed extensively in recent years (see, for example, Acs and Audretsch, 1988 and 1993; Love and Roper, 1997). In terms of product changes two indicators are standardly used; the number of innovations or

product changes made by each plant (extent) and the number of innovations per employee (intensity). Table 5.4 gives both measures for Northern Ireland and the Republic of Ireland and for plant sizebands in each area. On average the number of new and improved products introduced by Northern Ireland firms over the 1993-96 period was lower than that in the Republic of Ireland, as was the number of product changes per employee. This overall result was due primarily to lower levels of product innovation extent and intensity in small Northern Ireland plants; plants with more than 100 employees in Northern Ireland actually made more product changes than their Republic of Ireland counterparts.

Table 5.4: The Extent and Intensity of Product Innovation Activity in Northern Ireland and the Republic of Ireland: 1993-96

	Employment Sizeband				
	10-19	20-99	100-499	500 plus	All Plants
A. Average Number of New/improved Products Introduced					
Northern Ireland	1.46	3.51**	13.71**	34.49**	4.38**
Republic of Ireland	4.27	4.67	11.14	7.76	5.62
B. Average Number of New/Improved Products per Employee					
Northern Ireland	0.13	0.08**	0.08*	0.05**	0.10**
Republic of Ireland	0.27	0.13	0.06	0.01	0.14

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the Northern Ireland and Republic of Ireland samples come from the same population based on the Wilcoxon test (ρ = 0.05). * indicates rejection of the hypothesis at the 10 per cent level.

3. Sample sizes are as follows for Northern Ireland (the Republic of Ireland): 10-19 employees, 58 (34); 20-99 employees, 103 (195); 100-499 employees, 52 (93); 500 plus employees, 5 (21); All plants, 218 (343).

Source: PPDS

The number of product changes made by plants gives an indication of the extent of their innovation activity. It tells us little, however, about the commercial impact of those product changes on innovating plants. This type of information is available from the PPDS, however, in terms of the proportion of firms' sales that are derived from new, improved or unchanged products (Table 5.5). In both areas the proportion of sales derived from new products introduced during the 1993-96 period is very similar

at 12-13 per cent. Improved products are also broadly similar in importance accounting for 14-17 per cent of sales. This is despite the fact that the proportion of innovating plants in the Republic of Ireland was actually higher than that in Northern Ireland and Republic of Ireland plants were, on average, introducing more new/improved products.

Table 5.5: Average Percentage of Sales Derived from New, Improved and Unchanged Products: 1996

	Northern Ireland (n=270)	Republic of Ireland (n=415)
New products sold for first time (% sales)	10.0**	9.9
New products made before (% sales)	2.2**	3.9
Technically improved products (% sales)	7.9**	11.5
Appearance improved products (% sales)	5.8**	5.3
Unchanged products (% sales)	73.8**	69.5

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the Northern Ireland and Republic of Ireland samples come from the same population based on the Wilcoxon test (ρ = 0.05).

Source: PPDS

5.3.2 Technological Status of Product and Process Innovations

In addition to the number of product changes introduced, the PPDS also sought information on the technological characteristics of plants' current sales and the composition of their capital equipment. This information can be used to divide innovating firms into groups depending on the technological status of their sales and equipment. Five categories of firm can be distinguished in terms of the source of their current sales:

(a) *'Leaders'* are those innovators whose most important source of new revenue was *new products not previously manufactured;*

(b) *'Followers'* - are those innovators that derived most new revenue from products transferred from other plants, i.e. from products newly introduced since 1993 but previously manufactured elsewhere;

(c) *Technical Improvers* - are those plants whose most important new source of sales was products which they were producing in 1993 but which have since been technically improved;

(d) *Design Improvers* - are those plants whose most important new source of sales was products which were being produced in 1993 and have since been improved in a design or an aesthetic sense without improving technical performance;

(e) *Non-movers* are those firms conducting no product innovation activity over the 1993-96 period.

Table 5.5 gives the percentages of plants in each category in Northern Ireland and the Republic of Ireland. Reflecting the lower proportion of plants which did not introduce any new or improved products from 1993-96, the proportion of non-movers in Northern Ireland was greater than that in the Republic of Ireland. There was also a lower proportion of Technical Improvers and Followers in Northern Ireland, but a slightly higher proportion of Technology Leaders. In terms of product innovation, at least, this suggests that the technological status of plants in Northern Ireland is more polarised than that of the Republic of Ireland with more plants at both ends of the technological spectrum.

Table 5.5: Breakdown of Plants by the Technological Status of Product Innovation Activity: 1993-96

	Northern Ireland (n=249)	Republic of Ireland (n=368)
Leaders	24.3	21.1
Followers	2.6	6.9
Technical Improvers	13.7	22.4
Design Improvers	8.0	8.3
Non-movers	51.4	41.3
Total	100.0	100.0

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. The distributions of the Northern Ireland and Republic of Ireland samples between categories differed significantly at the 5 per cent level ($\chi^2(4) = 87.8$).

Source: PPDS

A similar analysis can be conducted in terms of the technological status of plants' process innovation. Here a four category distinction can be made from the information provided by the PPDS (Table 5.6):

(a) *Process Leaders* - those plants whose new plant purchases since 1993 have related to the introduction of new processes;

(b) *Process Improvers* - those plants whose new plant purchases since 1993 have related mostly to the significant improvement of existing processes;

(c) *Process Replacers* - those plants whose new plant purchases since 1993 have been to replace existing plant making only minor changes to the production process;

(d) *Process Non-movers* - plants that purchased no new plant since 1993.

Again reflecting the lower overall proportion of plants in Northern Ireland making process innovations over the 1993-96 period, the proportion of process non-movers in Northern Ireland was greater than that in the Republic of Ireland. Conversely, the proportion of Northern Ireland plants in each of the other process categorisations was lower than that in the Republic of Ireland. The general implication is that process developments in the Republic of Ireland were more common, and had a higher technological status, than those made in Northern Ireland.

Table 5.6: Breakdown of Plants by the Technological Status of Process Innovation Activity: 1993-96

	Northern Ireland (n=250)	Republic of Ireland (n=393)
Process Leaders	8.4	12.2
Process Improvers	12.6	17.3
Process Replacers	13.8	21.0
Process Non-Movers	65.2	49.5
Total	100.0	100.0

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. The distributions of the Northern Ireland and Republic of Ireland samples between categories differed significantly at the 5 per cent level ($\chi^2(3) = 89.1$).

Source: PPDS

5.4 R&D And Innovation

To highlight the link between R&D and product and process innovation we constructed correlation coefficients (Table 5.7). In all cases the correlation coefficients were positive and in all but one case were statistically significant at the 1 per cent level. The implication is that product and process innovation are closely and positively related, and that both are strongly related to R&D. Product innovation both in Northern Ireland and the Republic of Ireland, has a strong link to in-house R&D activity and a significantly weaker link to externally conducted R&D. This distinction is not evident for process developments which are related equally strongly to both in-house and external R&D

Table 5.7: Correlations Between R&D and Innovation Indicators

	New Improved Products	New Improved Processes	R&D in the Plant	R&D Dept in the Plant	R&D Elsewhere in Group
Northern Ireland					
New/Improved Products	1.000				
New/Improved Processes	0.328**	1.000			
R&D in the Plant	0.441**	0.210**	1.000		
R&D Dept in the Plant	0.264**	0.265**	0.421**	1.000	
R&D Elsewhere in Group	0.105**	0.211**	0.012	0.141**	1.000
Republic of Ireland					
New/Improved Products	1.000				
New/Improved Processes	0.310**	1.000			
R&D in the Plant	0.477**	0.277**	1.000		
R&D Dept in the Plant	0.308**	0.228**	0.484**	1.000	
R&D Elsewhere in Group	0.188**	0.212**	0.086**	0.161**	1.000

Source: PPDS

5.5 Summary

The larger proportion of Republic of Ireland plants involved in R&D was also reflected in a larger proportion undertaking product and process development over the 1993-96 period. Republic of Ireland plant engaged in product innovation also tended to be introducing more new or improved products than their Northern Ireland counterparts both in terms of the number of new products and the number of new products per employee. Despite this the breakdown of company sales between new, improved and unchanged products was similar in the two areas.

