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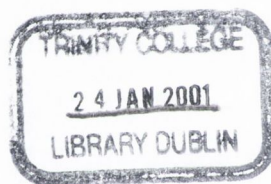
Essays on the Consequences of Research and Development for Manufacturing Firms in Ireland

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Doctor of Philosophy (Ph.D.)

December 2000



Thesis
6157

DECLARATION

I declare that this thesis, submitted to Trinity College for the degree of Doctor in Philosophy (PhD.) has not been submitted as an exercise for a degree at this or any other university. All research contained herein that is not entirely my own, but is based on research that has been carried out jointly with others, is duly acknowledged in the text wherever included.

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SUMMARY

The aim of this thesis is to investigate some of the economic consequences for manufacturing firms of investing in research and development (R&D), using the Irish manufacturing sector as a case study.

Chapter 1 outlines summary statistics on R&D in Irish manufacturing and the current policy objective of increasing R&D investment in Ireland. The aims, data sources and structure of the thesis are also outlined.

Chapter 2 benchmarks the post-entry survival and growth of almost 4,000 indigenous new entrant plants that entered the Irish manufacturing sector over the period 1985 to 1995. A limitation of earlier studies that have explored the effect of innovation on the post-entry survival and growth of new entrant plants has been the use of sectoral level innovation data. This has restricted the authors from reaching conclusions about the role of innovative activity within a plant on its subsequent survival and growth. Using a panel dataset of almost four thousand plants which entered the Irish manufacturing sector over the period 1985-1995, we find that innovating plants have a higher probability of survival, but having survived, enjoy lower annual growth rates than non-innovators. In addition, we suggest that a major advantage for an innovating plant is that its post-entry growth is not constrained by initial size. In contrast, we find that initial size remains a significant explanatory factor in the subsequent growth of non-innovating plants.

In Chapter 3 we question whether R&D activity is an important determinant of the probability that a plant will survive. We model the survival of a cohort of indigenous plants over the period 1986 to 1996 as a function of sectoral and firm characteristics. Using a Cox duration model we conclude that R&D activity is an important factor that increases the probability of survival for that plant. Specifically, R&D active indigenous plants have a higher probability of surviving the entire period 1986-1996 relative to non-R&D active plants. We show that this result is robust to alternative measures of technological activity in indigenous plants.

In Chapter 4, we examine whether investment in R&D increases or decreases labour demand in individual firms. We estimate a dynamic labour demand model using GMM estimation. It is found that employment growth is slightly higher in R&D active firms, not because of a greater propensity to increase employment as output increases, but because R&D active

companies have higher sales. Our second finding is that it is the quality rather than the quantity of employment that differs significantly between innovative and non-innovative plants.

The rapid growth over the past decade in (i) the number of foreign-owned plants in the high-tech sectors and (ii) the research and development activities of foreign-owned plants has given rise to an increased interest in the relationship between foreign direct investment (FDI) and economic growth in Ireland. The central question explored in Chapter 5 is whether the tangible contribution of MNC plants that undertake R&D investment in Ireland is greater than the tangible contribution of MNC plants that undertake no R&D investment. We use a plant-level dataset and conclude that the scale of R&D activity in an MNC plant is an important determinant in (i) lengthening the duration over which that plant will remain in Ireland and in (ii) improving the quality of employment created in that plant. Although it has long been recognised that the attraction of FDI to Ireland has been beneficial, the results of this chapter support the idea that R&D active firms generally provide greater benefit to the economy. On employment grounds alone, policy should favour R&D active plants in high-tech sectors.

The intangible benefits of R&D active foreign-owned plants are examined in Chapter 6. A key benefit of foreign direct investment, in addition to increased employment and capital inflows, is the potential spillover of technology from foreign to indigenous companies in the host region. Specifically, in the literature, it has been suggested that the presence of FDI in a host region can improve the productivity of local firms. Using the traditional productivity approach to measuring spillovers, it is found that there are productivity spillovers from foreign-owned plants to indigenous plants in Ireland. We conclude that although there is evidence of productivity spillovers, there is no evidence to suggest that any of these productivity spillovers are R&D productivity spillovers.

There are three parts to Chapter 7. The final chapter presents a brief summary of each chapter, policy implications and issues for future research.

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Finally, this thesis is dedicated to my family. To my mother who doesn't need another doctor in her life, to my father who has struggled with his long irons for too many years and to my sister who is convinced she was taken home by the wrong family. (F.T.A.B.N)

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CHAPTER 1

INTRODUCTION TO THE THESIS

1.1 Setting the Context

"R&D is seen as the life blood of our industry and its part in job maintenance and creation cannot be overstated. Government support for R&D can only be welcomed and encouraged. If the benefits of R&D were fully appreciated by government they would increase their support tenfold."

-Irish-owned engineering company employing 100+ persons.

"Supporting the growth of R&D helps increase the technology base making it attractive for multinationals to invest in Ireland. Furthermore it has the effect of creating an environment whereby our highly qualified young professionals can gain meaningful employment without going abroad or alternatively attracting those that have left back home."

-Foreign-owned electronics company employing 100+ persons.

"Government involvement in funding R&D in industry is not necessary - a business shouldn't require incentives to invest in the fundamental "lifeblood" of its existence."

-Irish-owned engineering company employing 100+ persons.¹

Following a period of recession, the Irish economy has enjoyed significant growth over the past decade, earning Ireland its "Celtic Tiger" nickname. Irish GNP increased by 70 per cent over the period 1987 – 1997 during which time the EU, US and UK economies expanded by 27, 24 and 20 per cent respectively.² The growth in GNP can be partly explained by growth in the Irish manufacturing sector. The contrast in manufacturing employment growth has been primarily with EU countries, which have

seen employment in manufacturing fall by approximately 21 per cent since 1977, while employment in the Irish manufacturing sector during the same period has risen by over 21 per cent.³

A key feature of Ireland's growth has been the expansion of R&D investment in the manufacturing sector. The Irish manufacturing sector has experienced remarkable growth rates in business expenditure on research and development (BERD) since 1982, which far outstripped those of other EU and OECD countries (Table 1.2). Since 1982, BERD as a percentage of GDP has increased over threefold in Ireland. In contrast, the corresponding estimates for other EU and OECD countries have increased by 0.05 and 0.01 per cent respectively. In 1997, the Irish manufacturing sector invested 1.11 per cent of GDP in R&D. This is similar to investment elsewhere in other European countries (1.15 per cent) but is below the OECD average of 1.49 per cent of GDP. The Irish Council for Science, Technology and Innovation advises that "*Ireland should aim to achieve a level of spending on R&D equivalent to 2.5 per cent of GDP.*"⁴ This target will require BERD as a percentage of GDP to double to over two per cent in the near future.⁵

¹ A selection of verbatim quotes on the role of government in supporting research and development, collected by the Science and Technology Division of Forfás in the 1993 *Survey of Technology in Industry* and which are available at <http://www.forfas.ie/forfasdev/publications/archive/rdbus.htm>.

² See Barry (1999, p.1).

³ See Table 1.1.

⁴ This target refers to all investment in R&D in Ireland (i.e., business expenditure (BERD), higher education (HERD) and government expenditure (GOVERD). The sum of these 3 categories of R&D investment is gross expenditure on R&D (GERD). See the statement from the Irish Council for Science, Technology and Innovation (1999) at <http://www.forfas.ie/report/rti.htm>.

⁵ This assumes that BERD will continue to account for approximately 75 per cent of all R&D in Ireland (i.e., GERD). See Table 1.3.

In endogenous growth models, the engine of growth that drives long run economic expansion is investment in research and development.⁶ These models would assign to the rise in BERD a major role in explaining Ireland's recent growth performance. For example, the latest OECD policy brief on innovation (September 2000) cites Ireland as an example of a country where multifactor productivity has increased and explains that this is due to *"improved managerial practices, organisational change, and, most importantly, to smarter and more innovative ways of producing goods and services"* (OECD, 2000, p.2).

The incentives of individual firms to undertake R&D investment are crucial in the context of R&D and macroeconomic growth. There will be no increases in aggregate R&D investment to drive macroeconomic growth if individual firms do not have the incentive to invest in research and development. The incentive to undertake R&D depends on the impact of this investment on firms' sales, profits and competitiveness. However, there is only a small fraction of manufacturing firms investing substantially and continuously in R&D in Ireland. The latest survey of technology in industry shows that in 1997 only 1,250 manufacturing firms, out of a population of 4,739, were engaged in R&D activities: 890 of these plants were indigenous and the remaining 360 were foreign-owned.⁷ Only 55 per cent of R&D active indigenous plants engaged in R&D on a continuous basis and only 39 per cent of these plants invested in excess of £100,000 in R&D in 1997. In contrast approximately 79 per cent of R&D active foreign plants invested in excess of £100,000 in the same year. Forfás surveyed a group of non-innovating firms to ascertain the factors that hampered innovation in

⁶ See Romer (1986, 1990) and Grossman and Helpman (1991).

⁷ See Forfás (1999) and CSO (2000b).

these companies.⁸ All of the significant issues raised by the respondents related to the issue of finance and the inherent riskiness of investment in R&D. The most significant issue was lack of appropriate finance, followed by the excessively high cost of innovation, the long pay-off period required and finally, that this type of investment involves excessive risk.⁹

While the Irish government stresses the importance of increasing BERD, it has not supported BERD to the same extent as other countries. Data in Table 1.4 show that although the percentage of BERD in Ireland funded from the exchequer has increased between 1991 and 1997, in contrast to other EU and OECD countries, the Irish state in 1997 still funded a below average percentage of BERD relative to the EU and OECD averages. The annual budget for R&D projects was approximately £20 million per annum over this period.¹⁰ The National Development Plan, published in November 1999, allows for an increase in this budget and £1.9 billion is to be allocated to support R&D projects over the period 2000-2006.¹¹ These grants are available to both indigenous and foreign-owned companies. The aim of the grants to indigenous plants is to increase their growth and competitiveness while the aim of grant-aiding research and development in foreign-owned firms is to increase their embeddedness in Ireland.¹² Hitherto, there has been no investigation as to whether increased R&D investment will increase the growth and competitiveness of indigenous firms or the embeddedness of foreign-owned plants in Ireland.

⁸ Forfás is the policy and advisory board for industrial development in Ireland.

⁹ See Forfás (1994).

¹⁰ See the Irish Times (November 19th, 1999).

¹¹ The evolution of government policy towards supporting this level of grant-aid for R&D can be followed in earlier publications, specifically in the *National Development Plan 1994-1999* (National Development Plan, 1993) and in a 'Strategy for enterprise in Ireland in the 21st century' published by Forfás (1996).

¹² See Table 6.1 (p.121) in the National Development Plan (1999).

1.2 Aims of the Thesis

The aim of this thesis is to investigate some of the consequences for manufacturing firms of investing in research and development, using the Irish manufacturing sector as a case study. This thesis presents the analysis of a dataset that allowed us for the first time to compare the performance of firms that are and are not engaging in R&D in Ireland.

Two chapters consider the survival and growth of new entrants and incumbent indigenous firms respectively in the manufacturing sector. First, we investigate whether investment in R&D increases the probability of survival and growth of new entrant plants. Our second investigation relates to how R&D activity might alter the probability of survival and growth of new entrants. Based on a theoretical model by Pakes and Ericson (1989, 1998) we conduct an econometric study which attempts to shed some light on the relationship between a new entrant's innovative activity and its ability to overcome its small initial size as an obstacle to future growth.

Investment in R&D is expected to improve a firm's sales, market share and profits. This should improve that firm's probability of survival. We analyse the probability of survival of indigenous incumbent plants and the role of R&D investment in improving their survival. A Cox duration model is estimated to determine the impact of R&D on the probability of survival, controlling for the myriad of other plant and sectoral characteristics that influence the probability of exit.

Our next investigation focuses on the possible conflict that exists between the policy-makers' desire to increase R&D investment on the one hand and to increase job creation on the other. It has been argued that investment in technology destroys jobs and reduces labour demand. We investigate to what extent the quantity and quality of labour demand differs between R&D active and non-R&D active indigenous firms.

Given the importance of multinational firms in terms of output, employment and research and development in Ireland, we investigate the impact of R&D in foreign-owned plants on the host region, using Ireland as a case study. After discussing the significance of R&D expenditures in foreign-owned plants in Ireland, we investigate to what extent it matters, in terms of the duration the plant operates in Ireland and the quantity and quality of the employment it creates, that a foreign-owned plant undertakes R&D in addition to its assembly operations. The presence of R&D investment in a foreign-owned plant may indicate a relatively greater commitment to the host region.

There may also be intangible benefits arising from R&D investment in foreign-owned plants. We attempt to examine whether there are (i) any intra-sectoral productivity spillovers from foreign-owned plants to indigenous plants and (ii) whether any of these productivity spillovers are in fact R&D productivity spillovers.

1.3 Data Sources

In 1996, when research on this thesis began, there existed no complete dataset on Irish manufacturing industry with which to analyse the issues set out in Section 1.2. All of the datasets used throughout this thesis were constructed from data generously

supplied by the Science and Technology Division of Forfás which also assisted in their construction. The datasets explored herein are a unique combination of three sources.

R&D data: The R&D data are drawn from a survey of R&D performing firms, undertaken by the Science and Technology Division of Forfás. This organisation has statutory responsibility for R&D statistics in Ireland. For the years 1986 to 1997, the biannual surveys (1986, 1988, 1990, 1991, 1993, 1995 and 1997) of technology in industry and a survey of innovation (1992) reported data on R&D performers in the manufacturing and internationally traded sectors. The surveys of technology in industry are undertaken every second year in accordance with OECD guidelines set out in the Frascati Manual (OECD, 1994a). The surveyors aspired to report data on all of those companies thought to undertake R&D investment in Ireland.

Throughout this thesis R&D is defined as “*creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications*” (OECD, 1994a, p.29). R&D expenditures in manufacturing companies include expenditures on the following areas¹³

- development of prototypes for new or improved products or processes,
- construction and development of pilot plants,
- industrial design and drawing directly linked to R&D projects,
- industrial engineering and tooling up directly associated with the development of new or improved products or processes,

- trial production (where this implies full-scale testing and subsequent further design and engineering)

while excluding expenditures on

- patent and licence work that is not related to any R&D project,
- routine testing, standardisation and pre-production preparation,
- after-sales service and trouble-shooting,
- general purpose data collection, including market research,
- feasibility studies,
- enforcement of standards and regulations.

Employment data: The employment data are drawn from the annual employment surveys undertaken by the same agency. These employment surveys cover the population of firms in the manufacturing and internationally traded service sectors. The employment dataset used varies across chapters. Chapter 2 (the study of new entrants) required the employment dataset to include only new entrant plants over the period 1980 to 1996. This required the exclusion of all plants from the dataset with positive employment (i.e., that were alive) in 1980. The employment data for Chapters 3 to 6 have been subdivided to include every firm with greater than or equal to ten employees in each year 1980 to 1998. We matched the R&D data to the employment data at plant level. Using the employment data as a definitive list of the population of manufacturing plants in Ireland, we subsequently divided this population into R&D active and non-R&D active plants.

¹³ These are the guidelines given to respondents of the Forfás *Surveys of Technology in Industry*.

Sales/Cost data: The data on sales and costs are drawn from the Irish economy expenditure (IEE) surveys undertaken by Forfás. These data are based on a sample of manufacturing plants and more recently with an emphasis on the largest indigenous and foreign-owned manufacturing plants (1983-1998).

Because of the long time frame over which this thesis has been researched, the data used in different essays are not identical. There have been three datasets constructed for the five essays in this thesis. The first dataset was built between October 1996 and June 1997. This dataset joined the R&D surveys (1986-1993) and employment surveys (1985-1996) for individual plants. This dataset was applied in our analysis in Chapters 3 and 5.

The second dataset was constructed for Chapter 2 between January and June 1999. A panel dataset of all new entrant plants over the period 1980-1996 was constructed based on the employment surveys. The second step was the matching of any of these plants to the R&D surveys where approximately 10 per cent of the plants could be matched against R&D expenditures.

The third dataset was constructed between January and July 2000 and was applied to the analysis in Chapters 4 and 6. This dataset is a copy of the integrated dataset (BIS) recently constructed by Forfás where the responses for all three surveys (R&D, employment and IEE) are stored in one file for each plant. For the first time, our data includes information on sales and costs for a sample of R&D active and non-R&D active plants.

1.4 Structure

This thesis contains five essays that are distinguished primarily by whether they relate to indigenous or foreign-owned¹⁴ plants or both. Studies of this topic in other countries typically look at all firms operating in the economy. In the Irish context we believe that it is important not to aggregate foreign and domestic firms for several reasons. First, as pointed out elsewhere, there are significant differences between foreign and domestic firms with regards to size, market orientation, etc.¹⁵ Second, it is not generally meaningful to try to relate R&D expenditures undertaken by FDI firms in the host country to employment growth in the host country, in the same manner as one might for domestically-owned firms, since FDI firms will typically benefit from current R&D expenditures in the home country or in other host countries¹⁶ and indeed from the firm's world-wide "knowledge stocks".¹⁷ Consequently, in this thesis we look at foreign and indigenous manufacturing industry separately.

The first essay, in Chapter 2, examines the survival and growth of new entrant plants from 1986-1995.¹⁸ Chapter 3 examines the role of R&D in the post-entry survival of indigenous incumbent plants over the period 1986-1996.¹⁹

The third essay (Chapter 4) examines the impact of technological activity on the quantity and quality of labour demand in manufacturing firms.²⁰

¹⁴ According to Forfás, a firm is classified as foreign-owned when 50% + equity is held by non-Irish resident(s).

¹⁵ See Ruane and Görg (1997).

¹⁶ Conversely, the FDI subsidiary may be undertaking R&D in the host country which generates employment in other countries, including the home country, where the company has plants.

¹⁷ This would be particularly the case for many of the major companies investing in Ireland over the past decade, such as Intel, Microsoft, IBM, etc.

¹⁸ A preliminary paper on this topic was awarded the Social Science Research Council research award in 1999 and was subsequently presented at the Irish Economics Association conference in April 2000.

¹⁹ A previous version of this chapter was presented at the Irish Economics Association conference in April 1998.

The final two essays examine the impact of R&D by foreign-owned manufacturing plants in Ireland. Chapter 5 examines the tangible consequences of R&D investment in foreign-owned plants. Specifically, it considers whether R&D active foreign-owned companies operate in Ireland for a longer duration and have a higher quantity and quality of job creation relative to non-R&D active foreign subsidiaries.²¹ Chapter 6 investigates whether there are any productivity spillovers from multinational plants to indigenous plants in Ireland. It concludes with an investigation as to whether there are any R&D productivity spillovers in the Irish case.²²

Each individual chapter contains an appendix including tables, graphs and other appendices referred to in the respective chapter. The final chapter, Chapter 7, presents a brief summary of each chapter, policy implications and issues for further research arising from this thesis.

²⁰ A very preliminary study of labour demand and R&D activity was presented at a conference on "Economic Growth and Employment" held by Statistics Canada, October 1997.

²¹ This chapter is forthcoming in *Research Policy* and was originally presented to the INTECH "Industrial Structure, Innovation Dynamics and Technology Policy" conference held in Lisbon, October 1998.

²² A very preliminary version of this chapter was presented to the Irish Economics Association conference in April 1999.

1.A Tables

Table 1.1: International Comparisons of Employment Growth in Manufacturing Sectors, 1977-1997

Country	Manufacturing Employment 1977 (000's)	Manufacturing Employment 1997 (000's)	Percentage Change 1977-1997
Ireland	226	274	21.2%
Portugal	918	982	7.0%
Netherlands	1,092	1,094	0.2%
Denmark	546	513	-6.0%
Greece ¹	633	576	-9.0%
Italy	5,441	4,548	-16.4%
Germany	11,369	9,000	-20.8%
Spain	3,192	2,432	-23.8%
Belgium ¹	1,007	683	-32.2%
United Kingdom	7,461	4,990	-33.1%
European Countries Total	31,885	25,092	-21.3%
Canada	1,951	2,167	11.1%
Japan	13,400	14,420	7.6%
USA	20,889	20,835	-0.3%

Source: OECD (1999).

Note: ¹ Latest Figures Available 1996.

² No figures available for France post-1989 and no comparable figures available for Luxembourg. Therefore both of these countries are omitted from this table.

Table 1.2: International Comparisons of Business Expenditure on Research and Development as a percentage of GDP, 1982-1997

Country / Organisation	1982	1988	1991	1993	1995	1997
Ireland	0.32	0.47	0.63	0.82	0.99	1.11
EU Average	1.10	1.28	1.23	1.17	1.14	1.15
OECD Average	1.48	1.60	1.58	1.46	1.46	1.49

Source: Forfás (1995) for data 1982-1991; Forfás (1999) for data 1993-1997.

Table 1.3: BERD as a percentage of Gross Expenditure on Research and Development (GERD), 1997

Country	BERD as a % of GDP	BERD as a % of GERD
France	1.38	61
Denmark	1.26	63
United Kingdom	1.26	65
Ireland	1.11	74
Netherlands	1.10	53
Belgium	1.07	67
Canada	1.03	63
OECD average	1.49	68
EU average	1.15	62

Source: Forfás (1999, p.23).

Table 1.4: The percentage of BERD financed by Government, 1991 and 1997

Country	% BERD financed by Government 1991	% BERD financed by Government 1997
France	22.3	13.1
Denmark	7.9	5.1
United Kingdom	14.6	9.5
Ireland	3.7	5.3
Netherlands	7.5	5.6
Belgium	7.8	4.4
Canada	9.8	7.0
OECD average	14.9	10.7
EU average	13.4	9.6

Source: Forfás (1999, p.24).

CHAPTER 2

DOES INVESTMENT IN INNOVATION IMPROVE THE SURVIVAL AND GROWTH OF INDIGENOUS NEW ENTRANT PLANTS?

2.1 Introduction

Since 1991, employment in indigenous manufacturing plants in Ireland has increased by almost 16 per cent to approximately 127,500 employees. This overall increase was determined in part by an underlying process of plant entry and exit. Over the period some 2,020 plants closed with the loss of over 34,000 jobs while simultaneously 2,205 plants entered with the creation of over 33,000 jobs.²³ In 1998, over 6 per cent of the operating indigenous plants had entered in the previous year and already accounted for nearly 4 per cent of total manufacturing employment (CSO, 2000b). If previous experience prevails, approximately 10 per cent of this cohort of new entrants will exit each year in the first three years after 1998. Within seven years fifty per cent of the cohort will have exited.²⁴

Geroski (1991, p.31) describes the consequences of most entry, "*[l]ife in the bottom end of the industry size distribution is, no doubt, nasty, brutish and short. To reach a position remotely comparable to the mean sized firm...requires a relatively long and highly risky expansion programme that most entrants quite simply fail to achieve.*"

Over fifty per cent of new indigenous plants enter the Irish manufacturing sector at

²³ See the annual *Census of Industrial Production* (published by the Central Statistics Office) for the years 1991 to 1998.

twenty per cent or less of minimum efficient scale (MES), where MES is a measure of the average scale of output per plant in the sector.²⁵ Since empirical evidence suggests that the probability of survival of any plant is increasing in its initial size,²⁶ the probability of post-entry survival and growth appears bleak for the majority of new entrant plants in Ireland. Several studies have attempted to explain the persistent survival and subsequent growth of new entrant plants as a vector of plant level, sectoral and macroeconomic characteristics (Audretsch 1991, 1995; Audretsch and Mahmood, 1995; Walsh, 2000). Specifically, many of these studies question whether it is realistic to expect a plant that enters at a relatively small scale to survive and grow subsequently.

Brock (1983) suggests that the role of innovation in new entrants is important in offsetting any initial size disadvantage and Acs and Audretsch (1990, p.74) argue that *"...innovative activity may be the single most significant strategic instrument available to small firms in compensating for size related cost disadvantages..."*. In this context, Audretsch (1991), Wagner (1994) and Audretsch and Mahmood (1995) estimated the probability of survival of new entrants controlling for the overall innovativeness and R&D intensity (i.e., the innovative environment) of the sector in which new entrants operated. Audretsch (1991) and Wagner (1994) found that the innovative environment has no implications for the new entrant survival rate. In contrast, Audretsch and Mahmood (1995) found that the risk of exit for new entrants was greater in highly innovative environments. All of these studies relied on sectoral rather than plant-level innovation data. Thus it was impossible for the authors to

²⁴ See Table 2.1.

²⁵ Own calculations based on Forfás employment data. See Table 2.2.

²⁶ See Audretsch and Mahmood (1995).

identify the direct contribution of innovative activity to the post-entry performance of an individual new entrant relative to other new entrant plants within the same sector.

The purpose of this chapter is to attempt to fill this gap in the literature. We estimate the post-entry survival and growth of new plants controlling for the presence of innovative activity within the individual plant. Specifically we test the hypothesis introduced by Pakes and Ericson (1989, 1995, 1998), namely, that the investment undertaken by new entrants in innovation creates a learning process that allows them to improve their post-entry probability of survival and growth in contrast with non-innovating new plants.

In Section 2.2 we outline the theoretical debate on the role of innovation in new entrant survival and growth. We link the role of innovation in improving plant performance to that of other plant, sectoral and macroeconomic characteristics. We describe our data sources, our data and our econometric methodology in Section 2.3. The econometric results are presented in Section 2.4, while Section 2.5 contains a brief summary and some conclusions. We find that innovating plants have a higher probability of survival, but having survived, enjoy lower annual growth rates than non-innovators. We suggest though that the major advantage to plants engaging in innovation is that their post-entry growth is not affected by initial entry size. In contrast, we find that the post-entry growth of non-innovating plants is dependent on initial size, i.e., their small initial size could constrain their post-entry growth.

2.2 A Theory of Post-Entry Survival and Growth

The majority of new entrants enter at a small scale and perhaps, most importantly, at a scale well below the minimum efficient scale (MES) of the industry in which they operate.²⁷ Jovanoic (1982) models entry on this small scale as a rational response on the part of new entrants.²⁸ An entrepreneur establishes a firm with some innovative idea that existing firms have not encountered or have encountered and dismissed. However, the entrepreneur has no idea of the true competence of the firm until it is operational. Exogenous factors such as insufficient demand or superior new entrant competitors may impact on the ability of the entrepreneur to succeed. Endogenous factors such as the quality of management employed by the company will also impact on the entrepreneur's success or failure. Jovanoic formalises this process of entry by initially noting that any new entrant faces costs that are randomly different across all new entrant firms. The new entrants know the distribution of the costs prior to entry and only know that their true costs (actual post-entry costs) will be drawn from this distribution. If a firm's true costs are low and its post-entry experience is good, it is likely to survive, and *vice versa*. The central feature of this model is that a new entrant can only have its expected success confirmed post-entry.

While there is a process of learning in Jovanoic's model, the process is restricted to learning about whether the firm is efficient relative to other new entrants. In particular, there appears to be no scope for any new entrant to learn how to change its relative efficiency post-entry in this model. In effect, the firm's probability of survival

²⁷ Own calculations based on Forfás employment data (Table 2.2). Also see Audretsch (1995, p.74).

²⁸ It is argued that new entrants may have no choice but to enter at this relatively small scale, as they face capital constraints and have no reputation on which to raise finance (Brouwer, 1999, p.8) or they enter small as a strategy to avoid the aggressive reaction of existing incumbents (Caves and Porter, 1977).

and its ability to grow to attain the MES of the industry is set forever.²⁹ However, Nelson and Winter (1982) note that many kinds of organisations commit resources to learning, especially attempting to learn from successful competitors. Crucially, they suggest that learning can be broadened beyond the concept of learning described by Jovanoic to include a process whereby the plant learns not only its true post-entry efficiency but also how to improve its relative efficiency. The improvement in efficiency arises from the plant growing and attaining the MES scale of output relatively more quickly than it would otherwise have done. Pakes and Ericson (1989, 1998) extend the Jovanoic model to incorporate strategies pursued by new entrants to accelerate the learning process, such as knowledge creating processes like R&D. They label this alternative model 'active exploration'. This model assumes *"that the firm knows the current value of the parameter that determines the distribution of its profits, but that the value of that profitability parameter changes over time in response to the stochastic outcomes of the firm's own investments, and those of other actors in the same markets"* (Pakes and Ericson, 1998, p.4).

We interpret Audretsch (1991, 1995) as using a reduced form version of the 'active exploration' model to estimate the probability of survival of new entrant firms. Audretsch proposes that the stochastic outcome of the firm's own investment in innovation will determine its survival and growth. The success of growth-inducing activities (i.e., innovation) will encourage the firm to remain in the industry where its low scale relative to MES might otherwise have convinced it to exit. Thus the probability of any firm remaining in business in period t , $\Pr(Q_{it} > 0)$, is determined

²⁹ Pakes and Ericson (1998) describe the Jovanoic model as 'passive learning': *"firms are endowed at birth with an unknown value of a time-invariant profitability parameter which determines the distribution of its profits thereafter. Past profit realisations contain information on the value of the*

by the marginal impact of innovation on growth and the extent to which a firm is burdened by a size disadvantage (size relative to MES)

$$\Pr(Q_{it} > 0) = f(i_{it}, c(Q_{it}) - c(Q^*)) \quad (1)$$

where i_{it} is the marginal impact of innovation on growth, $c(Q_{it})$ is the firm's average cost of producing at a scale of output in period t and $c(Q^*)$ is the average cost of producing at the MES level of output.

The marginal impact of innovation on growth, i_{it} , is a function of both the plant's own investments in R&D, and the innovative environment of the sector in which the plant operates. We expect i_{it} to be increasing unambiguously in the quantity of the plant's own R&D expenditures.

2.3 Data and Estimation

In this chapter, we test the hypothesis that the likelihood of survival and subsequent growth of individual new entrants is dependent on their probability of innovating, while controlling for other plant, industry and macroeconomic characteristics.

parameter which determines the distribution of possible future profit streams, and this fact is used by management to form a probability distribution over future cash flows" (p.4).

2.3.1 Data Sources

The dataset used in this analysis is a unique combination of two sources. The research and development data are drawn from a survey of R&D performing firms, undertaken by the policy and advisory board for industrial development in Ireland (Forfás). These data are the basis of Irish official data on R&D, as released in official publications and sent to the OECD and European Commission. For the years 1986 to 1995, the biannual surveys report data on the population of R&D performers in the manufacturing and internationally traded services sectors. We define an innovative plant as any plant that reported R&D expenditures at least once between 1986 and 1995. The employment data are drawn from the annual employment surveys undertaken by the same agency. We use the annual employment surveys to identify 3,876 new entrants over the period 1985-1995 (i.e., using their first recorded employment to indicate the time of entry). The subsequent employment performance of the plant allows us to quantify its growth and to determine whether the plant remains alive or has closed.³⁰

2.3.2 Description of Variables

The post-entry survival and employment growth performance of all new entrant plants (1985-1995) has been tracked annually from the date of entry until 1996. A plant is deemed to have survived if it is alive in 1996 and exited otherwise. We calculate the growth rate, g_{et} , of each plant as its employment growth rate (Davis *et al.*, 1996, p.189-190). Specifically,

³⁰ It would be preferable to measure the growth of a plant using output rather than employment data as employment growth may reveal the preference of firms for labour relative to capital, energy and other

$$g_{et} = \frac{n_{et} - n_{et-1}}{x_{et}} \quad (2)$$

where n_{et} and n_{et-1} are the employment levels of the plant in time period t and $t-1$ respectively and where

$$x_{et} = \frac{n_{et} + n_{et-1}}{2} \quad (3)$$

is the average employment size of the plant in both periods. The measure is symmetric about zero and lies in the closed interval $[-2, 2]$. A value of -2 indicates that the plant has ceased to exist and a value of 2 captures the birth of a plant.

As noted earlier, we model the survival and growth of new entrants as determined by the plant's innovative activity and by other plant, sectoral and macroeconomic characteristics.³¹

Innovative Activity: We proxy innovative activity at individual firm level using a dummy variable for the firm's research and development expenditures; this dummy variable assumes a value of 1 if the new entrant invested any positive amount in R&D over the period 1986-1995.³² We denote these plants as R&D active new entrant plants. This definition classifies 305 new entrants as R&D active and 3,469 plants as

inputs in the production process. However, the data available at firm-level relate to employment data only.

³¹ See Table A2.2 for summary statistics.

³² We adopt this lenient definition of an R&D active plant because (i) plants with small R&D expenditures may not consistently have been recorded in every survey and (ii) new entrant plants cannot be expected to satisfy the criteria used elsewhere in this thesis of a mean annual investment in

non-R&D active over the period 1985-1995. In this way we extend the Audretsch (1991) and Audretsch and Mahmood (1995) studies which were unable to distinguish the innovative activities of individual new entrants within a sector. We expect the probability of survival and the year-to-year employment growth rate to be greater for innovating (R&D active) relative to non-innovating (non-R&D active) new entrants within a sector. As outlined in Section 2.2, the process of innovating may allow new entrants to offset any disadvantages that arise from their small scale entry or intense competition from other non-innovating plants.

Plant Characteristics: We measure the initial size of an entrant in terms of its first recorded employment size relative to the MES in that year at the 3-digit NACE sectoral level.³³ We calculate a conservative estimate of MES for each of the eighty five sectors using employment data. In the spirit of Sutton (1991, p. 96) the MES of any sector at time t is the mean employment size of all plants alive at $t-1$ in each industry. We expect the probability of survival of new entrants to be greater the larger their scale of entry relative to MES. Storey and Wynarczyk (1996, p.1) argue that “*it is the much higher likelihood of death that, other than size per se, is the main feature that distinguishes small from large firms.*” A relatively larger firm may be more technically efficient and, as Nas and Lappalahti (1997) suggest, may have adequate size to consider downsizing before considering exiting in the face of an economic downturn. Small firms have no option to downsize and are immediately faced with the

R&D of £100,000 to be classified as R&D active. See Baldwin (1997) for a discussion of innovative small firms that are and are not engaged in R&D.

³³ It is questionable whether a firm arrives at its planned level of employment in its first calendar year of operations. It could be suggested that the process of birth for the plant takes 2 or 3 years, in which case the initial size of the firm should be measured at the end of year 2 or 3. However, we continue to measure the employment size in the first calendar year because of the difficulty in determining which plants arrive at their planned level of employment in year 1, 2 or beyond.

decision to exit. This relationship may be non-linear and to capture this we also include the squared value of the ratio of initial size to MES.

We include the annual age of the plants from the year of initial entry to 1996 in order to control for life-cycle effects. The probability of survival has been found to increase with age. As time passes surviving plants lose their 'liability of newness' because they benefit from increasing experience in the market place (Jovanoic, 1982; Hannan and Carroll, 1992; Majumdar, 1997). In similar fashion to initial size, this relationship may not be linear. To control for the plant life-cycle we include the annual age of the plant and this value squared to account for any non-linear relationship.