Evidence from a cohort of firms suggested an increase in levels of technological development activity between 1993 and 1996 in both Northern Ireland and the Republic of Ireland. The proportion of plants undertaking in-house R&D and having an R&D department increased in both areas, as did the proportion of firms undertaking product innovation.

Levels of R&D and product and process innovation activity differ significantly between sectors, plant sizebands and ownership categories. The key distinctions are as follows:

(a) In sectoral terms, electrical and optical equipment and food, drink and tobacco were the only sectors to have proportions of innovating plants above the average in terms of both product and process changes. Other sectors having above average shares of product innovators were textiles and clothing, wood and wood products

and other manufacturing. Chemicals were the only sector to have above average proportions of process innovators but below average shares of product innovators.

(b) Comparing the proportion of innovating plants in each sector in Northern Ireland and the Republic of Ireland suggests generally higher innovation rates in the Republic of Ireland. Exceptions, i.e. where the proportion of innovating plants was higher in Northern Ireland, were paper and printing and metals and fabrication in terms of product innovation and metals and fabrication in terms of process changes.

(c) Levels of R&D and innovation activity were greater among larger plants. Larger plants also tended to introduce more new products, but introduced fewer new or improved products per employee.

(d) Levels of R&D and innovation activity were higher among externally-owned plants firms in both Northern Ireland and the Republic of Ireland.

Chapter 6: Adoption of Best Practice Manufacturing Techniques

6.1 Introduction

New and more stringent demand conditions in international markets necessitate the truncation of product life cycles, the shortening of production runs and the achievement of shorter lead times in both manufacturing and design (PA Consulting Group 1989). It is clear that for many firms this will require a transformation of the workplace in terms of social and political relations and the adoption of *best practice techniques* (Gertler 1989). As Alderman and Thwaites (1992) remark:

> *' ... new technologies and innovations in control systems and organisational arrangements are becoming a necessary part of the process of meeting increasingly stringent customer demands for quality and reliability. The peripheral regions ... have experienced a disadvantage in technological terms relative to the core regions of the UK. Although the 1980s have seen new industrial structures emerging (a 'leaner', certainly, 'fitter', possibly, manufacturing base) with an enhanced level of technological change generally, regional disparities, particularly in the generation of new technologies remain apparent'.*

Other researchers have also noted the relatively low level of adoption of CNC/NC machinery in the peripheral regions of the UK (Harris 1991; Harris and Trainor 1995) and the poor utilisation of such equipment (Hitchens, Wagner and Birnie 1990). In other areas of best practice, however, manufacturing firms in Ireland and the UK periphery appear to have responded more positively. For example, publication of the North-South Quality Index by the IBEC-CBI Joint Research Council represents a positive response to the increasing need for quality certification before companies can obtain supply contracts in Europe.

The technological, informational and organisational techniques that are examined in this chapter, are intricately linked to the ability to meet international standards of quality and flexibility. In the design/manufacturing cycle this may involve the adoption of Computer Aided Design (CAD), and a range of possible manufacturing techniques based on new (and not so new) technologies. In some industries this may extend only to the use of CNC/NC machinery, while in other sectors (notably engineering) other techniques such as Computer Aided Manufacturing (CAM) and Computer Integrated Manufacturing (CIM) may be appropriate. Information technology allows such systems or indeed more traditional production systems, to be

monitored and controlled using computer based management information systems (MIS) and/or statistical process control (SPC) techniques.

Alongside these technologically based developments, organisational changes such as the introduction of modular or cellular manufacturing techniques and the associated multi-skilling of the workforce may also be relevant. Ensuring high and consistent quality during the manufacturing process has also assumed considerable importance in recent years (Luchs 1990). Quality assurance schemes (e.g.. ISO 9000) have a part to play in encouraging firms to develop quality monitoring systems as do organisational developments such as quality circles (Shea, 1986) and total quality management (TQM).

The need to increase flexibility and eliminate waste also provides an impetus for the adoption of Just-in-time manufacturing techniques (Monden, 1983). This applies directly to the reduction of buffer stocks of inventories and work-in-progress but also suggests a broader manufacturing ethos based on one-piece flow or small-batch production (Best, 1991).

The remainder of this chapter examines two main issues. First, we consider the proportion of firms' plant that consists of new or modified equipment, and examine the effect of this changed equipment on production methods. Second, we consider the use of specific production techniques, and identify disparities between different plant types. Because of the structure of the PPDS questionnaire discussion of the latter question is limited to those plants which introduced process innovations over the 1993-96 period.

6.2 Changes In Manufacturing Systems

In the PPDS plants were asked to outline the proportion of their production equipment, based on replacement cost, that had remained unchanged or was new or modified since 1993. In addition, where plants had introduced new or modified equipment from 1993-96, the impact of this was measured in terms of changes in production methods. This allowed us to identify the extent to which new technology led to new, slightly modified or unchanged production methods.

Overall, new or modified equipment was a higher proportion of all production equipment for plants in the Republic of Ireland, than in Northern Ireland (Table 6.1). An important relationship was also found between plant size and the introduction of new or modified production equipment. For plants in both Northern Ireland and the Republic of Ireland, as sizeband increased, the proportion of new or improved production equipment also increased. The composition of production equipment by ownership, was very similar for externally-owned plants in Northern Ireland and indigenously-owned and externally-owned plants in the Republic of Ireland, with these plants having, on average, one-fifth of their production equipment consisting of equipment newly introduced or modified since 1993. This compared to only 13.3 per cent for indigenously-owned plants in Northern Ireland.

Table 6.1: Change In Production Equipment And Methods, 1993 To 1996

	n	% Unchanged Equipment	% Totally New or Modified	% New or Modified Equipment		
				New Production Methods	Improved Production Methods	Unchanged Production Methods
A. By Region						
Northern Ireland	272	85.6**	14.4**	10.7**	14.9**	74.8**
Republic of Ireland	421	78.6	21.4	13.3	20.6	66.3
B. By Sizeband						
Northern Ireland						
10-19	51	89.1**	10.9**	6.8**	5.3**	87.9**
20-99	124	84.2**	15.8**	12.3	17.9	70.4**
100-499	64	77.5	14.4	14.4	27.6	58.0
500+	4	60.3	39.7	26.2**	47.5**	26.3
Republic of Ireland						
10-19	39	80.2	19.8	14.0	17.2	68.8
20-99	220	78.9	21.1	12.8	20.9	66.5
100-499	118	75.6	24.4	15.8	23.9	60.3
500+	26	64.7	35.3	12.9	33.7	53.4
C. By Ownership						
Northern Ireland						
Indigenous	214	86.7**	13.3**	9.9**	13.1**	77.3**
Externally-owned	55	78.4	21.6	15.0	24.9	60.2
Republic of Ireland						
Indigenous	264	79.4	20.6	12.2	20.9	67.1
Externally-owned	156	76.3	23.7	16.8	19.5	63.7

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$).

Source: PPDS

Sectorally, the higher share of new or modified production equipment in plants in the Republic of Ireland was again found (Table 6.2). It is also evident that some industrial sectors were more likely to have new or modified production equipment than others. For example, for Northern Ireland plants in the textiles and clothing sector 92.4 per cent of production equipment was unchanged since 1993, (82.3 per cent in Republic of Ireland plants). Republic of Ireland plants in the electrical and optical equipment industry, however, had newly introduced or modified 33.4 per cent of their production equipment since 1993. Similarly, transport equipment plants in

Northern Ireland had upgraded or newly introduced 34.7 per cent of their production equipment since 1993.