Industry Characteristics: We expect the probability of survival and growth to be greater for those new entrant plants that have entered growing (expanding) sectors, on the grounds that these expanding sectors may be expected to have higher price-cost margins that allow inefficient firms to remain profitable. In slow growing industries, where competition between plants may be more intense, we would expect a relatively higher exit rate among relatively less efficient firms (Audretsch and Mahmood, 1995; Walsh and Konings, 1997). Therefore we control for the industry growth rate. We calculate this as the percentage change in absolute employment in each of eighty five 3-digit NACE industries over the period 1985-1996.

Agarwal and Gort (1996) propose that the stage of evolution of a market is important for the survival of new entrant plants. They argue that the rate of growth in industry demand and the MES of the industry will change as a market evolves from infancy to maturity. In infancy an industry has a handful of sellers and as the market evolves

there is a period of high net entry. Eventually as the market matures the entry rate falls and there is net exit. Plants that enter during this latter stage exhibit higher probabilities of survival relative to plants that entered in the infancy of the market. Agarwal and Gort explain this apparent paradox (p.495) by noting that entrants which commence production during a period of net exit in a market must have superior initial endowments relative to firms that entered at any other stage. These later entrants are aware that the market is experiencing net exit and that competition within the market is consequently at its most intense. Thus entry tends only to be attractive to above average entrants. We include the annual birth rate and the annual plant turnover rate in eighty five 3-digit NACE industries to control for the stage of market evolution.³⁴

Macroeconomic Characteristics: We control for the likely effects of the business cycle by including time dummies.

2.3.3 Econometric Methodology

We model the annual employment growth rates of all new entrant plants from their date of entry to 1996 as determined by plant, sectoral and macroeconomic characteristics. Our dataset of new entrants is an unbalanced panel where new entrants enter and exit at different times. Sample selection bias, where a new entrant plant is incompletely observed for the full period (1985-1996) because of an endogenous reason, potentially poses serious problems for panel data estimators. Specifically, Verbeek (2000, p.345) concludes that while the fixed effects estimator may be

³⁴The annual entry rate is calculated as the number of plants that enter at time t divided by the average number of plants in the sector in t and $t-1$. The plant turnover rate is calculated as the number of plants

relatively more robust against selection bias than the random effects estimator, sample selection bias can render the fixed effects estimator inconsistent and the random effects estimator both biased and inconsistent.

We therefore use the Heckman (1979) two-step (probit/OLS) regression which estimates post-entry growth conditional on the probability of survival. This estimator controls for sample selection bias. Following the Heckman procedure we identify a list of variables thought to determine whether the dependent variable (i.e., growth rate) in the OLS equation is observed (i.e., the plant survived until 1996) or missing (i.e., the plant died prior to 1996). This equation takes the form of a probit regression. The dependent variable is 1 if the plant survived until 1996 and facilitated the recording of growth rates, and zero if the plant died prior to 1996. The second equation is an OLS regression which estimates the post-entry growth rate of plants conditional on their probabilities of survival estimated in the probit regression.

2.4 Empirical Results

2.4.1 Innovation, Survival and Growth

The results of the probit regression can be read from the top half of Table 2.3. The probability of survival for new entrant plants initially decreases with age at a diminishing rate. The sign of this coefficient is contrary to the expectation that the probability of a plant surviving is increasing in the amount of experience it has in the marketplace. Our results are opposite to those estimated for Audretsch (1991) and Audretsch and Mahmood (1995). This difference may be explained by the use of a

that enter and exit between $t-1$ and t divided by the average number of plants in the sector in t and $t-1$.

probit estimator to estimate the survival of the plant rather than a Cox duration (1972, 1975) model that takes into account duration heterogeneity (i.e., differences in the length of time a plant survives).

The greater the initial size of a plant relative to the MES of the sector in which it operates, the greater the probability of survival. As noted earlier, Audretsch (1991, 1995) modelled the survival of new entrant plants as depending in large part on the magnitude of the size disadvantage they faced. Our finding supports Audretsch's (1991, 1995) opinion that the small size of many new entrants may be problematic for their successful post-entry survival. In similar fashion to the life cycle effect the relationship is non-linear and the probability of survival increases at a diminishing rate.

The probability of survival of a new entrant plant is decreasing in the level of entry into the sector and increasing in the level of plant turnover. This latter finding supports the suggestion of Agarwal and Gorts' (1996), that plants which enter during periods of net exit are generally superior plants which have greater capabilities than plants which entered during a period of net entry.

We find that a new entrant has a greater chance of surviving the higher are industry growth rates. This estimate confirms Audretsch's (1995, p.162) expectation that low sectoral growth rates raise the share of exiting plants accounted for by new entrants.

See Davis & Haltiwanger (1990).

Finally, it is estimated that innovating plants have a superior probability of survival relative to non-innovating plants. We are not aware of any other studies linking new entrant plant's innovative activities and subsequent survival using plant level data. The relatively greater probability of survival estimated for innovating new entrants is similar to results found for incumbent Irish firms.³⁵

In the bottom half of Table 2.3 we present the coefficients of the explanatory variables of employment growth in new entrant plants that entered over the period 1985-1995.³⁶ These OLS coefficients are computed conditional on the probabilities of survival estimated in the probit regression.³⁷ Growth is initially decreasing in age but at a diminishing rate. Unexpectedly, new plants operating in high growth industries have lower growth rates where as we might have expected faster growing industries to offer the best chance to new firms to increase their market shares. The smaller the initial size of the plant relative to MES, the greater the growth rate. The sign of the coefficient of size/MES squared confirms that this is non-linear. We estimate that growth is now increasing in the entry rate into the sector. Finally, we find that non-innovating new entrants grow faster.

The major result of this analysis is that innovating plants have a higher probability of survival, but having survived, enjoy lower annual growth rates than non-innovators. While this result seems paradoxical, there is one obvious possible explanation. It may be that employment growth is a very inadequate measure of a plant's growth rate. It is reported that innovative companies generally exhibit higher profits (Geroski, 1994;

³⁵ This result is derived in Chapter 3.

³⁶ The reader is encouraged to compare the following coefficients with an ordinary OLS regression that suffers from sample selection bias. The results of the ordinary OLS are presented in Table A2.1. The sign, magnitude and significance of many of the variables are different.

Nas and Lappalahti, 1997) and relatively higher turnover and real export growth (Roper *et al.*, 1996) relative to less innovative plants. Thus innovating new entrants may have superior market share, profits or turnover growth that is not reflected in their employment levels. In a different context,³⁸ Blechinger *et al.* (1997, p.50) note a characteristic unique to small firms that they “*operate at a level at which additional output can be produced with less additional labour and/or capital.*” Therefore it is possible that innovating plants in our sample are growing relatively quickly, however it is a growth performance that is reflected in sales or profits and not increased labour demand.

2.4.2 Active vs. Passive Learning

It is not clear that tracking annual growth captures the sole advantage of innovating new entrants over non-innovators. Pakes and Ericson (1989, 1998) suggest that another real advantage for an innovating plant is its ability to 'actively learn' to overcome its initial entry size as a constraining influence on its future growth. Pakes and Ericson (1998) suggest an empirical regularity that allows us to distinguish between their concept of 'active learning' and 'passive learning'. If a new entrant plant engages in 'passive learning', its growth experience will be dependent on its initial conditions (i.e., its initial size). As outlined earlier the presence of innovative activity within the plant is interpreted as 'active learning' - an attempt by the new entrant plant not only to learn about its relative efficiency compared to other entrants (passive learning) but to seek to improve its relative efficiency. Pakes and Ericson (1998, p.37) note that “*the distinction [between active learning and passive learning stories] can*

³⁷ The sectoral variable ‘plant turnover’ has been omitted from the OLS equation.

³⁸ Blechinger *et al.* (1997) were seeking to explain why the elasticity of labour demand with respect to employment differed across European countries.

be taken to data (sic) by examining the regression function of current size on immediate past sizes and initial size. Both models imply that this regression function should be weakly increasing in initial size, but the passive learning model implies that it should be strictly increasing in that variable, while the active learning model implies that it need not be." The prediction of the active learning model is very powerful. Such an active learning plant can enter substantially below MES without this initial small size impacting adversely on its future growth.

To test this hypothesis, we estimate the regression function of annual employment growth on initial size relative to MES, controlling for other plant, sectoral and macroeconomic characteristics.³⁹ The function is estimated again using the two-stage Heckman (1979) estimator. We divide our plants into two cohorts, innovating and non-innovating new entrants, to test for the predicted consequences of 'active learning' and 'passive learning' in new entrants. In this way, we test for 'active learning' in innovating plants and 'passive learning' in non-innovating new entrants.

The post-entry growth of innovating plants can be characterised by 'active learning' if their post-entry growth does not depend on initial size relative to MES. There is evidence of two distinct types of learning between innovative and non-innovative new entrants respectively. The initial size of new entrants relative to their MES is insignificant in explaining the growth of innovative new entrants (Table 2.4). In the

³⁹ This is a similar specification to the regression suggested originally by Pakes and Ericson (1998). We model employment growth on initial size rather than current plant size on past sizes and initial size (as suggested by Pakes and Ericson). We altered the specification in this manner because Pakes and Ericsons' original specification involved panel data estimation with lagged dependent variables. This requires general method of moments (GMM) estimation. However we were unable to control for sample selection bias while also using the GMM estimator. Our suggested specification of employment growth on initial size can be estimated using the Heckman (1979) estimator that also controls for sample selection bias.

spirit of Pakes and Ericson (1998) this suggests that innovative activity is indeed an indicator of 'active learning' in these plants. In addition, we test for the presence of 'passive learning' and estimate the model for non-innovating new entrants only. In contrast, for non-innovators, growth is negatively related, at a diminishing rate, to initial size relative to MES (Table 2.5). Therefore, current employment growth is dependent on initial size for non-innovating new entrant plants. In the spirit of Pakes and Ericson (1998) this suggests that non-innovating new entrants may be passive learners. Their current growth is significantly dependent on initial size relative to MES. In contrast with innovating plants, non-innovating plants have not invested in research and development / innovation and consequently have not learned to break the link between their post-entry growth and initial entry size.

2.5 Summary and Conclusions

This chapter has added to a range of previous studies on innovation and new entrant plants (Audretsch, 1991; Audretsch and Mahmood, 1995) by using plant level data to determine the impact of innovation within an individual new entrant on its subsequent survival and growth. We estimated the survival and growth of over 3,500 new entrant plants (1985-1995) in the Irish manufacturing sector using plant level data. We add to the range of previous studies by accounting for innovative activity at the level of the individual plant rather than at sectoral level.

We found that innovative activity increases the probability of survival but not the post-entry growth rate of a new plant. Specifically, innovating plants have a relatively higher probability of survival, but having survived, enjoy lower annual growth rates relative to surviving non-innovators. We suggest that this apparently paradoxical

result may be the outcome of measuring post-entry growth using employment data, and that if post-entry performance were measured in terms of value-added, sales or profits, a different result might pertain. Unfortunately, our data do not allow us to undertake such an analysis.

Over fifty per cent of new indigenous plants enter the manufacturing sector at less than 20 per cent of minimum efficient scale. Consequently the prospects for post-entry survival and growth may be bleak for many of these relatively small firms. In this context we suggest that the major advantage of innovating new entrant plants is that their post-entry growth does not depend as critically on their small initial entry size. In contrast, the post-entry growth of non-innovating plants is found to be dependent on initial entry size. This may be evidence of 'active learning' occurring in innovative new entrants and 'passive learning' occurring in non-innovating plants (Pakes and Ericson 1989, 1998). Innovating new entrants 'actively learn' how to improve their post-entry growth and survival. In this way, their growth becomes less dependent on their initial size. By contrast, non-innovating plants by definition do not invest in such learning and therefore their post-entry growth remains dependent on their initial small size.

2.A Tables

Table 2.1: A Life-Table¹ Analysis of New Entrant Plants, 1981-1996

Time Survived	Probability of Surviving
Year 1	90.9
Year 2	81.2
Year 3	72.3
Year 4	65.0
Year 5	58.9
Year 6	54.6
Year 7	50.2
Year 8	47.0
Year 9	43.8
Year 10	41.4
Year 11	39.2
Year 12	37.7
Year 13	36.3
Year 14	35.4
Year 15	33.9
Year 16	33.9

Source: Own calculations based on *Forfás* data.

Note: ¹These are the results of a lifetable analysis of 5,790 indigenous plants that entered the manufacturing sector between 1981 and 1996. It shows the probability of a new entrant surviving a given time period. For example, the probability of surviving 1 year is nearly 91 per cent and almost 34 per cent to survive 16 years.

Table 2.2: A Classification of New Entrant Plants: Initial Size relative to Minimum Efficient Scale, 1981-1996²

Initial Size / MES (%)	Number of New Entrant Plants	% of all New Entrant Plants in this Initial Size/MES Category
0-9 %	1,618	28 %
10-19 %	1,401	24 %
20-29 %	730	13 %
30-39 %	514	9 %
40-49 %	338	6 %
50-59 %	201	4 %
60-69 %	143	2 %
70-79 %	122	2 %
80-89 %	91	2 %
90-99 %	83	1 %
100% +	488	9 %
Total	5,729	100%

Source: Own calculations based on *Forfäs* data.

Note: ² Initial size is first recorded employment size. MES of each 3-digit sector is the mean employment of all plants alive in previous year.

Table 2.3: Regression Results for Heckman Two Step Regression: *All New Entrant Plants*

Dependent Variable: Annual Employment Growth	Coefficients	(Standard errors)
Probit:		
Age_{it}	-.191 ***	(.011)
Age^2_{it}	.006 ***	(.001)
$(Size/MES)_i$	.116 ***	(.017)
$(Size/MES)^2_i$	-.013 ***	(.002)
$EntryRate_{jt}$	-2.393 ***	(.164)
$IndustryGrowth_{jt}$	.001 ***	(.000)
$PlantTurnover_{jt}$	1.476 ***	(.124)
$Innovator_i$	.906 ***	(.028)
Time Dummies	Yes	
OLS:		
Age_{it}	-.541 ***	(.008)
Age^2_{it}	.041 ***	(.001)
$(Size/MES)_i$	-.086 ***	(.012)
$(Size/MES)^2_i$	.008 ***	(.002)
$EntryRate_{jt}$	.919 ***	(.085)
$IndustryGrowth_{jt}$	-.001 ***	(.000)
$Innovator_i$	-.349 ***	(.017)
Time Dummies	Yes	
No. of Observations ^a	29,926	
athro	-1.681 ***	(.027)
Insigma	-.315 ***	(.009)
Rho	-.933	
Sigma	.730	
lambda	-.681	
χ^2	4222.94	
$Pr > \chi^2$	0.0000	
Log Likelihood	-28577.09	

Note: ^a This is the total number of observations entered at the probit stage. A smaller number of observations appears at the OLS stage.

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table 2.4: Regression Results for Heckman Two Step Regression: *Innovating New Entrant Plants*

Dependent Variable: Annual Employment Growth	Coefficients	(Standard errors)
Probit:		
Age_{it}	-.178 ***	(.041)
Age^2_{it}	.007 *	(.004)
$(Size/MES)_i$	-.200 ***	(.051)
$(Size/MES)^2_i$	.026 ***	(.009)
$EntryRate_{jt}$	.054	(.702)
$IndustryGrowth_{jt}$	.001 **	(.001)
$PlantTurnover_{jt}$	-.684	(.556)
Time Dummies	Yes	
OLS:		
Age_{it}	-.521 ***	(.016)
Age^2_{it}	.035 ***	(.001)
$(Size/MES)_i$	-.013	(.017)
$(Size/MES)^2_i$	-.001	(.002)
$EntryRate_{jt}$	.644 ***	(.186)
$IndustryGrowth_{jt}$	-.000	(.017)
Time Dummies	Yes	
No. of Observations ^a	2,627	
athro	-1.642 ***	(.070)
Insigma	-.662 ***	(.018)
Rho	-.928	
Sigma	.516	
lambda	-.479	
χ^2	191.65	
$Pr > \chi^2$	0.0000	
Log Likelihood	-2353.91	

Note: ^a This is the total number of observations entered at the probit stage. A smaller number of observations entered the OLS stage.
 *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table 2.5: Regression Results for Heckman Two Step Regression: *Non-Innovating New Entrant Plants*

Dependent Variable: Annual Employment Growth	Coefficients	(Standard errors)
Probit:		
Age_{it}	-1.847 ***	(.011)
Age^2_{it}	.005 ***	(.001)
$(Size/MES)_i$	.172 ***	(.019)
$(Size/MES)^2_i$	-.018 ***	(.003)
$EntryRate_{jt}$	-2.408 ***	(.166)
$IndustryGrowth_{jt}$	.001 ***	(.000)
$PlantTurnover_{jt}$	1.465 ***	(.123)
Time Dummies	Yes	
OLS:		
Age_{it}	-.542 ***	(.009)
Age^2_{it}	.041 ***	(.001)
$(Size/MES)_i$	-.124 ***	(.015)
$(Size/MES)^2_i$	.012 ***	(.002)
$EntryRate_{jt}$	.968 ***	(.095)
$IndustryGrowth_{jt}$	-.001 ***	(.000)
Time Dummies	Yes	
No. of Observations ^a	27,299	
athro	-1.789	(.000)
Insigma	-.243	(.010)
Rho	-0.946	
Sigma	.785	
lambda	-.742	
χ^2	2869.05	
$Pr > \chi^2$	0.0000	
Log Likelihood	-25920.07	

Note: ^a This is the total number of observations entered at the probit stage. A smaller number of observations entered the OLS stage.