Table 6.2: Change In Production Equipment And Methods, 1993 To 1996, By Industrial Sector

		% Unchanged Equipment	% Totally New or Modified	% New or Modified Equipment		
	n			New Production Methods	Improved Production Methods	Unchanged Production Methods
Northern Ireland						
Food Drink & Tobacco	51	82.5	17.5	11.2	15.4	73.4**
Textiles and Clothing	39	92.4**	7.6**	11.3	8.9**	79.8**
Wood and Wood Products	22	84.5*	15.5*	6.5**	15.3	78.2*
Paper and Printing	18	79.8	20.2*	11.6	16.3**	75.4**
Chemicals	11	87.9*	12.1**	7.3*	11.7	81.8**
Metals and Fabrication	18	87.5	12.5	15.5**	13.3	71.2**
Mechanical Engineering	31	89.2**	10.8**	14.3	15.4**	70.3
Electrical & Optical Equip.	16	80.1**	19.9**	10.9**	20.6	68.6**
Transport Equipment	9	65.3*	34.7	19.2	29.7**	51.0*
Other Manufacturing	41	85.9**	14.1**	9.4**	19.0**	71.7**
Republic of Ireland						
Food Drink & Tobacco	81	82.0	18.0	13.0	19.8	67.1
Textiles and Clothing	39	82.3	17.7	10.0	22.7	67.3
Wood and Wood Products	24	79.0	21.0	12.3	20.5	68.7
Paper and Printing	33	73.4	26.6	6.5	27.3	66.2
Chemicals	43	80.8	19.2	20.4	19.8	60.2
Metals and Fabrication	37	85.2	14.8	8.2	13.4	79.6
Mechanical Engineering	24	81.3	18.7	12.9	22.7	64.4
Electrical & Optical Equip.	76	66.6	33.4	24.9	20.2	54.9
Transport Equipment	16	78.3	21.7	19.4	15.3	65.2
Other Manufacturing	45	76.4	23.6	12.5	22.2	65.3

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$).

Source: PPDS

Not only were regional, sizeband, sectoral and ownership differences evident between the plants in terms of their proportion of new or modified production equipment, but disparities were also found in the impact of these technological changes on production methods (Table 6.1). For example, not only did the Northern Ireland plants have a lower proportion of their production equipment consisting of new or modified capital,

but of this changed equipment a smaller proportion led to changes in production methods. Conversely, the Republic of Ireland plants were not only more dynamic in introducing a higher percentage of new or modified equipment, but this led to over 13 per cent of production methods being newly introduced since 1993; 20.6 per cent of improved production methods; and only 66.3 per cent of unchanged production methods. This compared to 74.8 per cent of unchanged production methods in the Northern Ireland plants.

The importance of new or modified production equipment on changes in production methods is replicated for each plant sizeband. The sizeband effect is accentuated, however, as both the importance of new and modified production equipment and the proportion of that equipment that leads to new production methods increases with plant size. Indigenously-owned Northern Ireland plants, that had a lower proportion of new or modified production equipment than externally-owned Northern Ireland plants, were also introducing fewer new production methods. This result suggests that where production equipment was being replaced in these firms it was more likely to be 'replacement' equipment as opposed to 'new and innovative' equipment.

With the exception of plants in the transport equipment sector, Republic of Ireland plants had not only introduced a higher proportion of new and improved equipment since 1993, but they also had a greater propensity to introduce new or improved production methods. In particular, Republic of Ireland plants in the wood and wood products, chemicals and electrical and optical equipment sectors were introducing significantly more new production methods than the Northern Ireland plants. New production methods since 1993 were however slightly more important in the paper and printing plants in Northern Ireland than in their Republic of Ireland counterparts.

6.3 Adoption Of Best Practice Techniques By Process Innovators

In the PPDS process innovators were asked to indicate whether they were using a range of equipment-based, IT-based and managerial/organisational techniques. Equipment-based techniques consisted of NC/CNC machinery, robotic equipment and automated materials handling (AMH) equipment. IT-based techniques consisted o Computer Aided Design (CAD), Computer Aided Production Management (CAM) and Computer Integrated Manufacturing (CIM). Managerial/organisation techniques included quality certification, total quality management, quality circles and Just-in-Time (JIT) methods.

Considerably similarity was found between Northern Ireland and Republic of Ireland plants, not only in terms of their use of each of these techniques in 1996, but in the adoption of these techniques since 1991 (Table 6.3). Quality certification was the most common technique with 58.5 per cent of Northern Ireland plants and 64.5 per cent of Republic of Ireland plants having ISO 9000 in 1996. Quality circles were the least used technique for both the Northern Ireland (3.8 per cent of plants) and the Republic of Ireland plants (2.1 per cent of plants) in 1991. By 1996 however, the least common technique in both regions was the use of robotic equipment.

Table 6.3: Percentage Of Plants Using Best Practice Production Techniques; 1991, 1993 And 1996

	Northern Ireland					Republic of Ireland				
	n	1991	1993	1996	% change	n	1991	1993	1996	% change
NC/CNC	42	14.88	21.46	30.5**	105.0	96	12.96	18.37	31.1	140.0
Robotics	18	4.13	7.48	12.2	195.4	57	5.1	7.48	12.5	145.1
AMH	41	13.35	15.78	26.7**	100.0	87	10.52	19.61	29.9	184.2
CAD	61	10.95	24.47	42.8**	290.9	141	9.01	20.66	47.2	423.9
CAM	63	14.48	23.98	42.6**	194.2	124	9.46	17.97	42.8	352.4
CIM	37	7.25	15.03	24.1	232.4	61	4.96	10.32	18.3	269.0
Q. Cert.	82	14.16	32.76	58.5*	313.1	194	11.87	34.5	64.5	443.4
TQM	53	11.04	19.22	36.2**	227.9	107	5.33	13.91	34.6	549.2
Q. Circles	25	3.81	8.19	13.1**	243.8	52	2.14	9.28	19.0	787.9
JIT	36	9.72	16.55	23.9**	145.9	115	10.44	20.02	35.5	240.0

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between adoption profile in Northern Ireland and Republic of Ireland at the 5 per cent level on the basis of a χ^2 (2) test.

Source: PPDS

Combining each of the techniques into their respective groupings (i.e. equipment-based, IT-based and managerial/organisational) demonstrates that although equipment-based techniques were more prevalent among both the Northern Ireland and the Republic of Ireland plants in 1991, they subsequently spread to a lesser extent than the IT-based and managerial/organisational techniques over the 1991 to 1996 period (Table 6.4). Moreover, diffusion has occurred to a greater extent among the Republic of Ireland plants than those in Northern Ireland.

Table 6.4: Use And Diffusion Of Equipment, IT And Managerial/Organisational Techniques From 1991 To 1996, By Region

	Production Technique		
	Equipment Based	IT Based	Managerial/ Organisational
Northern Ireland	n=75	n=92	n=104
1991	10.7	10.9	9.6
1993	14.9	21.1	19.2
1996	23.1	36.5	32.9
% change	114.4**	235.0**	240.0**
Republic Of Ireland	n=161	n=200	n=229
1991	9.5	7.8	7.4
1993	15.1	16.3	19.4

1996	24.5	36.1	38.4
% change	157.2	362.2	415.7

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

Mjøset (1992, p. 132) suggests that

> *'the diffusion of both codified and tacit knowledge among firms in relatively equal relationships to one another ... is an important source of competitive advantage for small firms'.*

In the PPDS a clear tendency was evident for the use of each of the techniques to increase with plant size (Table 6.5). For robotic equipment and automated materials handling in the Northern Ireland plants and automated materials handling in the Republic of Ireland plants, however, this relationship was less clearly defined. For the smallest Northern Ireland plants, CAD and CAM were the most common techniques, with automated materials handling equipment and total quality management systems also being widely used among the smallest Republic of Ireland plants.

Table 6.5: Use Of Production Techniques In 1996 By Plant Size And Region

SIZEBAND	**10 - 19**		**20 - 99**		**100 - 499**		**500 +**	
	NI	**ROI**	**NI**	**ROI**	**NI**	**ROI**	**NI**	**ROI**
NC/CNC	19	15.9	28.6	30	40.3	38.9	63.6	54.7
Robotics	0**	4.8	17.4**	7.6	12.2**	28	36.4	46.3
Automated Materials Handling	13.5**	36.3	22.4	21.5	45.3	44.1	27.3*	58.5
Computer Aided Design (CAD)	38.1	41.4**	35.5	46	56.8	55.5	83.3	71.7
Computer Aided Management (CAM)	35.7	31.7	38.2	39.8	56.8	49.9	100**	57.4
Computer Integrated Man. (CIM)	18.1**	5.3	23.3**	16.9	29.1	27.5	83.3**	50.9
Quality Certification	27.8	22	56.9**	68.6	88.6**	80.9	83.3	94.3
Total Quality Management (TQM)	22.2*	31.9	31.3	29	56.4	48.7	100**	55.6
Quality Circles (QC)	5.6**	20.7	12.2**	17.2	14.8**	23.3	100**	16.7

Just-In-Time (JIT)	0**	22.5	27.3**	34.4	29.1**	50.1	83.3**	34

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (3) test.

3. Samples sizes are as follows for Northern Ireland (Republic of Ireland): 10-19 employees 14 (19); 20-99 employees 58 (126); 100-499 employees 45 (93); 500 plus employees 6 (25).

Source: PPDS

While the list of best practice manufacturing techniques used in the PPDS was designed to be broadly applicable, the characteristics of production technology in different industrial sectors will mean that some techniques will be more widely used in some sectors than in others. The PPDS data, however, suggests that the same sectors in Northern Ireland and the Republic of Ireland often had quite different levels of adoption (Table 6.6). For example, 24.3 per cent of Republic of Ireland metals and fabrication plants had robotic equipment, while none of the metals and fabrication plants in Northern Ireland had such equipment. Similarly, while 66.9 per cent of wood and wood products plants in Republic of Ireland had CAM, only 28.8 per cent of wood and wood products plants in Northern Ireland had similar systems. Further, for managerial/organisational techniques; 79.7 per cent of paper and printing Republic of Ireland plants had quality certification compared to only 18.2 per cent of the paper and printing plants in Northern Ireland.

In only three instances was there any similarity between the Northern Ireland and the Republic of Ireland plants in the importance of specific production techniques:

- In both the Northern Ireland and the Republic of Ireland mechanical engineering plants CAD was the most widely used of all the best practice techniques. 79.7 per cent of mechanical engineering plants in Northern Ireland had CAD as compared to 81.3 per cent of the Republic of Ireland plants.

- Both Northern Ireland and Republic of Ireland plants in the electrical and optical equipment sector had the highest incidence of quality certification, with 100 per cent of electrical and optical plants in Northern Ireland having quality certification as compared to 86.6 per cent in the Republic of Ireland.

- Plants manufacturing transportation equipment had the widest usage of quality circles, with 46.2 per cent of Northern Ireland plants and 37.8 per cent of Republic of Ireland plants using quality circles as a managerial/organisational production technique.

Table 6.6: Use Of Production Techniques In 1996, By Industrial Sector

	Food Drink & Tobacco	Textiles & Clothing	Wood and wood products	Paper and Printing	Chemicals	Metals and Fabrication	Mechanical	Elect. & Optical	Trans. Equip	Other Man.
Northern Ireland										
CNC/NC	8.2**	35.6**	59.3	18.5	33.3	35.3*	44.9**	47.1	26.9	27.6**
Robotics	4.5	10.2*	0.0	9.1	14.3	0.0**	14.7**	51.9**	8.0	17.1
AMH	29.9**	17.0	28.8	27.7**	57.1**	32.4	19.1	0.0**	8.0	44.7
CAD	13.3**	36.4	71.2*	53.8**	33.3*	33.3**	79.7	39.2**	73.1	39.5
CAM	51.1*	47.1**	28.8**	55.4**	57.1	58.8**	14.7**	38.5	36.0	43.4**
CIM	35.1*	20.5**	28.8**	36.4	14.3	29.4**	16.2**	0.0**	36.0	15.6
Q. Cert	53.0**	64.8	51.7**	18.2**	76.2	55.9	46.4	100**	80.8	71.1
TQM	26.1**	38.6	10.0	55.4	23.8	38.2	38.2**	19.6**	64.0*	60.5**
Quality Circles	12.7**	14.8**	0.0**	1.5**	33.3**	29.4**	8.7**	2.0**	46.2	21.1
Just-in-Time	26.1**	19.3**	10.0**	18.2**	33.3	29.4	17.4	36.5*	73.1**	19.7
Republic of Ireland										
CNC/NC	28.8	21.5	47.9	10.5	20.0	52.1	67.9	37.8	40.0	15.4
Robotics	8.2	4.2	3.3	8.2	20.0	24.3	3.6	20.6	8.9	15.4
AMH	46.1	21.5	31.4	14.3	26.7	34.5	11.6	21.0	17.8	36.6
CAD	22.9	36.1	57.0	36.6	54.1	53.6	81.3	65.1	77.8	37.3
CAM	59.9	71.7	66.9	32.8	41.9	40.0	32.1	34.9	37.8	20.3
CIM	25.9	7.6	14.0	25.4	22.1	5.7	3.6	21.4	28.3	20.9
Q. Cert	68.9	24.1	50.0	79.7	74.8	59.3	52.7	86.6	65.2	62.2
TQM	40.6	29.7	14.0	61.2	28.9	31.4	11.6	53.4	43.5	25.0
Quality Circles	22.9	26.2	11.6	14.3	3.0	13.6	20.7	16.8	37.8	21.9
Just-in-Time	40.1	54.9	28.3	46.3	22.1	36.7	25.0	51.3	40.0	16.8

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (1) test.

Source: PPDS

With the exception of CAD in Northern Ireland, and CAM and quality circles in the Republic of Ireland, a higher proportion of externally-owned plants, than indigenously-owned plants, were using each technique (Table 6.7). Comparing indigenously-owned plants, a higher proportion of Republic of Ireland plants were

using each of the techniques with the exception of robotics and computer integrated manufacturing. Among externally-owned plants most of the best practice techniques were more common in Northern Ireland. Exceptions were CAD and Just-in-time.

Table 6.7: Percentage Of Indigenously Owned And Externally-owned Plants Having Best Practice Technology In 1996, By Ownership And Region

	Northern Ireland		Republic Of Ireland	
Ownership	**Indigenously Owned**	**Externally-owned**	**Indigenously Owned**	**Externally-owned**
NC/CNC	29.8	35.3	30.0	33.8
Robotics	10.6	18.5	9.8	18.5
Automated Materials Handling	24.8*	35.1	29.6	30.8
Computer Aided Design (CAD)	44.9	34.4**	45.3	51.3
Computer Aided Management (CAM)	40.0**	51.3**	45.7	36.0
Computer Integrated Manufacturing (CIM)	20.3**	37.7**	15.7	24.7
Quality Certification	51.0**	87.3**	60.1	75.5
Total Quality Management (TQM)	32.2	51.7**	32.5	40.0
Quality Circles (QC)	11.4**	19.3	19.2	18.8
Just-In-Time (JIT)	22.0**	32.0*	33.4	40.0

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes a significant difference between the Northern Ireland and Republic of Ireland sample means at the 5 per cent level on the basis of a χ^2 (3) test.

Source: PPDS

6.4 Summary

It is widely recognised that if firms are to be competitive and meet the increasingly stringent demands of their customers they must maximise their use of best practice manufacturing techniques (Alderman and Thwaites 1992; Gertler 1989). This chapter has examined two areas: the composition of technology in manufacturing plants in Ireland, in terms of the introduction of new or modified production equipment; and, the adoption of specific equipment-based, IT-based and managerial/organisational techniques and the diffusion of these techniques since 1991.

Overall, Republic of Ireland plants have been more dynamic in the introduction of new or modified production equipment, than the Northern Ireland plants. In addition, the introduction of new production equipment was more likely to be associated with changes in production methods in the Republic of Ireland.

Plant size was found to have an important effect upon the likelihood of firms having new or modified production equipment. In general, as plant size increased so too did the proportion of production equipment that was new or modified since 1993. Regional disparities were also evident in that the Northern Ireland plants had a smaller proportion of new or improved production methods resulting from changes in production technology. It was also found that as plant size increased so too did the likelihood that new or modified production technology would be associated with new or modified production techniques.

Northern Ireland's indigenously-owned plants lagged behind the Republic of Ireland indigenously-owned and Northern Ireland and Republic of Ireland externally-owned plants, in their introduction of new or modified equipment. It followed that the Northern Ireland indigenously-owned plants were also less likely to have introduced new or modified production methods since 1993.