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

2.B Appendices

Appendix A

Table A2.1: Regression Results for OLS Estimation of Non-Failing New Entrant Plants assuming Random Selection, 1985-1996

OLS:	Coefficients	(Standard errors)
Age_{it}	-.583 ***	(.007)
Age^2_{it}	.041 ***	(.001)
$(Size/MES)_i$	-.037 ***	(.010)
$(Size/MES)^2_i$	.002	(.001)
$EntryRate_{jt}$	.573 ***	(.085)
$IndustryGrowth_{jt}$	-.000	(.000)
$Innovator_i$	.090 ***	(.011)
Time Dummies	Yes	
R^2	.549	
No. of Observations	13,852	

Note: *** significant at the 1% level.
Heteroskedastic consistent standard errors.

Table A2.2: Descriptive Statistics for Econometric Estimation

Variable	Obs	Mean	Std. Dev.	Min	Max
Age_{it}	29933	5.097184	3.030428	1	12
Age^2_{it}	29933	35.16447	35.76925	1	144
$IndustryGrowth_{jt}$	29933	21.63017	67.37141	-98	480
$(Size/MES)_i$	29933	.4062374	.7660534	0	16.8
$(Size/MES)^2_i$	29933	.751365	5.447844	0	282.2 4
$EntryRate_{jt}$	29933	.0677132	.0729527	0	1.286
$PlantTurnover_{jt}$	29933	-.0110824	.0850767	-1	1.143
$Innovator_i$	29933	.0877627	.2829542	0	1

Source: Own estimations.
Note: Number of observations is the number of plants * number of years that we observed the plant.

CHAPTER 3

THE POST-ENTRY SURVIVAL OF INDIGENOUS PLANTS: DOES A PLANT'S TECHNOLOGICAL ACTIVITY MATTER?

3.1 Introduction

Over the period 1991-1998, 2,020 indigenous plants exited the Irish manufacturing sector with the loss of almost 35,000 jobs. On average, 7.5 per cent of indigenous plants exited each year with over 4 per cent of manufacturing employment being destroyed as a result.⁴⁰ The magnitude of the job destruction is even more striking when compared against the level of job creation over the same period. Between 1991 and 1998 new entrant firms created almost 34,000 jobs while exiting firms simultaneously destroyed almost 35,000.⁴¹ It would appear that for every new job created over this period another job was destroyed as a consequence of exiting firms. The question arises as to what extent the survival of these indigenous firms varies with their individual characteristics and specifically to what extent investment in research and development (R&D) has altered the probability of survival of individual plants?

The exploration of the role of firm level technological activity⁴² and subsequent survival is a hybrid of two literature traditions. The first of these relates to the determinants of survival itself. For example, in empirical studies, the probability of survival of a plant has been found to increase with the size of the firm (Evans, 1987),

⁴⁰ See Table 3.1.

⁴¹ See Table 3.2.

the age of the firm (Dunne *et al.*, 1989), the lower the rate of entry into the industry (Siegfried, 1992), and the greater the growth rate of the industry in which the plant operates (Audretsch and Mahmood, 1995).

The second of these traditions started with Winter (1984), who focused on the issue of the survival of new entrants relative to incumbent plants. He postulated that the probability of survival of new entrant firms relative to incumbent firms in an industry, depended on which group controlled the technological development and future of that industry. Where incumbent firms were responsible for the majority of innovations in an industry, they had a relatively higher probability of survival than new entrant firms. Sutton (1991) used the theory of endogenous sunk costs to explain how incumbent firms could improve their probabilities of survival by controlling the technological environment. His theoretical analysis showed that by investing in R&D, incumbent firms increased the minimum efficient scale (MES) of the industry, which decreased the probability of growth and survival of new entrant firms. Audretsch (1991, 1995) and Audretsch and Mahmood (1995) used technological dominance to explain variations in the survival of new entrant firms in the United States. They found that control of the technological environment was empirically important in improving the probability of survival of new entrant firms and by inference decreasing the probability of survival of incumbent firms. Walsh and Konings (1997) applied a variation of this analysis to Ireland. They used a dichotomous variable to describe which subsectors in the Irish manufacturing sector were relatively more or less R&D intensive. They concluded that indigenous plants in R&D intensive industries had lower probabilities of exit relative to indigenous plants in less R&D

⁴² In this chapter we use the terms technological activity and R&D activity interchangeably.

intensive sectors. We are not aware of any studies that has related the survival of an individual plant to the scale of its own R&D investment.

In this chapter we examine the determinants of the probability of survival of *indigenous incumbent* plants in the Irish manufacturing sector. We limit our study to *indigenous* plants because we are concerned with the link between R&D behaviour at plant level and the survival of the firm. In the majority of indigenous cases this link is present as the plant is the firm, in contrast with the foreign-owned sector in Ireland where all plants are subsidiaries.⁴³ We focus on *incumbent* plants because we believe that R&D investment may have very different consequences for new entrant and incumbent firms. Specifically, we suggested in Chapter 1 that R&D investment by new entrants may compensate for a small initial entry size. Invoking endogenous sunk cost theory, we suggest for incumbent firms that the issue may be more about increasing the MES in the sector as a means to increasing its probability of survival relative to other incumbents and new entrants.

In the analysis we use plant-level technological data rather than sectoral level data to explore this relationship. We estimate two models of the probability of survival; a logit model and a Cox duration model. We estimate the survival experience of a cohort of indigenous incumbent plants (1986-1996) as a function of their technological activity and other plant and industry characteristics. We find that technological activity has a positive influence on a plant's probability of survival. This conclusion is robust to several different measures of a plant's technological activity: scale of R&D activity, R&D intensity and sales of innovative products. We find that

plant size and the extent of new firm entry into an industry are also important determinants of an incumbent plant's probability of survival.

In Section 3.2 we outline sectoral patterns of firm survival. A theory of plant level technological activity and superior probabilities of survival is developed in Section 3.3. Section 3.4 presents the results of a logit model that seeks to explain variations in the survival rates between firms. The results of a Cox duration model that takes account of the limitations of this logit model are presented in Section 3.5. The final section contains some conclusions.

3.2 Sectoral Patterns of Firm Survival

The survival rates of a cohort of plants⁴⁴ over the period 1986-1996 are shown in Table 3.3. The overall percentage of 2,114 plants that survive the eleven years is 69 per cent. We can disaggregate further and explore the survival rates of plants in the high-tech relative to the low-tech sector.⁴⁵ The high-tech (low-tech) sector contains high (low) R&D intensive sectors according to the OECD classification. The probability of a plant surviving the period 1986-1996 in the high-tech sector is 73.04 per cent, compared with the corresponding probability for plants in the low-tech sector of 68.35 per cent.⁴⁶ While at this aggregate level, there is a suggestion that

⁴³ Dunne *et al.* (1989) concluded that the survival experiences of a subsidiary plant will be different to that of a single plant firm. The continuing survival of a subsidiary plant will be influenced by political decisions as well as economic performance.

⁴⁴ This cohort of 2,114 indigenous plants includes all plants with ten or more employees and are three or more years of age in 1986.

⁴⁵ We have adapted the OECD classification of high-tech, medium-high, medium-low and low-tech into two sectors. High tech is the aggregation of high and medium high-tech. The low-tech sector is the aggregation of medium-low and low-tech. The OECD classification is set out in Table 3.3.

⁴⁶ These probabilities have been estimated using life-table analysis. Life-table analysis is a technique which permits the estimation of the probability of an event (exit) occurring at different time (years) points. It allows for the fact that not all plants will have exited during the period of observation. Life-table analysis allows a cohort to be distinguished by one characteristic only and the differing probabilities to be estimated for each group. A Wilcoxon(Gehan) test for equality of the estimated

plants in an R&D intensive industry have a higher probability of survival (a similar result to that estimated by Walsh and Konings, 1997), this difference is not statistically significant when we disaggregate further into the individual subsectors. There is an enormous variation in the probabilities of survival between these subsectors, as evident in Table 3.3.⁴⁷ The range of probabilities in those subsectors in the high-tech sector is from 50.00 per cent to 82.61 per cent. Similarly in those subsectors which comprise the low-tech sector, the range of probabilities of survival is from 43.42 per cent to 88.89 per cent. How do we account for this variation in survival rates between subsectors that are classified as having the same level of technological sophistication?⁴⁸ Audretsch and Mahmood (1995) in a study of the variations of survival rates among new entrant plants emphasise the importance of plant characteristics. It is the central hypothesis of this chapter that the overall classification of sectors cannot explain survival rates and that the presence or absence of research and development spend in an individual plant should be taken into account.

We divide our cohort into R&D spenders and non-R&D spenders to conduct a life-table analysis. This analysis will provide us with the estimated probabilities of survival for both groups over the period 1986-1996. In Figure 3.1 we have graphed both survivor functions. The probability of survival for the R&D spending plants exceeds that of the non-R&D spending plants at every point in time 1986-1996. The probability of an R&D spending plant surviving ten years after 1986 at 85.96 per cent, is significantly higher than the corresponding estimate for non-R&D spending plants

probabilities of survival should be undertaken. In this case the different probabilities of survival for the high-tech and low-tech sectors are statistically insignificant at the 10% level (probability=.130).

⁴⁷ We disaggregate into the OECD 24 industrial subsectors.

of 66.36 per cent.⁴⁹ Why could we expect *ex ante*, that R&D spending plants would have a higher probability of survival relative to non-R&D spending plants?

3.3 Theory of Technological Activity and Survival

We take a simple approach to modelling the probability of survival of an individual plant. We adapt a model first introduced by Audretsch (1991) and later developed by Audretsch and Mahmood (1995). These authors tested the hypothesis that the probability of any given firm j , of age t , remaining in industry i , $\Pr(Y_{it}^j > 0)$, is a function of the technological regime in the industry in addition to traditional industry and plant characteristics. The technological regime in an industry defines industries according to whether the majority of innovations are produced by incumbent firms or new entrant firms. We consider a model below where plant level technological activity rather than the industry's technological regime is a determinant of the probability of survival.

Successful innovative activity is the means by which firms grow and prosper. Audretsch (1991) justifies the inclusion of the probability of innovative activity as a determinant of the survival of new entrant firms because innovative activity is the means by which new firms grow and attain the industry minimum efficient scale. A simple theory of the costs of production justifies this approach. A new entrant ignores its fixed costs in the short run and increases its output as long as its price is greater than average variable cost. However as a firm undergoes the transition from a new entrant to a young incumbent, it must consider payment of its fixed costs, as price

⁴⁸ High-tech and low-tech represent two differing levels of technological sophistication. All subsectors in each of these sectors by definition have the same level of technological sophistication.

must cover average cost in the long run. We hypothesise that growth in profitability (π) for a given scale of output becomes relatively more important a consideration than increasing scale. In this instance the probability of survival of an incumbent firm j , of age t , in industry i is determined by its current and expected profitability. The more profitable that the firm is, the greater its probability of survival:

$$Pr(Y_{it}^j > 0) = f(\pi_{it}^j) \quad (1)$$

We can think of Equation 1 as a model of income choice in the tradition of Knight (1971).⁵⁰ Therefore we consider that the probability that a firm will decide to remain in the industry is increasing in the level of profitability the firm currently enjoys.

In turn, profitability is determined by the price-cost margin that the firm earns which in turn depends on market size and the number of firms in the industry. If we assume that the firms are Cournot quantity setters and they compete in homogeneous products, a typical profit function for a firm j of age t in industry i can be written as

$$\pi_{it}^j = b \left[\frac{S}{2 + (n-1)} \right]^2 \quad (2)$$

⁴⁹ The Wilcoxon (Gehan) test shows that these different survivor functions are statistically different at the 1% level. (Prob. .0000)

⁵⁰ Jovanoic (1994) and Blanchflower and Meyer (1994) have used a model of income choice to interpret the decision of an individual to start a new firm or become the employee of an existing firm. The probability of an individual starting a new firm is greater when the gap between the expected profits from being an entrepreneur exceed the expected wage they would receive as an employee. In Equation 1 we are reversing this decision process. A firm has a current level of profitability. This is to be benchmarked against the next best income choice facing the owners if they applied their resources outside the industry.

where π_{it}^j are the profits earned by this firm, S is the size of the market and n is the number of firms in the marketplace. In this case if we consider Equation 2 along with Equation 1, the probability of survival of this firm depends on the number of firms in the industry because for a given market size, the number of firms in the industry determines the profits earned by the firm.

An extension to the standard Cournot result presented in Equation 2 is to allow for differentiated products.⁵¹ One firm j differentiates its products relative to its rivals. Product differentiation raises consumers' willingness to pay. Specifically, a product may be differentiated by raising its quality above the quality of competing products. If quality is important to consumers, they will be willing to pay a higher price for this higher quality product. We can introduce a parameter θ into Equation 2 to measure the degree of product differentiation attributable to our firm relative to the remaining firms. If $\theta=1$, the products are completely homogeneous between firm j and the remaining firms. If $\theta=0$, the products sold by firm j are completely differentiated from the remaining firms in the industry. We obtain a modified profit function for firm j

$$\pi_{it}^j = b \left[\frac{S}{2 + (n-1)\theta} \right]^2 \quad (3)$$

where S and n are the size of the market and the number of firms in the market. Equation 3 states that the profits earned by any firm of a given age in any industry is determined by the degree of product differentiation and the size of the market. When

a firm differentiates completely its products ($\theta=0$) relative to those sold by rivals in the industry, the firm removes the interdependence of its profits on the number of firms in the market. The firm becomes a monopolist for the differentiated product and remaining firms compete with the original homogeneous product ($\theta=1$). Their profits remain dependent on the number of firms in the marketplace.

Successful product innovation⁵² is the source of product differentiation. Following the notation developed in Equation 3, the probability that $\theta=0$ is increasing in the success of a firm's technological activity, as defined by a successful innovative output (SIO)

$$\Pr (\theta = 0) = f(SIO) \quad (4)$$

Through the various mechanisms outlined in Equations 1 - 4, we arrive at the central hypothesis of this chapter, namely that the probability of survival of a firm j , of age t , in industry i , will be determined by the extent of successful innovation (SIO) in this firm

$$\Pr (Y_{it}^j > 0) = f(SIO) \quad (5)$$

To our model in Equation 5 we must add some more traditional plant and industry characteristics that have traditionally explained variations in the probability of survival between firms. We consider each of these variables in turn.

⁵¹ See Martin (1993).

⁵² We could model process innovation in a similar fashion by extending the Cournot model to account for differing marginal costs. Process innovation would result in lower marginal costs for a firm relative to rivals.

Plant size: The probability of survival for a firm increases with its size. Majumdar (1997) notes in a study of Indian firms that with increasing size comes more diverse capabilities, superior access to capital and a superior ability to exhaust economies of scale and scope. Nas and Lappalahti (1997) focus on the ability of a firm to react to changes in its external environment. The option of downsizing in the face of an economic downturn is only available to large firms. Large firms have adequate size to consider downsizing before they consider exiting the industry. By contrast, small firms have no option to downsize, and are immediately faced with the decision to exit.

Plant age: The probability of survival increases with the age of the firm. Jovanoic (1982) termed the benefits gained from increasing experience in a market as *market entrenchment* benefits. Learning is important in exhausting economies of scale and scope and learning is a function of time. Majumdar (1997) summarises this point when noting that older firms are not prone to the *liability of newness*.

Entry: Love (1996) in a study of variations in firm exit across the British counties concludes that new firm entry is the dominant determinant of exit. There is an expected positive correlation between the extent of entry into an industry and the rate of exit of incumbent plants, i.e., the probability of survival of incumbent plants falls as the rate of entry increases. Audretsch (1995) describes the process as one of *displacement*. It occurs where informational asymmetries exist between the existing incumbent firms and potential new entrant firms. Innovative ideas occur outside of the industry and are ignored by the existing incumbents. New entrant firms enter with these innovative ideas and steal market share, eventually growing to displace the

existing incumbents. Siegfried (1992) provides evidence of inefficient incumbents being displaced by new entrant firms in the United States while Kleijweg and Lever (1996) provide similar evidence for Dutch manufacturing firms.

Rate of growth: Audretsch and Mahmood (1995) and Walsh and Konings (1997) model the probability of survival of a firm as determined by the rate of growth in the industry. These authors expect that the probability of survival for all firms in an industry will be higher, the greater the rate of growth of the industry. Relatively faster growing industries are thought to have elevated price-cost margins. These elevated margins are more forgiving for less efficient firms in the industry, which can still enjoy profitability despite their uncompetitive position. In slow growing industries, where intense price and non-price competition may result for a given market share, we would expect a high rate of exit among inefficient firms.

Thus we extend Equation 5 to take account of these factors. The probability of survival of an indigenous incumbent plant j , of age t , in industry i , in the Irish manufacturing sector will be determined as follows⁵³

$$\Pr(Y_{it}^j > 0) = (SIO(+), Size(+), Age(+), Ind. Entry Rate(-), Ind. Growth Rate(+)) \quad (6)$$

⁵³ The expected influence of the variable on the probability of survival is noted as (+) or (-) in parentheses.

3.4 Logit Regression

3.4.1 Data Sources

The data used here are a unique combination of two sources. The R&D data are drawn from a survey of R&D performing plants, undertaken by the policy and advisory board for industrial development in Ireland (Forfás). This organisation has statutory responsibility for R&D statistics in Ireland. For the years 1986 to 1993, the biannual surveys reported data on the population of R&D performers with ten or more employees in the manufacturing and internationally-traded services sectors.⁵⁴ The employment data are drawn from the annual employment surveys undertaken by the same agency. Similar to the R&D data, these employment surveys cover the population of plants in the manufacturing and internationally traded service sectors.⁵⁵ The employment survey data covers all firms and in matching the two Forfás surveys, we have excluded any plant with less than ten employees through the period 1986 to 1996.