Sectoral analysis suggests that while some industrial sectors had more new or improved production equipment than others, Republic of Ireland plants within each of the industrial sectors had a higher proportion of new and modified technology. The only exception to this was the transportation equipment sector in Northern Ireland for which new or modified equipment accounted for 34.7 per cent of production technology in Northern Ireland and only 21.7 per cent in the Republic of Ireland. Again it was found that not only were Republic of Ireland plants within each of the sectors introducing more new or modified technology since 1993, but they were also introducing more new or modified production methods than their Northern Ireland counterparts.

Among product innovators considerable similarity was found between plants in Northern Ireland and the Republic of Ireland, not only in their use of best practice manufacturing techniques but in the diffusion of these techniques since 1991. Quality certification, CAM and CAD were the most widely used techniques, with the least common techniques being robotic equipment. With the exception of computer integrated manufacturing (CIM) and total quality management (TQM) each of the techniques were more common in the Republic of Ireland plants.

Plant size was found to have a positive effect upon the usage of each technique. However, anticipated differences in the use of best practice techniques between sectors were not supported by the data. In both Northern Ireland and the Republic of Ireland, CAD was most widely used in the mechanical engineering sector; quality certification was most widely used in the electrical and optical equipment sector, and quality circles was most important to plants in the transportation equipment sector.

In summary, the results suggest that Republic of Ireland plants have been more dynamic over the 1993 to 1996 period not only in terms of the introduction of new or improved production technology, but also in upgrading their production methods.

Adoption of best practice manufacturing techniques is, however, very similar between the region, with this being reflected in similar rates of diffusion since 1991.

Chapter 7: Innovation and Business Performance

7.1 Introduction

As the discussion in Chapter 1 suggests innovation does not take place in a vacuum. Plants innovate for a reason that may be related to market conditions or opportunities or some technological stimulus. In either case the underlying rationale is that innovation is necessary for improved business performance. The main issue addressed in this Chapter is whether the supposedly positive relationship between innovation and business performance is observable and significant. Prior research studies suggest a mixed picture. Storey (1994), for example, summarises the results of eight studies of the association between new product introductions and the growth of small firms: *'five suggesting that more rapidly growing firms are more likely to have made new product introductions. The remaining three studies do not find this impact on firm performance'* (p. 149). More recent studies by Barkham et al (1996) and Roper (1997) have reinforced the evidence of a positive linkage between new product introductions and turnover growth. There is, however, less evidence on the relationship between technological developments and profitability although theoretical considerations suggest a positive relationship[1]. It is possible, however, that risky investments in new products may have a negative impact on either growth or profitability particularly when combined with a weak market position (Buzzell and Gale, 1987).

In the PPDS information was sought on plants' turnover and employment growth over the 1993-96 period and on value added, sales and profit margins in the 1995 business year. In the following sections we compare the performance of the group of innovating and non-innovating plants. These comparisons have the advantage of simplicity but do not take account of any differences in the sizeband or sectoral composition of the groups of innovating and non-innovating firms. Aggregate comparisons may therefore be somewhat misleading and wherever possible disaggregated results are also given[2].

[1] In product life-cycle models, for example, products are said to earn higher margins during the introductory or expansion phase. It could be argued, however, that this effect is likely to be more important for larger firms which may be better able to exploit the full market potential of new product innovations or introductions.

[2] For example, the high proportion of large firms in the 'innovators' group means that cell sizes in the group of non-innovators are very small. In this case meaningful comparisons cannot be made.

7.2 Innovation, Growth And Profitability

Baseline comparisons of the turnover and employment growth and profit margins of innovating and non-innovating plants are given in Table 7.1. Real turnover growth over the 1993-95 period was faster for plants undertaking both product and process innovations. Process innovation had a markedly more significant turnover growth effect than did that related to new or improved products. In terms of employment growth the effects of innovation were also generally positive with process changes again associated with a larger proportionate effect. Profit margins were also higher among innovators in both Northern Ireland and the Republic of Ireland, although the difference between the profit margin of innovators and non-innovators was relatively small.

Table 7.1: Innovation, Growth and Profitability

	Northern Ireland			Republic of Ireland		
	n	Innovators	Non-Innovators	n	Innovators	Non-Innovators
Product Innovation						
Turnover Growth 1993-96(%)	267	33.9**	26.3	423	44.2**	33.5
Employment Growth 1993-96 (%)	269	19.0**	7.9	427	20.6**	21.4
Profit Margin 1995 (%)	225	30.8**	25.7	354	27.4**	26.9
Process Innovation						
Turnover Growth 1993-96 (%)	267	41.4**	20.6	419	48.1**	24.2
Employment Growth 1993-96 (%)	270	20.9**	7.8	423	23.3**	10.2
Profit Margin 1995 (%)	229	29.2	28.3	345	25.8**	29.2

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$).

Source: PPDS

Table 7.2: Sales Growth 1993-95 of Product Innovator Plants: By Sector

	Northern Ireland	Republic of Ireland

	n	Innovators	Non-Innovators	n	Innovators	Non-Innovators
A. By Industrial Sector						
Food, Drink and Tobacco	51	30.7**	19.9	82	26.2**	12.0
Textiles, Clothing	45	26.3**	16.4	40	29.8**	12.9
Wood Products	22	33.3**	13.0	25	30.5	20.4
Paper and Printing	16	20.2	33.8	32	94.9**	21.4
Chemicals	11	99.5**	20.2	42	51.9	29.2
Metals and Fabrication	18	43.8**	22.9	41	38.3**	18.6
Mechanical Eng	27	32.8	40.9	25	76.6**	43.2
Electrical and Optical Equip.	15	29.9	30.2	71	71.8	123.5
Transport Equip.	8	33.5	81.3	16	38.0*	36.1
Other Manufacturing	38	37.9	30.1	46	44.9	49.3
Total	267			423		
B. By Ownership						
Indigenously-Owned	209	37.0	28.0	267	39.5**	27.9
Externally-Owned	68	21.6	13.2	156	55.2	63.6
All Plants	267			423		

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$). * denotes rejection of the hypothesis at the 10 per cent level.

Source: PPDS

Table 7.3: Sales Growth 1993-95 of Process Innovators Plants: By Sector

	Northern Ireland			Republic of Ireland		
	n	Innovators %	Non-Innovators %	n	Innovators %	Non-Innovators %
A. By Industrial Sector						
Food, Drink and Tobacco	50	25.6	27.4	82	24.7*	20.2
Textiles, Clothing	43	38.7**	11.3	39	30.0	22.2
Wood Products	22	28.0	22.7	35	41.1**	15.5
Paper and Printing	16	26.3**	25.0	34	52.5**	14.4
Chemicals	11	101.0**	18.4	41	54.0**	24.7
Metals and Fabrication	18	52.9**	15.4	41	39.4**	20.5
Mechanical Eng	28	54.2**	13.2	23	57.2	63.6
Electrical and Optical Equip.	15	41.5**	9.3	69	95.9**	25.0
Transport Equip.	9	84.9**	13.2	16	40.0	31.7
Other Manufacturing	39	38.4*	32.9	46	49.0**	39.2

Total	267					
B. By Ownership						
Indigenously-Owned	210	45.7**	22.3	266	37.8**	24.9
Externally-Owned	57	25.2**	7.9	153	71.8**	21.2
All Plants	267			419		

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$). * denotes rejection of the hypothesis at the 10 per cent level.

Source: PPDS

Although reliable comparisons of the performance of innovating and non-innovating plants by sizeband are not possible due to the relatively small number of plants in the non-innovating group, it is possible to make comparisons on a sectoral and ownership basis. Table 7.2 gives the sales growth of product innovators and non-innovators over the 1993-96 period, and Table 7.3 gives the same information for process innovators. The tables provide a more general confirmation of the positive link between innovation and business growth evident in the aggregate data (Table 7.1). Some exceptions were evident, however, the majority of which were in the engineering sectors. In Northern Ireland and the Republic of Ireland, plants making no product changes had faster turnover growth in the electrical and optical equipment industries although process changes were associated with faster growth in both areas. Other sectors where the sales growth of product innovators was slower than that of non-innovators were: in Northern Ireland, paper and printing, mechanical engineering and transport equipment; and in the Republic of Ireland, other manufacturing (Table 7.2). Fewer exceptions were evident in terms of process innovation, but here sales growth was faster among non-innovators in the Northern Ireland food sector and the mechanical engineering and transport equipment sectors in the Republic of Ireland. Excepting externally-owned, product innovators in the Republic of Ireland, sales growth was also faster among both indigenously and externally-owned plants making product and process innovators.

7.3 Innovation And Labour Productivity

Information from the PPDS also provides some insight into the effect of product and process innovation on levels of value added per employee (labour productivity) and the proportion of sales that is accounted for by value added. Product innovation can affect labour productivity in a number of ways. For example, the unit value of products may be increased if their performance or desirability is enhanced. Alternatively, product innovation may lead to increased levels of physical productivity if new products are easier to manufacture or are manufactured by more

capital intensive methods. Process innovation is less likely to impact on the unit value of products, although product quality improvements may give significant market advantages. Such developments are perhaps more likely to lead to reduced unit cost or increased physical productivity thereby increasing value added as a percentage of sales. The strong and significant links between product and process innovation mean that it is unlikely that any of these effects will be observed in isolation. *A priori*, however, we would expect process innovation to have a stronger effect on value added as a proportion of sales than on labour productivity. Conversely, product innovation would be expected to have stronger productivity effects.

Table 7.4 gives value added as a percentage of sales and labour productivity for innovators and non-innovators. Value added per employee for both product and process innovators was higher than that for non-innovators in both Northern Ireland and the Republic of Ireland. Value added as a percentage of sales was also higher for both groups of innovators in Northern Ireland. In the Republic of Ireland, while product innovation also had a positive effect on both ratios, value added as a proportion of sales was higher for non-innovators. The proportionate differences between the value added ratios for innovators and non-innovators also provides little support for the idea that process changes are likely to have a greater effect on value added as a proportion of sales.

At a sectoral and plant sizeband level, reliable productivity comparisons between innovators and non-innovators were not feasible due to small sample sizes and a higher than average level of non-response to the survey question on the breakdown of costs. In general, however, the aggregate results were closely reflected in sectoral figures with the group of innovating plants in most sectors having higher value added per employee than the group of non-innovators. Similar results also applied to each ownership category with the exception of externally-owned plants in Northern Ireland.

7.4 Summary

Comparisons of the performance of innovating and non-innovating plants suggest, like the majority of earlier studies, a strong positive linkage between innovation and turnover and employment growth. Proportionately smaller but still positive effects are also evident on profit margins. Comparisons by sector and ownership category indicate the representativeness of these aggregate results. Labour productivity (i.e. value added per employee) and the value added share of sales are also positively related to innovation. No clear difference emerges, however, between the impact of product and process innovation on the value added indicators.

Table 7.4: Innovation and Productivity

	Northern Ireland			Republic of Ireland		
	n	Innovators	Non-Innovators	n	Innovators	Non-Innovators

Product Innovation 1993-95						
Value Added to Sales 1995 (%)	227	30.8**	25.7	354	27.3**	26.9
Value Added per Employee (£000)	218	25.8**	24.2	347	34.9**	20.5
Process Innovation 1993-95						
Value Added to Sales 1995 (%)	239	29.2**	28.2	354	25.8**	29.2
Value Added per Employee (£000)	220	26.7**	24.2	347	36.6**	20.9

Notes

1. Sample observations are weighted to allow for sample structuring, differential response and differences in industrial structure. See Appendix 1 for details.

2. ** denotes rejection of the hypothesis that the samples of innovators and non-innovators come from the same population based on the Wilcoxon test ($\rho = 0.05$). * denotes rejection of the hypothesis at the 10 per cent level.

Source: PPDS

Chapter 8: Final Remarks

The PPDS has highlighted the potential contribution of R&D and innovation to the performance of manufacturing firms. For example, turnover growth among product innovators in Northern Ireland from 1993-96 averaged 33.9 per cent compared to 26.3 per cent for non-innovators. Moreover both profit margins and labour productivity were higher in innovating firms both in Northern Ireland and the Republic of Ireland. The PPDS and the earlier PDS also provide some indication of the position of Northern Ireland and the Republic of Ireland in a wider context. For example, 71 per cent of German plants with more than 20 employees introduced new or improved products over the 1991-93 period (Roper et. al, 1996, p. 13). Comparable figures for Northern Ireland and the Republic of Ireland were 60 per cent and 68 per cent respectively. By 1996 the proportion of similar plants making product innovations had risen to 66 per cent in Northern Ireland and 68 per cent in the Republic of Ireland. In other words, over the 1993-96 period, Northern Ireland firms had closed around half of the innovation gap relative to Germany's position in 1993. Republic of Ireland firms, starting from a higher point, had maintained their position relative to that of Germany in 1993.

These aggregate comparisons depend to some extent, however, on the comparability of the 1993 and 1996 surveys of innovative activity. This difficulty is avoided if we consider the cohort of 550 firms in Northern Ireland and the Republic of Ireland that responded to both the 1993 and 1996 surveys. Among this cohort there was an increase over the 1993-96 period, in the proportions of firms undertaking both R&D and product innovation.

The evidence from this cohort and the comparison with Germany suggest two main points. First, there is evidence that product innovation in manufacturing firms in both Northern Ireland and the Republic of Ireland has become more widespread since 1993. This is reflected in the higher levels of R&D spend by businesses noted in recent official surveys in both Northern Ireland and the Republic of Ireland. Second, despite these very positive developments there remains a gap between the proportion of plants undertaking R&D and product innovation in Ireland and Germany. This suggests that despite improvements there can be little room for complacency if Irish companies are to increase their export market share.

With innovation, however, it is not simply a case of 'more is better'. Innovation is a costly and often risky business, factors that any business will want to bear in mind before embarking on product or process developments. Similarly, agencies charged with encouraging and grant-aiding firms to undertake R&D or innovative activity also needs to be mindful of the balance between the risks and benefits of innovation. For example, we encountered a situation recently where a small engineering firm had undertaken some product development because grant support was available. The firm

indicated to us that without the grant it would not have undertaken the development. As it was the engineering aspects of the product development were successfully completed but no machines were ever sold.

Another theme that runs through the PPDS results is the lower level of innovative activity in smaller plants in both Northern Ireland and the Republic of Ireland. This reflects the findings of other European innovation surveys, and reflects the balance of risk and reward for innovation in small and large companies. Larger firms may, for example, be undertaking a portfolio of product and process developments at any one time, reducing the risk attached to any single development. Smaller firms tend to undertake developments more sequentially increasing the risk implicit in any single development. It may therefore be appropriate to shift more support for innovation towards smaller companies. This might help to increase the overall level of innovation in this section of the economy by changing the risk/reward balance.

The PPDS also provides some more specific indications of the constraints on firms' innovation activity (Table 8.1). As in the earlier PPDS, financial barriers dominated firms' responses, acting as an 'important' or 'very important' constraint on innovation activity in more than a third of cases. Lack of market opportunities was highlighted as a constraint by around a fifth of firms with a similar proportion emphasising a lack of appropriate in-house expertise. Less common constraints were a lack of information about technologies and regulatory requirements.

Table 8.1: Important Constraints on Innovation Activity of Plants in Northern Ireland and the Republic of Ireland

(Percentage of plants)

Innovation Constraint	% of Plants
Lack of Necessary Finance	38.8
Low Rate of Return	34.1
Riskiness of Innovation	27.3
Few Market Opportunities	22.8
Lack of Appropriate Expertise	21.1
Legislation or regulatory requirements	14.3
Lack of Information about Technologies	12.5
Attitudinal barriers in the plant	9.4
Lack of partners	6.7

Source: PPDS

Grant support, such as that provided by the Compete scheme in Northern Ireland, is already available to offset financial constraints on firms' innovative activity and reduce the risk involved in innovation. From the relatively low level of innovation in smaller companies, however, it is clear that this type of measure is not sufficient to fully counter the adverse risk/reward balance in smaller firms. One possibility would

be a combined grant/loan package that might be restricted to smaller businesses. Grant-aid might be provided on the same basis as at present with the possibility offered of a top-up loan that would be repayable if the development was commercially successful.