Within indigenous plants, we focus only on the incumbent plants. We do this by generating a cohort that includes all plants with ten or more employees and three or more years old in 1986. We then analyse their survival until 1996.⁵⁶ A plant is deemed to have survived if it has positive employment in 1996 and exited from the cohort if it has zero employment in 1996. Where a plant has positive employment in one year followed by a report of zero employment in the following year, we deemed

⁵⁴ Forfás estimate a response rate close to 100% for this survey.

⁵⁵ The response rate is greater than 90% for this survey (Strobl, 1996).

⁵⁶ This eliminates any new entrant firms (1987-1995) from being included in our analysis. This allows us in empirical testing to focus only on incumbent firms. Our cohort is the population of indigenous incumbent plants in 1986.

that plant to have exited the cohort during that year. In this way we capture the duration of the plant's life after 1986.

3.4.2 Description of the Variables

Technological activity: We use the five R&D surveys between 1986 and 1993 to measure technological activity in plants in our cohort. Given that these surveys report R&D spend for the population of indigenous R&D spenders, a plant with zero spend is considered as a non-R&D spending plant. We measure scale of R&D activity as the mean R&D spend per annum in the plant (1986-1993). The population of R&D spending firms and non-R&D spending firms remains the same for all three measures of plant level technological activity. For the R&D spending firms only, we calculate two alternative measures of their technological activities. The first measure is *R&D intensity* i.e., the mean R&D spend of the plant as a percentage of its sales. The second measure relates to innovative output. It is the mean percentage of the firm's sales that is accounted for by products developed within the firm in the last three to five years.

Plant size: We measure plant size as the employment size of the plant in 1986 and we normalise this with the industry minimum efficient scale (MES) in 1986. In the spirit of Sutton (1991, p.96) we measure the MES of each subsector at time t as the mean employment size in the subsector at time $t-1$.

Plant age: Plant age is the age of the plant in 1986.

Entry: The industry entry rate is calculated using methodology outlined in Davis and Haltiwanger (1990). An annual plant turnover rate by industrial subsector (using the 24 sector OECD aggregation) is calculated annually between 1986 and 1996. We then measure the number of plants entering as a percentage of this turnover. We calculated the mean annual entry rate for each of our subsectors as a measure of the extent of entry into an industry (1986-1996).

Growth rate: The industry growth rate is measured as the growth in value added by industrial subsector (1986-1995). These measures were sourced from the Census of Industrial Production. We used concordance tables to translate the CSO industry classification into the OECD industrial classification.⁵⁷

3.4.3 Logit Regression Results

We use a logit regression model to estimate the probability of an indigenous incumbent plant surviving the period 1986-1996. The dependent variable captures whether the plant survived or exited over the period. A value of one implies the plant survived while a value of zero classifies the plant as having exited. We regress this dependent variable on each of our three measures of technological activity listed above as well as the plant and industry characteristics outlined in Section 3.3. We include also a dummy variable to control for the industrial subsector in which the plants are located. We present the results of Equations (4.1) through (4.3) in Table 3.5.

⁵⁷ Table 3.4 presents summary statistics for all of the variables used in this chapter.

Equations 4.1, 4.2 and 4.3 differ only in the measure of technological activity used. All of these measures of technological activity have positive coefficients and are statistically significant at the 1 per cent level. As the scale, intensity and output of the plant's R&D activity increases, the greater the probability that the plant survived the period 1986-1996. This is the central hypothesis of this chapter.

In accordance with expectations, as the size of the plant relative to industry minimum efficient scale increases, the greater the probability of survival for the plant. For a given plant size, the higher the minimum efficient scale of the industry, the lower the probability of survival for an incumbent plant. This reflects the traditional industrial organisation result of MES as a determinant of the number of firms in an industry.

The mean annual entry rate into an industry is significant in Equations 4.2 and 4.3 at the 10 per cent level. The positive coefficient conflicts with our expectation that the greater the extent of entry into an industry the lower the probability of survival would be for incumbents. However, an alternative view of entry and the survival of incumbents exists. The greater the extent of plant entry into the industry, the more intense the competition between new entrants for a given market share. The competition may be so intense that the vast majority of new entrant plants fail and are forced to exit, i.e., the revolving door metaphor, where an entrant arrives and subsequently exits (Audretsch, 1995). The remaining new entrant plants are so crippled by this early competition that they are not in a position to grow and displace the incumbents. This would result in a positive coefficient as reported in our logit regression.

The age of the plant and the growth rate of the industry are insignificant explanatory variables of the probability of survival. We do not display the results for the 24 category sectoral dummy variable for illustration purposes. In all of the equations, only four of the twenty-two subsectors have significant explanatory power.⁵⁸

3.4.4 Limitation of the Logit Regression: Duration heterogeneity

The first limitation of the logit model is its inability to account for duration heterogeneity, i.e., the difference in a plant exiting our cohort in 1987 and a plant exiting in 1995. Clearly survival time is important but it cannot be introduced as an explanatory variable into the logit model. Cox and Oakes (1984, p.6) note that *“inclusion of the actual failure time as an explanatory variable in a discriminant analysis (dichotomous dependent variable) would be a serious error, as the failure time is part of the response, not part of the factors influencing response.”* We need to model the survival experience of plants in our cohort taking into account differences in survival times.

3.5 A Duration Model

3.5.1 Econometric Methodology

The Cox (1972, 1975) duration model estimates the risk of exit (hazard) facing a plant in our cohort as a function of the explanatory variables already used in the logit regression. This proportional hazards model takes account of duration heterogeneity. The hazard is the conditional probability of a plant leaving the manufacturing sector

⁵⁸ These are Clothing, Leather and Footwear, Paper and Paper Products and Furniture and other Manufacturing when compared to Food, Drink and Tobacco.

at duration t . The hazard rate is the rate at which a plant exits during period t given that it has survived until time t , i.e., it measures the risk of exit for a plant during the next year. We obtain a baseline hazard function, $h_0(t)$, which is estimated when all of the explanatory variables (covariates) are set to zero. It is an estimate of the risk of exit facing each plant in the cohort in each year 1986-1996. The Cox model then estimates the influence of each of our explanatory variables on this baseline hazard function. Is the hazard of a plant exiting at a moment in time increased or decreased when an explanatory variable is nonzero? A negative (positive) coefficient indicates that this baseline risk of exit at a moment in time is reduced (increased).

In order to use the proportional hazards Cox model, we must assume that the ratio of the baseline hazard function $h_0(t)$ and the estimated hazard function $h(t)$ (when an explanatory variable is included) is proportional across time. This implies that the contribution of the explanatory variable to the risk of exit across time is identical. In our case, the contribution of R&D activity to the risk of exit facing a plant is the same in 1986 as it is in 1996. The implication of using this proportional hazards model is that none of our explanatory variables vary across time. They are all cross-sectional.⁵⁹

We express the model to evaluate many independent variables as

⁵⁹ The analysis in this chapter was initially completed in March 1998 when the time-varying Cox duration model could not be estimated due to the lack of a panel dimension in our first dataset. We have subsequently tested the robustness of the following results in a time-varying model, using a similar cohort of plants but also using the third and most recent dataset that we have constructed. This recent analysis could not be incorporated directly into the text because we cannot confirm that the descriptive statistics presented throughout the chapter apply to our most recent dataset (i.e., the OECD sectoral classification used in this chapter is no longer stored in our new dataset). The time-varying analysis is outlined in Appendix B.

$$h(t) = [h_0(t)]e^{(\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_N X_n)}$$

where $h_0(t)$ is the baseline hazard function when all of the covariates are set to zero and $h(t)$ is the estimated hazard function when the value of the covariates $(x_1, x_2 \dots x_n)$ are nonzero.

The emphasis of this chapter is on the probability of survival for an indigenous plant given its characteristics and external environment. The survival function $S(t)$ is an estimate of the probability of surviving longer than a specified period. The cumulative hazard function $H(t)$ is related to the survival function: $H(t) = -\ln S(t)$, where

$$S_t = [S_0(t)]^p$$

and where $p = e^{\beta x}$. The survival function is obtained by raising the baseline survival function (this is the function when all the explanatory variables are set to zero) to the power of $e^{\beta x}$. The cumulative hazard and the cumulative survival functions approximately add to one. The difference from one will be due to the standard error of the cumulative survival estimates. Therefore the probability of surviving a given time period is one minus the probability of dying in that period.

3.5.2 Results of the Cox Duration Model

Table 3.6 shows the regression results from four alternative equations (5.1-5.4). All four of these equations differ in one respect only, namely the measure of plant level technological activity used. Equation 5.1 uses a dichotomous variable that indicates whether the plant is an R&D active or non-R&D active plant. The coefficient of this variable is negative and statistically significant. This implies that the risk of exit for an R&D spending plant at a point in time (1986-1996) is less than that for a non-R&D spending plant. The only remaining statistically significant variable is the annual entry rate into the industry. The coefficient of this variable is positive. This confirms similar results elsewhere that the risk of exit at a point in time (1986-1996) facing indigenous incumbents is increased the greater the extent of plant entry into their industry (Siegfried, 1992; Audretsch, 1995; Kleijweg and Lever, 1996; Love, 1996). This is in contrast to the positive influence of entry on the probability of survival of incumbent plants estimated in our logit model.

The output from Equation 5.1 is graphically presented in Figures 3.2 and 3.3 that show the recovered hazard and survival functions, estimated for non-R&D and R&D active firms, respectively. These functions have been estimated using the mean values of the covariates specified in Equation 5.1. We can illustrate the importance of the plant being an R&D active or non-R&D active plant over this period. At any point in time during 1986-1996, the risk of exit facing a non-R&D spending plant is greater than that of an R&D spending plant (Figure 3.2). Conversely, the probability of surviving into the next period is greater at every point in time for an R&D spending plant than a non-R&D spending plant (Figure 3.3).

In Equation 5.2 (Table 3.6) we consider the scale of R&D activity among R&D active plants. The coefficient of R&D scale is negative and significant, i.e., the risk of exit facing an indigenous plant in our cohort is decreased as the scale of R&D activity in the plant increases. The size of the plant relative to the industry minimum efficient scale is negative, confirming our expectation that as a firm becomes large relative to the minimum efficient scale of the industry, its risk of exit decreases. The industry entry rate increases the risk of exit for all the incumbent plants in our cohort.

In Equation 5.3 we introduce the percentage of a plant's sales that is invested in R&D as a measure of incumbents' technological activity. This variable has the expected negative coefficient, i.e., the more intensively a plant engages in R&D, the lower its risk of exit will be. In similar fashion to Equation 5.2, both plant size relative to minimum efficient scale and the industry entry rate have the expected negative and positive coefficients respectively.

In Equation 5.4 we consider our final measure of a plant's technological activity. It is the percentage of their sales revenue that is accounted for by products developed within the firm in the last 3-5 years. The coefficient is negative, i.e., the greater the extent of sales revenue accounted for by sales of innovative products, the lower the risk of exit facing the plant. Again, the greater the extent of entry into the industry, the greater the risk of exit facing the plants in that industry. The larger the size of the plant relative to minimum efficient scale, the smaller the risk of exit facing the plant will be.

It is suggested based on our results that the probability of survival is relatively greater in R&D active firms. We speculated in Section 3.3 that we might record a higher probability of survival for R&D active firms because they are more profitable relative to non-R&D active firms. There has not been an econometric study of innovation and profitability for firms in the Irish manufacturing sector. We can only observe that R&D active firms in the Irish manufacturing sector grow relatively faster and consequently may be more profitable firms. Kearns and Ruane (1997) noted that R&D spending firms in Irish manufacturing had superior employment growth to non-R&D spenders while Roper *et al.* (1996) observed for a sample of firms in the Irish manufacturing sector that employment, turnover and real export growth per annum (1991-1993) was higher for innovating than for non-innovating companies. However, the general conclusion of the empirical studies to date is that relatively more technologically active firms have higher profits growth. Geroski (1994) observed that innovating firms earn higher profits because they have larger market shares than non-innovators. This market share is more valuable to innovating firms because they earn higher margins than non-innovators. Nas and Lappalahti (1997) report higher profits for Norwegian innovating companies when compared to non-innovating companies. The authors also conclude that these profit differences are persistent across time.

3.6 Summary and Conclusions

Between 1991 and 1998 new entrant firms created almost 34,000 jobs while exiting firms simultaneously destroyed almost 35,000. It would appear that for every new job created over this period another job was destroyed as a consequence of exiting firms. The question arises as to what extent the survival of these indigenous firms varies with their individual characteristics? The central hypothesis of this chapter is that

technological activity within plants is an important determinant of that plant's probability of survival. We outlined a theoretical model whereby the probability of a plant surviving is determined by the success of a plant's technological activity. We extended the results of previous papers that have used sectoral level data on technological activities in determining the probability of survival of incumbent plants.

Using a dataset of indigenous incumbent plants in the Irish manufacturing sector, we concluded that technologically active firms have superior probabilities of survival relative to less technologically active firms. This was confirmed using life-table analysis, logit analysis and a Cox duration model. This result was consistent across the range of variables typically used to measure a plant's technological activity, namely, scale of R&D activity, R&D intensity or sales of innovative products developed within the plant.

3.A Tables

Table 3.1: Percentage of (i) Indigenous Plants Exiting the Manufacturing Sector and (ii) Jobs Lost through Plant Exit, 1991-1998

Year	Number of existing Plants	Number of plants closed	% of all plants lost	Number of jobs	Employment lost in closed plants	% of all employment lost
1991	3,792	324	8.5%	110,009	6,371	5.8%
1992	3,808	363	9.5%	114,144	5,695	5.0%
1993	3,827	268	7.0%	111,167	4,369	3.9%
1994	3,851	254	6.6%	109,706	3,768	3.4%
1995	3,857	290	7.5%	116,714	5,233	4.5%
1996	3,858	262	6.8%	120,224	3,826	3.2%
1997	3,993	259	6.5%	125,498	5,615	4.5%
Total		2,020			34,877	
Mean			7.5%			4.3%

Source: Own estimations based on *Central statistics Office* (Census of industrial production 1991-1998) data. See CSO (1997a, 1997b, 1997c, 1998a, 1998b, 1998c, 2000a, 2000b).

Table 3.2: A Comparison of Jobs Lost and Gained through Plant Exit and Entry, 1991-1998

Between Years:	Number of jobs lost in exiting firms	Number of jobs gained in new firms	Net Difference
	(1)	(2)	(2)-(1)
1991-1992	6,371	4,819	-1,552
1992-1993	5,695	4,710	-985
1993-1994	4,369	4,073	-296
1994-1995	3,768	3,994	226
1995-1996	5,233	4,768	-465
1996-1997	3,826	6,459	2,633
1997-1998	5,615	5,038	-577
Total	34,877	33,861	-1,016

Source: Own estimations based on *Central statistics Office* (Census of industrial production 1991-1998) data. See CSO (1997a, 1997b, 1997c, 1998a, 1998b, 1998c, 2000a, 2000b).

Table 3.3: Cohort Survival Rates Over Time by Manufacturing Subsector

Year	1986	1988	1990	1992	1994	1996	Probability of
Manufacturing Sector	Number of Surviving Firms from 1986 Cohort. Survival Rates (%)						Surviving the Period
High-Tech Sectors:							
Machinery n.e.c.	88	78	68	60	57	56	63.64
		89%	77%	68%	65%	64%	
Computer/Office Mach	14	12	11	11	10	9	64.29
		86%	79%	79%	71%	64%	
Electrical machinery	51	48	44	43	40	36	70.59
		94%	86%	84%	78%	71%	
Electronics	3	3	3	2	2	2	66.67
		100%	100%	67%	67%	67%	
Instruments	32	30	27	26	26	25	81.25
		94%	84%	81%	81%	78%	
Motor Vehicles	46	44	42	41	40	38	82.61
		96%	91%	89%	87%	83%	
Other transport	14	14	11	9	8	7	50.00
		100%	79%	64%	57%	50%	
Chemicals	22	21	18	18	18	18	81.82
		95%	82%	82%	82%	82%	
Pharmaceuticals	35	31	29	29	27	27	77.14
		89%	83%	83%	77%	77%	
High-Tech Sectors	293	281	253	239	228	214	73.04
		96%	86%	82%	78%	73%	
Low-Tech Sectors:							
Food/Drink/Tobacco	541	495	453	423	399	384	71.71
		91%	84%	78%	74%	71%	
Textiles	86	73	66	57	53	52	60.47
		85%	77%	66%	62%	60%	
Clothing	152	121	95	83	75	66	43.42
		80%	63%	55%	49%	43%	
Leather/Footwear	35	30	23	21	20	17	48.57
		86%	66%	60%	57%	49%	
Wood/Wood Products	102	91	83	72	66	62	62.69
		89%	81%	71%	65%	61%	
Paper/Paper Products	45	42	42	41	40	40	88.89
		93%	93%	91%	89%	89%	
Printing/Publishing	165	155	150	148	137	132	80.60
		94%	91%	90%	83%	80%	
Rubber/Plastic Prod's	81	76	69	67	65	61	75.31
		94%	85%	83%	80%	75%	
Non-Metallic Minerals	146	134	124	121	110	106	73.26
		92%	85%	83%	75%	73%	
Basic Metals	15	13	9	9	9	8	53.33
		87%	60%	60%	60%	53%	
Fabricated Metals	268	242	225	212	197	190	70.90
		90%	84%	79%	74%	71%	
Furniture/Other Manu.	173	151	136	128	121	113	65.46
		87%	79%	74%	70%	65%	
Low-Tech Sectors:	1821	1623	1475	1382	1292	1245	68.35
		89%	81%	76%	71%	68%	
Total (Cohort)	2114	1904	1728	1621	1520	1449	69.00
		90%	82%	77%	72%	69%	

Source: Own Estimations based on Forfás data.