Such measures to assist individual firms should, however, be balanced with schemes designed to promote collaboration particularly among smaller companies or between large companies and their smaller suppliers. Although lack of partners was not perceived by firms to be a significant barrier to innovation it is clear from the PPDS that there is substantial variation in the extent of firms' innovation networks. Along with intra-group technology transfer, such networks provide a potentially important source of new ideas and – as the PPDS indicated – can contribute to the speed and cost-effectiveness of innovation. Extending firms' innovation networks would counter two of the most common constraints on innovative activity; first, it would help to make firms aware of potential market opportunities and, secondly, it would contribute to the cost-effectiveness of their innovation activities.

Some very positive steps in this direction are already being made. For example, NORWESCO is currently working with staff from the Ulster Business School to establish an innovation network for small companies from Northern Ireland and the Republic of Ireland. The aim of the project is to set up self-supporting networks of small firms that can encourage and help each other to establish an innovative culture within the firm. Similar types of initiative have also been organised by Forbairt who recently worked with PA Consultants on developing the innovation capability of small firms in the Limerick area.

Other types of network building activities not specifically related to innovation may also be important in helping firms to identify new market opportunities or promote the transfer of technology from large to smaller companies. In this respect, policy is most strongly developed in the Republic of Ireland through the National Linkages Programme although organisations such as the Northern Ireland Growth Challenge perform something of a similar role. Major research projects are currently underway in both Northern Ireland and Scotland to investigate the potential for such supply-chain relationships to lead to increased innovative activity and the spread of manufacturing best practice to smaller firms.

Appendix 1: Data Sources and Methods

A1.1 Introduction

This appendix gives details of the original PDS conducted between October 1994 and April 1995 (see Roper et. al, 1996) and subsequent Product and Process Development Survey (PPDS) conducted between November 1996 and March 1997. It also describes the longitudinal sample of manufacturing plants that responded to both surveys.

A notable characteristic of both the PDS and PPDS is that they are both surveys of manufacturing *plants* rather than manufacturing *companies*. This is important because in the UK, at least, doubts have been expressed about individual plants' ability to implement new product and process developments and exploit new technologies. Any difficulties of this type might be missed by a company-based approach. Other aspects of innovation behaviour which were taken into account in designing the sampling frames were that R&D investments and innovation behaviour have been shown to differ significantly between manufacturing sub-sectors (Geroski, 1991), plant sizebands (Acs and Audretsch, 1988 and 1993) and geographical areas (e.g. Alderman and Thwaites, 1995).

Section A1.2 gives details of the sampling frames developed for the original PDS and used in the follow-up PPDS. Section A1.3 then gives details of the response rates achieved by both the PDS and PPDS Section A1.4 describes the construction of sample weights designed to give representative results.

A1.2 Sampling Frames

To take account of differences in R&D and innovation behaviour between plant sizebands and industries, as well as the relatively small number of plants in some industries in Ireland, structured sampling frames were used. In Northern Ireland this was constructed the *Size Analysis of Manufacturing Businesses*. This provides a count of manufacturing establishments by plant sizeband and industry and gives their employment. Ten industrial categories and four plant sizebands were distinguished[1].

[1]The industrial categories were combinations of SIC80 two digit classes: Minerals and Ores, 21-22; Extraction of minerals, 23-24; Chemicals, Man-made Fibres, 25-26; Metals, Mechanical Eng, 31-32; Instrument and Elect Eng, 33,34,47; Vehicles and Other Transport Equipment, 35,36; Food, Drink, Tobacco, 41-42; Textiles and Clothing, 43-45; Timber, Paper Industries, 46-47; Misc Manufacturing, 48-49. The four plant sizebands were: 10-19 employees; 20-99 employees; 100-499 employees; 500 plus employees.

The population of manufacturing establishments is given in Table A1.1, part A. From this population structure sampling fractions were derived intended to give sufficient cell sizes in all industries and plant sizebands. The number of units sampled is given in Table A1.1, part B. The number of units in each cell together with the SIC code were then provided to British Telecom and a random sample was drawn from the Yellow Pages database. The final sampling fraction in Northern Ireland was 74 per cent.

In the Republic of Ireland, at the time the sampling frame for the PDS was being constructed, the most recent information on the size-structure of Irish manufacturing firms was the 1990 Census of Production. Because of potential changes in industrial structure since this survey, it was not used in the construction of the sample. Instead a simple sampling schema was used based solely on establishment size (see Table A1.2). Sample details for companies for the Republic of Ireland survey were obtained from Forfas and were used to draw a random sample within plant sizebands[2]. An average sampling fraction of 62 per cent was used.

A1.3 Survey Methodology And Response Rates

Details of the conduct and results of the PDS have been given elsewhere (see, for example, Roper et. al, 1996). The PPDS was undertaken in a very similar way. An initial pilot survey of 100 companies was contacted in October 1996. This allowed the wording of questions to be evaluated and some minor changes to the questionnaire were made at that point. The finalised version of the questionnaire is included in Appendix 2. The main postal survey was conducted between November 1996 and March 1997 with each company being sent an initial form and up to two postal reminders. Respondents to the PDS from which replies had not been received were then contacted by telephone to boost the size of the longitudinal sample. The final group of PPDS respondents consisted of 752 plants. Of these companies 557 were respondents to the earlier 1995 survey (Table A1.3).

One weakness of the original PDS was the lack of any non-response checking. This is important in assessing the extent of any non-response due to the inclusion of out of scope companies in the sample. Evidence on this point is available from a survey of non-responders to the PPDS. This indicated that around 12 per cent of the original PDS sample for Northern Ireland and 2 per cent of the Republic of Ireland sample were out of scope (i.e. non-manufacturing companies). Taking these adjustments into account it is possible to construct appropriate response rates for the PDS (Table A1.3). By 1997 the proportion of out-of-scope companies in the original sample had increased due to liquidation, changes of address or changes in the nature of firms' business. PPDS response rates are therefore constructed relative to a slightly smaller sample size (Table A1.3). The overall PPDS response rate was 32.9 per cent, 43.1 per cent in Northern Ireland and 28.6 per cent in the Republic of Ireland.

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[2] This was understood to cover all manufacturing establishments and other companies assisted by the agency. However, comparison of the information provided by FORFAS with that from the 1990 Census suggests that a number of smaller companies were missing from the address list provided (Table A1.2).

Comparison of the original group of PDS respondents and that from the PPDS indicates the structure of the implicit longitudinal sample (Table A1.4). From the original group of 922 respondents to the PDS, 557 plants (60.4 per cent) also responded to the PPDS. This group constitutes the longitudinal sample. Of the remainder, 3.5 per cent of the original group of PDS respondents were un-contactable and the remainder was unable or unwilling to provide the information requested.

One potentially significant issue both with the PPDS and the longitudinal groups of respondents is their representativeness of the overall population. Plants, which either undertake R&D and/or innovation, might be thought more likely to respond to an innovation survey than non-innovating companies. To check the representativeness of the sample a non-response check of 196 non-respondents to the PPDS was undertaken. These plants were sampled at random from the group of non-respondents and a brief telephone interview conducted with each plant. Plants were asked about the nature of any R&D activity which they undertook and whether they had made any product and process changes since 1993 (Table A1.5). Little difference was evident between PPDS respondents and non-respondents. It was therefore concluded that the sample of PPDS was broadly representative of the underlying population.

A1.4 Sample Weights

As indicated earlier, the PPDS like the PDS was based on a sampling frame and sample structured to take account of the plant size and sectoral distribution of manufacturing activity. To derive representative results it is therefore necessary to weight the sample observations. The weights were also constructed to control for differential response rates between sizebands and industrial sectors. The proportions of the population of establishments and employment covered by respondents to the various surveys are given in Tables A1.6 and A1.7 respectively. The weights are derived as the reciprocal of these percentages with separate weighting systems used for the PPDS and longitudinal samples.