Note: The survival rate or the percentage of firms surviving is the number of firms surviving after a given time period divided by the total number of firms originally in the industry in 1986.

Table 3.4: Summary Statistics for Regression Variables

Variable	Mean	Std Dev.	Min	Max	N
<i>Plant Characteristics:</i>					
(Plant Size / MES)	1.00	1.54	0.07	33.87	2114
Plant Age (Years)	21.06	18.78	3	84	2114
<i>Industry Characteristics:</i>					
Industry Entry Rates (%)	0.06	0.02	0.04	0.17	2114
Industry Growth Rates (%)	3.54	4.14	1.07	16.86	2114
<i>Technological Activity:</i>					
Scale of R&D Activity (000's)	18.56	96.83	0	1980	2114
R&D Intensity (%)	0.01	0.03	0	0.28	2114
Sales of Innovative Prods (%)	6.26	18.15	0	100	2114
<i>Status and Duration:</i>					
Plant Survived (1) or Died (0)?	0.69	0.46	0	1	2114
Life of Plants post 1986 (Years)	8.96	3.39	1	11	2114

Source: Own Estimations.

Table 3.5: Regression Results for Logit Estimation

Independent Variables ⁶⁰	Equation 4.1	Equation 4.2	Equation 4.3
Scale of R&D Spend (p)	.004*** (.0088)		
R&D Intensity (p)		14.540*** (.0004)	
% Sales Innov. Prod's (p)			0.022*** (.0000)
Age of plant in 1986 (p)	0.001 (.6663)	0.001 (.6768)	0.001 (.6188)
Plant size / MES (p)	0.117** (.0207)	0.152*** (.0017)	0.121** (.0127)
Annual Entry Rate 86-96 (i)	73.525 (.1375)	86.097* (.0938)	85.652* (.1000)
Industry Growth Rate (i)	-0.086 (.1896)	-0.097 (.1450)	-0.093 (.1625)
Constant	-4.018 (.1896)	-4.926 (.1239)	-4.963 (.1267)
Overall Chi Square Score	121.723	129.932	153.321
Significance Level	.0000	.0000	.0000
-2LL	2495.290	2487.081	2463.692
Overall Predicted	70.20%	70.29%	70.53%
N	2114	2114	2114

Note: *p* values in parentheses.

*** significant at the 1% level, ** significant at the 5% level, *significant at the 10% level;
(*i*) variable varies at industry level, (*p*) variable varies at plant level.

⁶⁰ A sectoral categorical variable for the 24 OECD sectors was included. The variable improved the explanatory power of the model. The breakdown of this variable (23 categories) is not included for presentation purposes.

Table 3.6: Regression Results for the Cox Duration Model

Independent Variables	Equation 5.1	Equation 5.2	Equation 5.3	Equation 5.4
R&D Active (Yes/No) (p)	-1.030*** (.000)			
Scale of R&D Spend (p)		-0.004*** (.002)		
R&D Intensity (p)			-14.551*** (.000)	
% Sales Innov. Prod's (p)				-0.0202*** (.000)
Age of plant in 1986 (p)	-.003 (.141)	-0.002 (.382)	-0.002 (.309)	-0.0024 (.266)
Plant size / MES (p)	-0.061 (.116)	-0.083** (.048)	-0.121*** (.003)	-0.099** (.014)
Annual Entry Rate 86-96 (i)	10.213*** (.0000)	10.896*** (.000)	11.116*** (.000)	11.503*** (.000)
Industry Growth Rate (i)	-.015 (.116)	-0.015 (.121)	-0.013 (.174)	-0.014 (.144)
Overall Chi Square Score	94.820***	36.396***	41.378***	64.843***
Significance Level	(0.0000)	(0.0000)	(0.0000)	(0.0000)
N	2114	2114	2114	2114

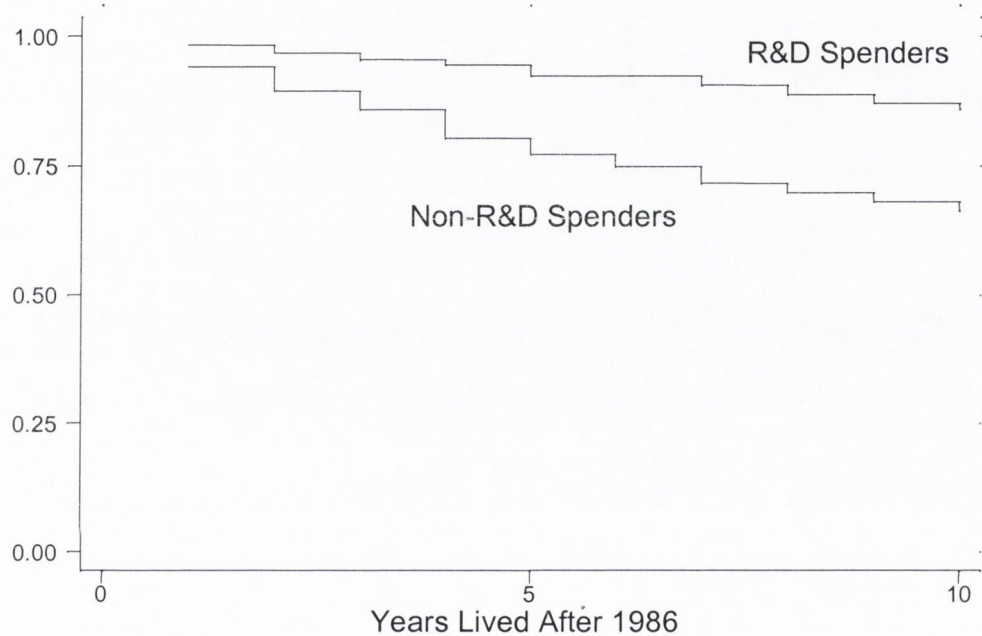
Note: *p* values in parentheses.

*** significant at the 1% level, ** significant at the 5% level, *significant at the 10% level;

(*i*) variable varies at industry level, (*p*) variable varies at plant level.

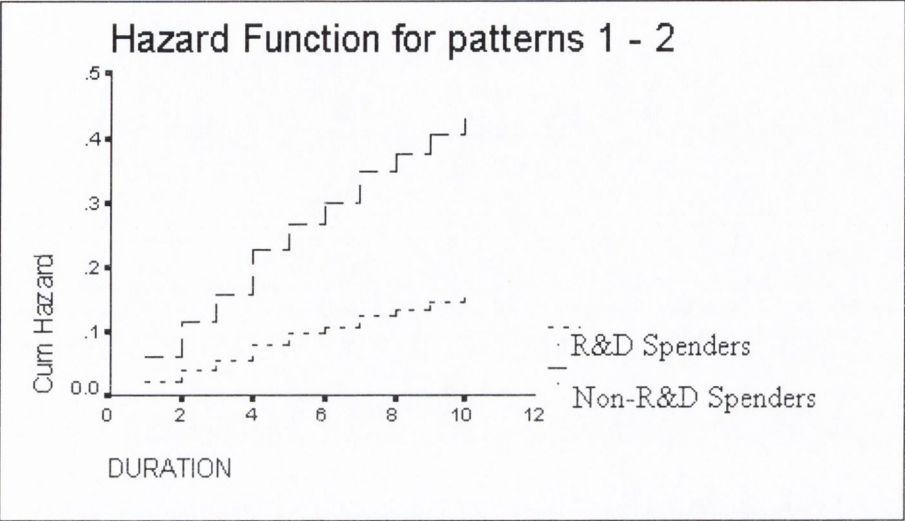
3.B Figures

Figure 3.1: A Survivor function of R&D Spenders relative to non-R&D Spenders using Life-table Analysis



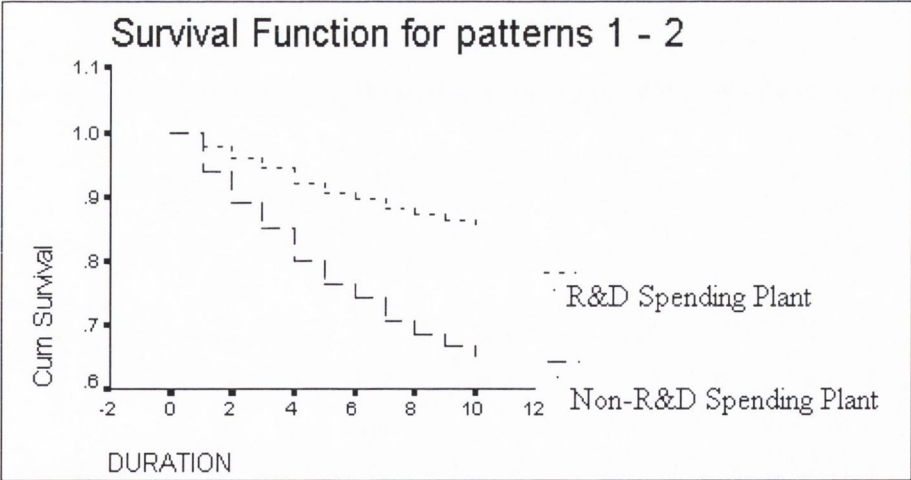
Note: The vertical axis is the probability of survival.
Over the entire duration (1986-1996) the probability of survival for R&D spending firms is greater than that of non-R&D spending firms.

Figure 3.2: Hazard Functions based on Cox Regression (Equation 5.1) estimated for R&D Spenders vs. Non-R&D spenders



Note : The longer the time period considered (duration) after 1986, the greater the risk of exit facing all of the plants. However this risk of exit is lower for the R&D spending plants relative to the non-R&D spending plants over the entire period. This function is estimated using the mean of the covariates.

Figure 3.3: Survival Functions based on Cox Regression (Equation 5.1) estimated for R&D Spenders vs. Non-R&D spenders



Note: The longer the time period considered (duration) after 1986, the lower the probability of survival facing all plants. However the probability of survival is higher for the R&D spending plants relative to the non-R&D spending plants over the entire period. This function is estimated using the mean of the covariates.

3.C Appendices

Appendix A: Diagnostics for the Life-Table Analysis

Table A3.1: Wilcoxon (Gehan) Statistics of the Probabilities of Survival across Subsectors

24 SECTORAL CLASSES					
Overall comparison statistic=	101.463		D.F.=21		Prob.=0.0000
Sector Names	Total N	Exited	Survived	% N Censored	Mean Score
Food/Drink/Tobacco	541	153	388	71.72	60.3087
Textiles	86	34	52	60.47	-206.6163
Clothing	152	86	66	43.42	-564.3487
Leather/Footwear	35	18	17	48.57	-440.7429
Wood/Wood Products	102	38	64	62.75	-118.8039
Paper/Paper Products	45	5	40	88.89	425.1111
Printing/Publishing	165	32	133	80.61	266.2606
Chemicals	22	4	18	81.82	245.0455
Pharmaceuticals	35	8	27	77.14	125.9429
Rubber /Plastic Products	81	20	61	75.31	143.2469
Non-Metallic Products	146	39	107	73.29	93.863
Basic Metals	15	7	8	53.33	-363.9333
Fabricated Metals	268	78	190	70.9	39.8284
Machinery N.E.C.	88	32	56	63.64	-137.6364
Computer/Office Mach.	14	5	9	64.29	-97.0714
Electrical Machinery	51	15	36	70.59	81.451
Electronics	3	1	2	66.67	39.6667
Instruments	32	6	26	81.25	247.1563
Motor Vehicles	46	8	38	82.61	308.0217
Other Transport	14	7	7	50	-326.5714
Furniture/Other Manu.	171	59	112	65.5	-85

Table A3.2: Wilcoxon (Gehan) Statistics of the Probabilities of Survival between High and Low-Tech Sectors.

Overall comparison statistic=	2.281		D.F.=1		Prob= 0.1309
	Total N	Exited	Survived	%	Mean Score
High tech	293	79	214	73.04	81.8737
Low tech	1821	576	1245	68.37	-13.1735

Table A3.3: Wilcoxon (Gehan) Test for Non-R&D Spenders Vs. R&D Spenders

Overall comparison statistic=	79.565		D.F.=1		Prob= 0.0000
	Total N	Exited	Survived	%	Mean Score
Non-R&D Spenders	1661	591	1070	64.42	-101.285
R&D Spenders	453	64	389	85.87	371.3775

APPENDIX B⁶¹

Table B3.1: Regression Results for the (Time Varying) Cox Duration Model

Independent Variables	Equation B.1	Equation B.2
R&D Active (Yes/No) (p)	.310*** (.039)	
Scale of R&D Spend (p)		.994*** (.002)
Age of plant (p) (t)	.985* (.009)	.986* (.008)
Age of plant squared (p) (t)	1.000** (.000)	1.0000* (.000)
Plant size / MES (p) (t)	.904 (.094)	.831** (.072)
Plant size / MES squared (p) (t)	1.012** (.005)	1.016*** (.005)
Annual Entry Rate 86-96 (i) (t)	.335 (.498)	.419 (.618)
Industry Growth Rate (i) (t)	.995* (.003)	.996* (.002)
Sector Dummies	Yes	
Time Dummies	Yes	
Overall Chi Square Score	389.47	
Significance Level	0.0000	

Note: Standard errors in ()s. *** significant at the 1% level ** significant at the 5% level .
 (p) the variable is measured at the plant level, (i) the variable is measured at industry level,
 (t) the variable varies annually.

The non-time-varying covariate Cox duration model (Table 3.6) was estimated based on the proportional hazards assumption. Essentially, the impact of any individual variable on the risk of exit is assumed to be identical at any two points in time (for example in 1986 and in 1996). In addition, this particular form of the Cox model did not allow us to introduce a time dummy to control for the macroeconomic

⁶¹ We do not include the following analysis directly into the text of the chapter because although the analysis is based on the same cohort of plants, the data used cover a longer period and thus the descriptive statistics provided throughout the rest of the chapter do not apply to the data below. In addition, the sectoral classification (OECD) used throughout this chapter is not available in the later data which is classified according to NACE REV 1.

environment because all of the independent variables were time invariant. We estimated subsequently a time-varying Cox duration model using more recent data (i.e., covering two more years, from 1986 to 1998) for the same cohort of plants. Table B3.1 is a replication of Table 3.6 using (i) data that covers the period 1986-1998 and (ii) the Cox duration model with time varying covariates. It is based on a similar cohort of all plants with ten or more employees and three or more years of age in 1986. We estimate the survival of indigenous incumbent plants as determined by the same variables used in the earlier analysis. In addition to these variables we include now the squared values of age and plant size relative to MES to capture any non-linearities in these relationships. All of the variables are time varying with the exception of the R&D dummy variable and scale of R&D investment. This allows us to test the robustness of our results on the impact of R&D activity on the probability of survival when the remaining variables are allowed to vary across time. The reported coefficients are hazard ratios. A coefficient value of less than 1 should be interpreted as indicating that the variable reduces the risk of exit. A value greater than 1 indicates that the variable increases the risk of exit.

Equation B.1 is similar to Equation 5.1 where we use a dummy variable to indicate whether the firm invests in R&D or not. A firm is classified as R&D active where that firm reported any positive amount of investment in R&D activities. We find that R&D activity decreases the risk of exit facing individual plants.

Equation B.2 is similar to Equation 5.2 where R&D activity is measured as the mean annual R&D investment in each plant over the period 1986-1997. Once again we

estimate that R&D investment within a plant increases the probability of survival for that plant.

CHAPTER 4

LABOUR DEMAND AND R&D INVESTMENT: A FIRM LEVEL STUDY OF EMPLOYMENT GROWTH IN THE INDIGENOUS MANUFACTURING SECTOR (1984-1998)

4.1 Introduction

Net output in the Irish manufacturing sector increased on average by 4.7 per cent per annum over the period 1991-1998. The corresponding annual increase in employment was 2.2 per cent.⁶² There is nothing unusual in the rate of employment growth of manufacturing plants being exceeded by growth in net output. Alänge *et al.* (1996) have observed that the manufacturing sectors in the majority of OECD countries over the last three decades can be characterised as moving between job-less growth and growth with less jobs. They expect this process to continue and explain that “[t]he reason for our expectations is that industry is introducing new technical and organisational innovations; innovations which have a proven capacity to reduce labour drastically” (p.29). The OECD have confirmed that this view on the destructive potential of technical change is not unfounded: “[t]echnical change is, in the words of Schumpeter, a process of creative destruction” (OECD, 1994b, p.123).

Increasing numbers of firm-level empirical studies investigate the impact of firm-level innovative activities on subsequent labour demand. However, no unambiguous

⁶² Own estimates based on annual *Census of Industrial Production* for the period 1991-1996 CSO (1997a, 1997b, 1997c, 1998a, 1998b, 1998c). These estimates of net output and employment change are calculated for indigenous plants only.

conclusion is drawn on the question of whether the impact of innovation on labour demand is positive or negative. For example, Brouwer *et al.* (1993), Klette and Førre (1995) and Leo and Steiner (1995) reach the conclusion that there is no clear-cut positive relationship between R&D investment and net job creation for Dutch, Norwegian or Austrian plants, respectively. Further, Garcia *et al.* (1998) find a positive but very weak effect of innovative activity on employment in Spanish plants. In stark contrast to the majority of these studies, Van Reenan (1997) finds that innovative activity *causes* higher employment growth in UK manufacturing plants.⁶³

The majority of the studies cited above follow a similar methodology. The approach in these studies controls for the innovative activity of a plant by including a variable to measure innovative activity directly into a labour demand equation. The authors interpret the effect of innovative activity on labour demand according to the sign, size and significance of the coefficient on innovative activity. For example, a positive coefficient on innovative activity is interpreted as indicating that labour demand increases with innovative activity. This approach does not investigate how more traditional determinants of labour demand (e.g., the elasticity of substitution) might differ across innovative and non-innovative firms. In order to carry out this investigation, the labour demand equation needs to be estimated separately for two groups of firms (i.e., more and less innovative firms) and the coefficients compared across both subsets of plants. In this chapter we adopt this approach and estimate a dynamic labour demand model for R&D and non-R&D active companies separately. In doing so, elasticities are compared across both sets of plants in an attempt to understand why labour demand might differ between them.

⁶³ See Van Reenan's (1997, p.278-280) comprehensive survey of other microeconomic studies of

In Section 4.2 we outline briefly a theory of innovation and labour demand. We distinguish between process and product innovations and observe that while product innovations are expected to increase labour demand, the impact of process innovations on labour demand is ambiguous. In Section 4.3 we present summary statistics of labour demand in R&D active and non-R&D active companies. We question whether the relatively lower job creation rate combined with the higher turnover growth rates for R&D active firms relative to non-R&D active firms suggests that output in R&D active plants in Ireland is labour saving. We estimate dynamic labour demand equations in Section 4.4. Some limitations of our approach are outlined in Section 4.5, while Section 4.6 contains a brief summary and some conclusions. Overall we find that employment growth is slightly higher in R&D active companies, not because of a greater propensity to increase employment as sales increase, but because R&D active companies have higher sales growth. We distinguish between product and process innovating firms and find that, as expected, product innovators have higher labour demand relative to process innovating plants. A limitation of this econometric analysis is that it does not account for the quality of the jobs created. We find that job persistence is much higher in more innovative companies: while almost 100 per cent of jobs created in R&D active firms survive for at least ten years, by contrast, there is a survival rate of only one third of jobs created in non-R&D active firms over the same time period.

labour demand and technical change and Blechinger *et al.* (1997) for a similar survey.

4.2 Innovation and Firm-level Labour Demand

A first step in deciding whether firm-level investment in innovation increases or decreases labour demand is to distinguish between two types of innovative output, namely process or product innovation. The impact of process innovation on labour demand is more ambiguous than the impact of product innovation.

(i) Process Innovation

Stoneman (1987) models the impact of process innovation on labour demand.⁶⁴ The production function includes only two inputs, labour and capital. The overall impact of technological change on factor demands is determined by considering the magnitude of four parameters: the rate of factor augmentation, the elasticity of substitution, the degree of scale economies in production and the elasticity of demand.

Stoneman derives the following expression for the rate of change in labour demand.⁶⁵

The growth in labour demand is given by

$$\frac{\partial L}{L} = \alpha K (\sigma - \eta) \left(\frac{\partial b}{b} - \frac{\partial a}{a} \right) + \left(\frac{\partial b}{b} (\eta - 1) \right) \quad (1)$$

where $\frac{\partial L}{L}$ is the rate of change of demand for labour, αK is the share of capital in

output, $\frac{\partial a}{a}$ is equal to the rate at which capital is augmented, $\frac{\partial b}{b}$ is the rate at which

labour is augmented, σ is the elasticity of substitution between labour and capital and

⁶⁴ Technological change and process innovation are used interchangeably in Stoneman's (1987) model.

⁶⁵ The derivation of this factor demand equation is outlined in Stoneman (1987, p.88-93). See Bosworth *et al.* (1996) for a brief discussion of this model.

η is the elasticity of demand. The derivation of Equation 1 assumes fixed factor prices and constant returns to scale.

Stoneman (1987, p.76) summarises the outcomes for labour demand (and capital) for relative values of $\frac{\partial a}{a}, \frac{\partial b}{b}, \sigma$ and η in Box 1.

Box 1: Factor Demands

		Labour Saving Technological change		Neutral Technological Change	Capital Saving Technological Change	
		Pure augmentation	Relative augmentation	Equal augmentation	Pure augmentation	Relative augmentation
<i>Elasticity of Substitution:</i>		$\frac{\partial a}{a} = 0, \frac{\partial b}{b} > 0$	$\frac{\partial b}{b} > \frac{\partial a}{a} > 0$	$\frac{\partial a}{a} = \frac{\partial b}{b} > 0$	$\frac{\partial a}{a} > 0, \frac{\partial b}{b} = 0$	$\frac{\partial a}{a} > \frac{\partial b}{b} > 0$
		(1)	(2)	(3)	(4)	(5)
$\sigma > 1$:						
$\sigma < \eta$	$\frac{\Delta L}{(\Delta K)}$	? (+)	? (+)	+ (+)	+ (?)	+ (?)
$\sigma = \eta$	$\frac{\Delta L}{(\Delta K)}$	+ (0)	+ (+)	+ (+)	+ (+)	0 (+)
$\sigma > \eta$	$\frac{\Delta L}{(\Delta K)}$	? (-)	? (?)	? (?)	? (?)	- (?)
$\sigma < 1$:						
$\sigma < \eta$	$\frac{\Delta L}{(\Delta K)}$	? (?)	? (?)	? (?)	? (?)	+ (?)
$\sigma = \eta$	$\frac{\Delta L}{(\Delta K)}$	- (-)	- (-)	- (-)	- (+)	0 (+)
$\sigma > \eta$	$\frac{\Delta L}{(\Delta K)}$	? (?)	? (-)	- (-)	- (?)	- (?)

Source: Stoneman (1987, p.76).
 In each cell of the table, the top sign (**bolded**) is the demand for labour. Underneath in brackets is the demand for capital. The signs should be interpreted as follows: ? effect cannot be signed, + positive effect, - negative effect, 0 no effect on factor demand.

Labour-saving technological change, where labour productivity is increased relative to the productivity of all other factor inputs, does not necessarily lead to a decrease in labour demand. If labour is purely augmented (Column 1), i.e., the only factor that is augmented by process innovation is labour, then the demand for labour will still rise if

the elasticity of substitution is greater than one and the elasticity of substitution is equal to the elasticity of demand. If the elasticity of substitution is less than one but still equalled the elasticity of demand, labour demand would fall. The complexity of these relationships and the myriad of combinations of various parameters makes it very difficult to predict unambiguously whether process innovation does eventually increase or decrease labour demand within the firm. Process innovation initially reduces labour demand through increasing labour productivity (i.e., augmenting labour) but the final impact on labour demand depends on whether the decreased labour demand due to higher labour productivity is compensated for by the increased labour demand due to increased production, which in turn depends on the level of consumer demand.

(ii) Product Innovation

The theoretical discussion of product innovation is relatively shorter in the literature because the expected outcome of product innovation on labour demand is unambiguous. Vivarelli *et al.* (1996, p.1015) observe that product innovations “*open the way to the development of either entire new goods or main differentiations of mature goods*” and consequently “*...generally involve an increase in employment both at the firm level, at the sectoral level and at the national level.*” The only exception to this general rule occurs (i) where a firm replaces a successful product with an unsuccessful one and/or (ii) where the firm switches from a high-volume low profit product to a low-volume high profit product. These exceptions imply that a successful product innovation could reduce labour demand within the firm.

4.3 Aggregate Statistics of Job Creation, Turnover Growth and Labour Productivity

The question arises as to whether investment in research and development (i.e., innovation⁶⁶) by indigenous manufacturing firms has resulted in a lower demand for labour relative to less innovative companies.

Table 4.1 summarises annual job creation rates for R&D active⁶⁷ and non-R&D active plants respectively. Job creation is defined as the percentage annual change in employment in all indigenous plants that increase employment between any two years over the period 1984-1998.⁶⁸ Over the period, R&D active firms record a lower average job creation rate (7 per cent) relative to non-R&D active firms (9 per cent). The average job creation rate is greater for non-R&D active plants in thirteen of the fourteen years. This is similar to statistics for Norway where Klette and Førre (1995, p.9) report that *“no-R&D plants have higher job creation rates in all years and that the difference between the R&D and the no-R&D plants is very stable”*. However, these job creation statistics must be set in the context of turnover growth for the same firms. On average R&D active firms enjoyed an annual turnover growth of 15 per cent relative to 11 per cent for non-R&D active plants. Non-R&D active firms record only 4 years where their turnover growth is greater than or equal to that of R&D active plants. It can also be seen that the pattern of relative job creation rates is not replicated

⁶⁶ In this chapter we proxy investment in innovation by investment in research and development.

⁶⁷ We define an R&D active plant as any plant with a mean annual R&D expenditure (in 1986 prices) of at least £100,000 over the period 1986-1997. A non-R&D active firm invests nothing or less than an average of £100,000 annually in R&D over the same period.

⁶⁸ The dataset used is based on the population of indigenous owned manufacturing plants with ten or more employees over the period 1984-1998. This population of plants numbers over 7,000 of which 251 are R&D active over this period. We have matched a smaller dataset to this employment data. This dataset, known as the Irish economy expenditures (IEE), provides firm-level data on sales, profits, wages and many other firm characteristics. These data are collected from a sample of plants whose coverage varies annually. We have at least one years observations on 1,460 plants (1,296 of these being non-R&D active and the remainder (164) being R&D active plants).

when we examine the mean annual profit margin earned by both groups of plants.⁶⁹ Profit margins are more evenly matched for both groups relative to the job creation rates. One possible explanation for a relatively poorer job creation rate and simultaneously higher turnover growth rates is *labour-saving* output growth in R&D active firms.

We suggest that technological progress may have resulted in job-less growth or growth with less jobs for indigenous R&D active firms. The question arises as to whether this is an adequate explanation for the statistical pattern outlined in Table 4.1. The first step in *labour-saving* output growth is the rate at which both factors, capital and labour, are augmented. The consequence of a series of process innovations augmenting labour is to increase labour productivity. The immediate impact of this augmentation is to reduce the demand for labour. Table 4.2 shows that the average annual value-added per employee between 1984 and 1997 (in 1984 prices) in R&D active firms is twice that in non-R&D active firms. Labour productivity has also risen in R&D active companies by approximately 82 per cent between 1984 and 1997. In contrast, labour productivity in non-R&D active plants increased by approximately 38 per cent over the same period.⁷⁰ Increases in labour productivity such as this will decrease labour demand. Can we conclude that labour demand is relatively lower in R&D active relative to non-R&D active firms as a consequence of the increasing labour productivity in R&D active firms? As noted in Section 4.2, the extent to which the demand for labour is altered further depends on (i) the ability of the firm to substitute labour for other factor inputs or vice versa (i.e., the elasticity of

⁶⁹ We define profit margin as (sales minus costs) divided by sales.

⁷⁰ These estimates are quite sensitive to using 1997 as the final year rather than 1996. The value-added per employee for R&D active companies is significantly higher in 1997 from 1996. If 1996 is chosen as

substitution) and (ii) the extent to which increased output impacts positively on the demand for labour.

4.4 Estimation of Dynamic Labour Demand

4.4.1 Model Specification and Approaches to Estimation

We use a model of dynamic labour demand in order to estimate the elasticity of labour demand with respect to output and the elasticity of substitution between factor inputs. First, the elasticity of labour demand with respect to output captures the extent to which changes in output are associated with changes in the level of labour demanded. Second, the elasticity of substitution captures the extent to which other factor inputs and labour are substitutable for each other.

Hamermesh (1993, p.30) derives an expression for labour demand from a constant elasticity of substitution (CES) production function (Equation 2). The CES production function is preferred over other production functions⁷¹ because the elasticity of substitution between labour and other inputs is free to fluctuate between zero and infinity and consequently its size can be estimated. Labour demand (L_{it}) is determined by real wages (w_{it}) and output (Y_{it}) where i is an individual firm and t denotes a point in time:

$$\ln L_{it} = \alpha - \sigma \ln w_{it} + \beta \ln Y_{it} \quad (2)$$

the benchmark year, value-added per employee in R&D active plants has increased by almost 38 per cent relative to an increase of 26 per cent in non-R&D active companies.

⁷¹ Specifically the Cobb-Douglas or Leontief production functions which restrict the size of the elasticity of substitution to one and zero respectively.

where the coefficient on the log of wages (σ) is the elasticity of substitution⁷² and the coefficient on the log of output (β) is a measure of the elasticity of labour demand with respect to output.

Equation 2 represents a static labour demand model. Van Reenan (1997) criticises the static model because it takes no account of adjustment costs. Adjustment costs are most easily described as the costs that firms face when hiring and firing labour. The presence of adjustment costs “*implies that labour demand is slow to adjust to shocks to equilibrium employment*” (Hamermesh, 1993, p.214). It is especially important in this context to account for adjustment costs because, as Meghir *et al.* (1995) argue, more innovative companies have relatively lower adjustment costs. Consequently, innovative companies can adjust their employment levels from one time period to another relatively more quickly than less innovative firms with higher adjustment costs. A standard approach to account for these adjustment costs is to include employment lags (L_{it-1}, L_{it-2}).

A standard approach to investigating the role of firm-level innovative activity on labour demand is to include some indicator variable of the firm’s innovative activity in the labour demand specification (Ross and Zimmermann, 1993; Leo and Steiner, 1995; Vivarelli *et al.*, (1996); Van Reenan, 1997 and Garcia *et al.*, 1998). For example, the basic stochastic form of the static labour demand model estimated by Van Reenan (1997, p.261) is

$$n_{it} = \alpha_1 INNOV_{it} + \beta_3 w_{it} + \beta_4 k_{it} + \tau_t + u_{it} \quad (3)$$

⁷² The interpretation of the coefficient on wages being an estimate of the elasticity of substitution is derived from Marshall’s first law of labour demand. Bosworth *et al.* (1996, p.105) summarise this law

where (n_{it}) is labour demand in firm i at time t , $INNOV$ is a proxy for the innovativeness of any particular firm, w_{it} is the average wage per employee, k_{it} is a measure of the capital stock, τ_t is a full set of time dummies and u_{it} is a white noise error term. Van Reenan captures the additional effect of innovative activity having controlled for the elasticity of substitution and other factors. The sign and size of the coefficient on innovative activity attempts to answer the question: do innovative companies have higher employment growth? However, this approach yields a limited understanding as to why labour demand growth might be different in innovative and non-innovative companies because it does not allow us to compare the coefficients on wages and output between both sets of firms. In contrast to the methodology adopted by many of the previous studies cited earlier, this chapter seeks to determine whether the more traditional parameters driving labour demand growth in individual firms are significantly different for R&D active and non-R&D active firms.⁷³ Therefore, Equation 4 is estimated separately for 147 R&D active firms and 1,174 non-R&D active firms.⁷⁴

The dynamic labour demand model that is estimated for non-R&D active and R&D active firms in this chapter is

and note that the “...demand for any particular factor is more elastic, the more readily substitutes for that input can be obtained (other things being equal).”

⁷³ Our approach is motivated in part by the observation that it appears that it is differences in sales and labour costs rather than technology that primarily determines labour demand in individual firms. For example, Zimmermann (1991) concluded that the main determinants of labour demand in order of decreasing importance were demand, technological progress and labour costs while Ross and Zimmermann (1993) estimated the influence of demand on employment to be only twice that of technological progress. Blechinger *et al.* (1997, p.70) concluded similarly that “[e]mployment is essentially determined by sales.” Therefore we want our approach to compare how the role of sales and labour costs differs across R&D active and non-R&D active firms respectively.

$$\ln L_{it} = \alpha - \sigma \ln w_{it} + \beta \ln Y_{it} + \lambda \ln L_{it-1} + \delta \ln L_{it-2} + \tau_t + I_{jt} + u_{it} \quad (4)$$

where labour demand (L_{it}) is total firm employment measured annually, average wages (w_{it}) are calculated annually by dividing the firm's total wage bill (deflated to 1984 prices) by the number of reported employees and output (Y_{it}) is proxied annually by the total sales (turnover) of the firm (deflated to 1984 prices).⁷⁵ We include two lags of the dependent variable in order to estimate a dynamic labour demand model (L_{it-1}, L_{it-2}). A full set of time dummies to account for macroeconomic changes (τ_t) and 4-digit NACE industry dummies (I_{jt}) are included to control for sector specific effects.

We allow for the fact that both wages and output may be endogenous in all regressions, (i.e., that output and wages might also depend on labour demand).⁷⁶ Therefore, established panel data estimators (i.e., the fixed or random effects estimators) cannot be used because of the endogeneity of the independent variables. Baltagi (1995, p.126) summarises the results of previous studies that have investigated the impact of endogenous variables on the fixed effects estimator and concluded that *"for the typical labor panel where N is large and T is fixed, the within estimator is biased and inconsistent."* The consequences are very similar for random effects estimators.

⁷⁴ The estimation dropped a number of R&D active and non-R&D active firms because of the shortened time period (1987-1997) over which the labour demand function is estimated by our estimation technique.

⁷⁵ The price indices used to deflate these variables are two-digit sectoral wholesale price indices published quarterly by the Irish Central Statistics Office. See CSO (1989, 1993, 1996, 1998d).

⁷⁶ Van Reenan (1997) assumes that wages are endogenous while any production function relates the level of output to the level of factor inputs such as labour.