Table A1.1: Sampling Frame of Northern Ireland Manufacturing Establishments and Employment: 1993

	Employment Sizeband				
	10-19	20-99	100-499	500 plus	Total
A. Number of Establishments					
Minerals and Ores	2	3	1	0	6
Extraction of Minerals	65	75	6	0	146
Chemicals, Man -Made Fibres	16	11	9	1	37
Metals, Mechanical Eng	105	112	8	1	226
Instrument and Electrical Eng	27	37	15	3	82
Transport Equipment and ote	14	14	9	5	42
Food, Drink and Tobacco	117	112	47	4	280
Textiles and Clothing	54	101	79	4	238
Timber and Paper	131	129	24	1	285
Miscellaneous Manuf	33	38	16	2	89
All Plants	564	632	214	21	1431
B. Sample Structure					
Minerals and Ores	2	3	1	0	6
Extraction of Minerals	45	56	6	0	107
Chemicals, Man -Made Fibres	16	11	9	1	37
Metals, Mechanical Eng	60	80	8	1	149
Instrument and Electrical Eng	20	28	15	3	66
Transport Equipment and ote	14	14	9	5	42
Food, Drink and Tobacco	60	80	47	4	191
Textiles and Clothing	40	76	79	4	199
Timber and Paper	68	95	24	1	188
Miscellaneous Manuf	25	30	16	2	73
All Plants	350	473	214	21	1058

Source: Size Analysis of Manufacturing Businesses, Product Development Survey.

Table A1.2: Sampling Frame for the Republic of Ireland Sample

(Number Of Establishments)

Employment Sizeband	1990 Census of Production	Information Provided by Forfas	Final Sample	Sampling Fraction (%)
10-49	2058	1752	791	45.1
50-499	839	863	805	93.2
500 plus	36	82	71	86.5
Total	2933	2697	1667	61.8

Sources: **Forfas, Census of Production 1990**

Table A1.3: Response Rates to the Product Development Survey (PDS)

And Product and Process Development Survey (PPDS)

	Northern Ireland		Republic of Ireland		Total	
	n	%	n	%	n	%
1995 Product Development Survey (PDS)						
Sample Size	796	100.0	1617	100.0	2413	100.0
Response	374	46.8	548	33.9	922	38.2
1997 Product and Process Development Survey (PPDS)						
Sample Size	679	100.0	1604	100.0	2283	100.0
Response	293	43.1	459	28.6	752	32.9
of which:						
PDS Respondents	227	33.4	330	20.6	557	24.4
PDS Non-Respondents	66	9.7	129	8.0	195	8.5

Sources: PDS, PPDS.

Table A1.4: Details of Longitudinal Sample

	Northern Ireland		Republic of Ireland		Total	
	n	%	n	%	n	%
PDS Respondents	**374**	**100.0**	**548**	**100.0**	**922**	**100.0**
PPDS Responses	**374**	**100.0**	**548**	**100.0**	**922**	**100.0**
Respondents	227	60.7	330	60.2	557	60.4
Non-contacts	20	5.3	12	2.1	32	3.5
Non-Respondents	127	33.9	206	37.6	333	36.1

Sources: PDS, PPDS

Table A1.5: Non- Response Analysis of Main Technological Indicators

	Northern Ireland			Republic of Ireland		
	PPDS	LONGIT	Non-Response Check	PPDS	LONGIT	Non-Response Check
n	293	222	94	459	320	102
Undertaking R&D in plant (%)	46	49	49	53	54	52
R&D Dept in plant (%)	17	19	10	26	27	18
Product Changes Since 1993 (%)	59	64	74	71	70	73
Process Changes Since 1993 (%)	50	55	78	65	66	74
Links to Other Firms (%)	36	39	45	47	50	43

Sources: PPDS, Non-Response Survey

Table A1.6: Percentage of Plants in Population included in Each Survey: By Sizeband and Sector

	SIC 80	Northern Ireland				Republic of Ireland			
		Population %	PDS %	PPDS %	LONGIT %	Population %	PDS %	PPDS %	LONGIT %
A. Industrial Sector									
Minerals and Ores	21-22	100.0	66.7	33.3	33.3	100.0	7.4	3.7	1.9
Extraction of Minerals etc	23-24	100.0	13.7	28.8	10.3	100.0	24.6	18.0	11.5
Chemicals, Synthetic Fibres	25-26	100.0	37.8	32.4	21.6	100.0	25.9	23.9	17.8
Metals, Mechanical Engineering	31-32	100.0	27.0	22.1	18.1	100.0	16.3	13.8	10.1
Instrument and Electrical Eng	33,34,37	100.0	23.2	19.5	14.6	100.0	22.9	22.6	15.4
Vehicles and Transport Equip	35,36	100.0	33.3	23.8	19.0	100.0	38.8	25.4	17.9
Food, Drink and Tobacco	41,42	100.0	16.8	18.9	15.4	100.0	17.2	15.0	11.1
Textiles and Clothing	43-45	100.0	25.2	20.6	16.8	100.0	16.7	13.2	10.4
Timber, Paper Industries	46,47	100.0	18.2	14.7	11.9	100.0	13.3	12.4	8.6
Misc Manufacturing	48,49	100.0	24.7	19.1	14.6	100.0	15.8	11.7	8.3
All Firms		100.0	21.9	20.5	15.1	100.0	18.2	15.7	11.2

Table A1.6 (Continued)

		Northern Ireland				Republic of Ireland			
	SIC 80	Population %	PDS %	PPDS %	LONGIT %	Population %	PDS %	PPDS %	LONGIT %
B. Plant Sizeband									
10-19 Employees		100.0	9.9	10.8	5.7				
20-99 Employees		100.0	25.0	20.9	16.3	100.0	9.9	8.3	5.7
100-499 Employees		100.0	40.7	32.2	29.4	100.0	29.3	26.7	20.2
500 plus Employees		100.0	57.1	28.6	19.0	100.0	53.8	74.4	51.3
All Firms		100.0	21.9	18.7	14.1	100.0	18.2	14.4	10.4

Sources: Size Analysis of UK Manufacturing Businesses 1993, Census of Industrial Production 1990, PDS, PPDS.

Table A1.7: Percentage of Employment in Population included in Each Survey: By Sizeband and Sector

		Northern Ireland				Republic of Ireland			
	SIC 80	Population	PDS	PPDS	LONGIT	Population	PDS	PPDS	LONGIT
		%	%	%	%	%	%	%	%
A. Industrial Sector									
Minerals and Ores	21-22	100.0	14.7	6.9	6.9	100.0	8.0	1.6	0.9
Extraction of Minerals etc	23-24	100.0	34.0	46.3	23.2	100.0	46.1	42.7	12.3
Chemicals, Synthetic Fibres	25-26	100.0	44.4	29.8	28.2	100.0	46.1	61.0	43.0
Metals, Mechanical Engineering	31-32	100.0	48.4	30.0	27.9	100.0	27.7	21.7	13.6
Instrument and Electrical Eng	33,34,37	100.0	39.8	28.3	13.5	100.0	51.3	48.7	33.3
Vehicles and Transport Equip	35,36	100.0	62.9	72.7	72.6	100.0	83.7	30.3	27.6
Food, Drink and Tobacco	41,42	100.0	34.9	25.8	23.8	100.0	43.2	34.1	29.2
Textiles and Clothing	43-45	100.0	41.1	23.8	21.6	100.0	45.9	33.6	31.9
Timber, Paper Industries	46,47	100.0	25.7	21.8	20.0	100.0	20.4	24.7	17.0
Misc Manufacturing	48,49	100.0	27.1	37.1	18.5	100.0	27.2	16.2	12.3
All Firms		100.0	40.7	33.7	29.0	100.0	41.7	35.7	26.2

Table A1.7 (Continued)

		Northern Ireland				Republic of Ireland			
	SIC 80	Population	PDS	PPDS	LONGIT	Population	PDS	PPDS	LONGIT
		%	%	%	%	%	%	%	%
B. Plant Sizeband									
10-19 Employees		100.0	10.0	10.5	5.8				
20-99 Employees		100.0	27.6	22.6	18.1	100.0	1.3	1.0	0.7
100-499 Employees		100.0	39.2	32.4	29.6				
500 plus Employees		100.0	67.3	55.1	46.9	100.0	41.3	43.3	31.9
All Firms		100.0	40.7	33.6	29.0	100.0	41.7	35.3	25.9

Sources: Size Analysis of UK Manufacturing Businesses 1993, Census of Industrial Production 1990, PDS, PPDS.

Appendix 2: Questionnaire

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