Anderson and Hsiao (1981) suggest two steps to estimate correctly panel data models with endogenous variables. First, variables are ‘first differenced’ to eliminate the individual firm specific effects. Second, endogenous variables are ‘instrumented’ with appropriate instruments. However, in a first differenced specification the lagged dependent variables become endogenous and must also be instrumented. The method of estimation is the generalised method of moments estimator (GMM) proposed by Arellano and Bond (1991).⁷⁷ Konings and Walsh (1993, p.552) note that “*the advantage of GMM over other commonly used panel data estimation techniques, such as those proposed by Anderson and Hsiao (1981, 1982), lies in the more efficient use of the available instruments. Arellano and Bond (1991) show that in a first difference model, valid instruments for endogenous variables are the levels of the endogenous variables dated $t - 2$ and before.*” We, thus, instrument all endogenous variables using the levels of these variables dated $t - 2$ or before. Baltagi (1995), Arellano and Bond (1991) and Doornik *et al.* (1999) note that the consistency of the GMM estimator relies on the fact that there is no serial correlation in the levels of the error term ($v_{i,t}$). Doornik *et al.* (1999, p.8) argue that “[i]f the disturbances v_{it} are not serially correlated, there should be evidence of significant negative first order serial correlation in differenced residuals (i.e. $\hat{v}_{i,t} - \hat{v}_{i,t-1}$), and no evidence of second order serial correlation in the differenced residuals.” They propose two tests to determine the extent of any serial correlation in the errors. The first of these is a test for serial

⁷⁷ The package used is DPD. See Doornik *et al.* (1999) for the specifications of this package.

correlation.⁷⁸ Second, the validity of the variables used to instrument the endogenous variables is tested using the Sargan test of over-identifying restrictions.⁷⁹

4.4.2 Econometric Results

(i) R&D active vs. Non-R&D active companies

Equation 4 was estimated for R&D active and non-R&D active companies separately and the results are presented in Table 4.4 (Column 1 and 2). The estimates satisfy the Sargan test and the first test of serial correlation at the 5 per cent level. Two lags of employment to control for adjustment costs in changing labour demand were included. The sum of the coefficients on the lagged terms is less than 1, i.e., the models are dynamically stable (See Van Reenan 1997, p.268).⁸⁰

The elasticity of labour demand with respect to output is significantly positive for both subsets of plants. A one per cent rise in output will result in an increase in labour demand of 0.33 and 0.34 per cent for non-R&D and R&D active plants respectively. These elasticities are lower than those recorded for other European countries. Blechinger *et al.* (1997, p.50) estimated the elasticity of employment with respect to sales to be 0.77 for Germany, 0.65 for Denmark, 0.68 for France, 0.55 for Belgium and 0.55 for Spain. They note that that the size of this coefficient is decreasing in the percentage of small-medium sized enterprises (SMEs) in a country because SMEs

⁷⁸ The null hypothesis is the absence of first and second order serial correlation. We want to reject the null of first order serial correlation and accept the null of second order serial correlation.

⁷⁹ The test statistic is distributed as a χ^2 with $(p - k)$ degrees of freedom, where p and k are the number of instruments and regressors respectively. The null hypothesis is that the instruments are exogenous and hence valid instruments. We do not want to reject this null hypothesis.

⁸⁰ The coefficient on the second lag of employment is insignificantly different from zero, therefore, we interpret the value of this coefficient as zero and note that the sum of the two coefficients (.532 + .000) is less than unity.

*“operate at a level at which additional output can be produced with less additional labour and/or capital.”*⁸¹

The coefficient on average wages, estimating the elasticity of substitution, is negative and significant. At -0.323 and -0.386 for non-R&D active and R&D active companies respectively, these elasticities are below the results of other microeconomic studies surveyed by Hammermesh (1993, p.99). The studies of Sosin & Fairchild (1984) and Jones and Pliskin (1989) estimated elasticities of substitution using microeconomic data at 0.50 and 0.48 respectively. Verbeek (2000, p.335) suggests that elasticities of substitution estimated using microeconomic data are far in excess of those estimated using macroeconomic time series data. Layard *et al.* (1991) and Bean *et al.* (1986) quote aggregate elasticities of substitution for Ireland (assuming the share of labour in profits is 30 per cent) as 0.12 and 0.23 respectively. Consistent with Verbeek’s view, our estimates for both sets of plants are far in excess of these aggregate estimates for Ireland.

The elasticity of growth in labour demand with respect to output differs insignificantly across both sets of plants.⁸² The manner in which R&D active and non-R&D active plants have increased labour demand for a unit change in output is almost identical. However as documented earlier in Table 4.1, the average annual real turnover growth for R&D active plants was 4 per cent higher relative to non-R&D active plants. This four per cent differential with an elasticity of labour demand with

⁸¹ We do not have the necessary data to test this proposition.

⁸² This is based on a standard t test. The test statistic is calculated as $\left(\frac{\beta_{R\&D} - \beta_{non-R\&D}}{SE_{R\&D} - SE_{non-R\&D}} \right)$, where β is the coefficient on output in the estimated regression for R&D and non-R&D active companies

respect to output of 0.344 should lead to 1.38 per cent (i.e., $0.344 * 4$) higher employment growth in R&D active plants. In summary, we can expect employment growth to differ in R&D active companies because they have higher sales growth rather than because of any difference in the responsiveness of R&D active and non-R&D active firms in changing employment when output changes. The question remains as to why the change in labour demand with respect to output has been so similar in R&D and non-R&D active companies. In Section 4.2, we noted that Stoneman (1987) highlighted the importance of the elasticity of substitution on labour demand.⁸³

Our initial finding that the elasticity of labour demand with respect to output is insignificantly different between R&D and non-R&D active firms is supported by the similarity in the elasticities of substitution between labour and other inputs for both groups of plants. The difference in elasticities of substitution between both groups of plants is significant but small (0.063).⁸⁴ The responsiveness of both sets of plants to changes in the relative costs of labour to other inputs is almost identical. Thus there is no evidence to suggest that changes in the cost of labour relative to other factor inputs will impact differently on labour demand in R&D active and non-R&D active companies.

Although our approach to estimating labour demand for both groups of plants is different, our results are very similar to and consistent with those of the majority of

respectively and SE is the standard error of those coefficients. The t-test statistic is 0.424 which does not reject the null hypothesis of no difference in the coefficients at the 10 per cent level.

⁸³ The theoretical discussion in Section 4.2 also highlighted the degree of factor augmentation, the degree of economies of scale and the elasticity of demand as important explanatory factors. Unfortunately, data limitations do not allow us to estimate coefficients for these variables.

other studies that have estimated a weak or insignificant impact of innovative activity on labour demand at firm level. For example, Brouwer *et al.* (1993, p.158) found that R&D intensity in Dutch manufacturing plants is an insignificant determinant of employment growth. Klette and Førre (1995, p.15) concluded that there is no clear-cut positive relationship between R&D investment and net job creation. They noted *“[c]onsidering Norwegian manufacturing plants over the period 1982-92, we find that both at the industry and the plant level, the most R&D intensive units have declined in terms of jobs (i.e. employment) relative to the rest of the manufacturing sector.”* Leo and Steiner (1995, p.19) investigated Austrian plants and concluded that *“[t]here seems to be no clear-cut relationship between expenditures on innovations and subsequent employment behaviour at the firm level.”* Garcia *et al.* (1998) examined Spanish manufacturing plants. They estimated that a 1 per cent increase in the stock of knowledge leads to a final increment in labour demand of between 0.07 per cent and 0.11 per cent. However, our results offer no evidence to support the conclusions of Van Reenan (1997), who in a study of UK manufacturing plants, concludes *“[t]he main finding is that technological innovation was associated with higher firm-level employment in our data set...[t]his suggests that we really are capturing causality from technical change to jobs”* (p. 275).

(ii) Product Innovating vs. Process Innovating R&D active firms

A further step in our analysis investigates how labour demand differs for those R&D active plants engaged in process as opposed to product innovation. Approximately 55 per cent of all R&D expenditure in Irish plants between 1986 and 1997 has been

⁸⁴ The test statistic in this case is -3.316 which rejects the null hypothesis of no difference in the coefficients at the 1 per cent level.

applied to improving or developing products (i.e., product innovation).⁸⁵ The remainder of this investment has been invested in process innovation – the improvement or development of processes. As noted above in Section 4.2, the impact of product innovation on labour demand is expected to be unambiguously positive while the effect of process innovation is more ambiguous.

The dynamic labour demand equation for those R&D active plants that engage primarily in product innovation was estimated and the results are outlined in Table 4.4 (Column 3). The results for those plants engaged in process innovation are outlined in Column 4.⁸⁶ It is estimated that the growth in labour demand because of the growth in output is significantly larger in product-innovating R&D active companies.⁸⁷ The elasticity of labour demand with respect to output is 0.457 in product innovating companies and 0.264 in process innovating companies. These results are consistent with the findings of previous studies. For example, Brouwer *et al.* (1993, p.158) found that firms with a high share of product related R&D recorded an above average growth of employment. König *et al.* (1994) concluded that product innovations have an employment increasing effect at the firm level while there was no evidence that process innovations reduced employment. Leo and Steiner (1995, p.19) concluded for Austrian plants that “[a]lthough both types of innovation tend to increase subsequent

⁸⁵ A firm is engaged primarily in product innovation when in excess of fifty five per cent of their R&D investment is directed towards that purpose. 55 per cent represents the mean amount of R&D investment invested on product innovation over the period 1986-1997. A firm is primarily engaged in process innovation when less than 55 per cent of their R&D expenditure is directed towards that purpose.

⁸⁶ The consistency of the GMM estimator depends on the lack of serial correlation in the error term. There are two tests proposed to check for serial correlation in the errors, a test of second order serial correlation and the Sargan test. The estimation for process innovators passes the Sargan test and the second order serial correlation test is just significant at the 5 per cent level. We proceed to describe the results because the Sargan test is satisfied and the AR(2) test is only marginally significant at the 5 per cent level.

⁸⁷ The t-test statistic is -3.45. The t-test rejects the null hypothesis of no difference in the coefficients at the 1 per cent level.

employment these effects are weak, in particular in the case of process innovations.”

Van Reenan (1997, p.274) found that his results were “*consistent with the theoretical prior that product innovations should lead to greater job creation.*”

The difference in the elasticity of substitution may partly explain the difference in the elasticity of labour demand with respect to output between both sets of plants. Process innovating R&D active plants have a significantly larger elasticity of substitution (-0.497) relative to product innovating plants.⁸⁸ Labour and other factor inputs are relatively more substitutable for each other in process innovating R&D active plants. The suggestion can be made that the other factor inputs have been substituted for labour in process innovating plants. However, it is not possible to confirm this suggestion without estimating the demand for all other factor inputs in these plants.⁸⁹

4.5 Limitations of Approach

While the analysis in this chapter introduces some significant improvements on earlier studies, it suffers also from clear limitations. Our econometric analysis, and by extension the majority of previous studies, may have underestimated the impact of innovative activity on labour demand by focusing exclusively on the *quantity* rather than the *quality* of labour demanded. For example, Van Reenan (1997, p.275) comments on the general nature of results such as those we have presented above and the results of previous studies that “[w]e may actually be underestimating the effects of innovation as no controls have been made for the fact that innovators are more likely to survive than non-innovators.” Job persistence measures the percentage share of newly created jobs that subsequently survive for a given time period. Thus,

measures of job persistence can reflect innovative firms' superior probability of survival.⁹⁰ Non-innovating firms may have higher job creation rates relative to non-innovating firms (as reported earlier in Table 4.1), but with innovating plants surviving longer, the newly created jobs in innovating plants may themselves survive relatively longer. In Table 4.5 we present the mean job persistence rates by R&D activity for the period 1984-1998 based on the approach of Davis *et al.* (1996, p.21-26). The difference between R&D active and non-R&D active plants is striking. On average, 93.8 per cent of all newly-created jobs in non-R&D active companies survive one year. The corresponding estimates for five and ten years are 68.5 per cent and 34.8 per cent respectively. In contrast, on average 98.5 per cent of all jobs created by R&D active companies over the period 1984-1998 survive the subsequent 10-year period.

Secondly, our study has concentrated exclusively on the manufacturing sector. Vivarelli *et al.* (1996) concludes that focusing exclusively on the manufacturing sector emphasises the large labour-displacing effects of technology in manufacturing enterprises while compensation for these job losses through additional job creation outside the manufacturing sector is neglected. We have not accounted for any product and process innovations that 'spill-over' and create employment outside of the manufacturing sector.

⁸⁸ The t-test statistic is 25.57. The t-test rejects the null hypothesis of no difference in the coefficients at the 1 per cent level.

⁸⁹ We cannot undertake this exercise due to data limitations.

⁹⁰ In Chapter 3 we estimated, in a study of indigenous manufacturing enterprises, that the probability of survival of R&D-active plants over a ten-year period (1986-1996) was 86 per cent as opposed to 66 per cent for non-R&D active firms.

Thirdly, a related limitation arises because our estimation technique has concentrated on the effects of innovating on the labour demand choice of the individual firm. In adopting this approach we ignore the wider consequences of the diffusion of any innovation to other firms and the subsequent employment consequences for those firms (Klette and Førre, 1995, p.12). Vivarelli *et al.* (1996, p.1014) make a similar point noting that “[t]he use of establishment and firm data does not allow us to assess the overall employment impact of a given innovation...[a]ppplied researches which are based on firm data cannot claim to assess the overall impact of technical change, but are limited to consider the micro-effects of innovations.”

Fourthly, we have only considered technological innovation and its impact on labour demand and have not considered other sources of innovation: for example managerial or organisational innovations. In addition, we have measured the extent of innovative activity within a firm by its mean annual R&D expenditure. A well-known criticism of R&D expenditure is that it is an input into the innovation process and consequently it does not capture the success or failure of much of this investment. However, Klette and Førre (1995, p.3) suggest that “*this narrow focus is not uninteresting as a considerable amount of governmental subsidies is aimed at boosting (private and public) R&D investment with job creation as one primary objective.*” In contrast, Brouwer *et al.* (1993) and Van Reenan (1997) use a measure of innovative output at firm level. However, we suggest that these measures are also limited because they give no indication of the cost of a particular innovation. Other authors suggest using measures of technological activity that combine information on R&D expenditure and innovative output. For example, Blechinger *et al.* (1997) estimated a labour demand model for two groups of companies: innovating firms that did not invest in R&D and

innovating firms that also invested in R&D. They concluded that “[i]nnovation has no measurable impact on employment...[w]hat does really matter for employment in Europe, however, is whether innovative firms are engaged in R&D...so innovative seems to be too imprecise to measure employment impacts of innovations. It contains all types of innovations, some of them marginal, others of the more radical type” (p.50).

A final limitation arises from using the number of employees rather than the number of hours worked as a measure of labour demand. It has been noted that “[i]f the labour saving potential is implemented through the reduction of hours worked instead of a reduction in the number of employees, the extent to which the introduction of new technologies induces a decline in employment can be underestimated” (Blechingner *et al.* 1997, p.30).

4.6 Summary and Conclusions

In this chapter we have examined whether the R&D activities of indigenous firms has impacted negatively or positively on their labour demand. We investigated whether there was evidence of substantial job-less growth in technologically active companies relatively to less technologically active firms operating in the Irish manufacturing sector.

We estimated a dynamic labour demand model for a sample of indigenous non-R&D active and R&D active firms in the Irish manufacturing sector. It is estimated that that there is no significant difference in the elasticity of labour demand with respect to output between both subsets of plants. The extent to which labour demand differs

between both groups of plants is determined by their relative sales growth rates rather than a different propensity to increase employment as output increases. We found also that the elasticity of substitution between factor inputs is negligibly different in both groups of plants. This may partly explain the propensity of both sets of plants to increase employment by the same amount for a given increase in output.

A traditional question in the literature has been to what extent labour demand differs between product and process innovating R&D active plants. We do find significant differences in labour demand in these two sets of plants, a result that mirrors the results found in existing studies. The elasticity of labour demand with respect to output is significantly higher in product innovating companies relative to process innovating R&D active firms. We suggest that this may be explained partly by the fact that the elasticity of substitution across factor inputs is relatively much lower in product innovating plants.

Our analysis supports the results of many previous studies (with the exception of Van Reenan, 1997) that found an insignificant relationship between innovative activity and labour demand. We extended the analysis of previous studies and we examined differences in the quality of jobs created in R&D active and non-R&D active plants. The persistence of newly created jobs was found to be significantly higher in R&D active plants, only one third of all jobs created in non-R&D active plants compared with almost all newly created jobs in R&D active firms survive for ten years.

In summary, we find no evidence that investment in innovative activity destroys jobs. We confirm the results of previous studies which found that technological activity

appears to be a relatively insignificant determinant of the quantity of labour demanded. However, in analysing the quality of labour created, we found the quality of labour demanded (as measured by job persistence) depended significantly on a firm's investment in research and development. While R&D active firms may not create substantially more employment, the employment those firms create persists for a relatively longer period.

4.A Tables

Table 4.1: Annual rate of Job creation, Turnover growth and Average Profit Margins for all Plants that Increase Employment Over Two Subsequent Years, by R&D Activity, 1985-1997

Job Creation Rate			Turnover Growth Rate			Mean Profit Margin		
Year	Non-R&D firms	R&D firms	Year	Non-R&D firms	R&D firms	Year	Non-R&D firms	R&D firms
1985	0.07	0.07	1985	.12	.10	1985	.09	.11
1986	0.08	0.07	1986	.10	.08	1986	.07	.06
1987	0.08	0.07	1987	.11	.09	1987	.09	.09
1988	0.10	0.08	1988	.13	.18	1988	.10	.10
1989	0.11	0.09	1989	.11	.20	1989	.10	.10
1990	0.10	0.08	1990	.13	.15	1990	.10	.10
1991	0.08	0.06	1991	.09	.13	1991	.10	.11
1992	0.08	0.09	1992	.11	.17	1992	.11	.11
1993	0.08	0.07	1993	.06	.17	1993	.11	.09
1994	0.09	0.07	1994	.17	.17	1994	.11	.09
1995	0.10	0.07	1995	.11	.20	1995	.11	.11
1996	0.10	0.06	1996	.10	.15	1996	.11	.10
1997	0.10	0.08	1997	.12	.18	1997	.12	.11
1998	0.09	0.08	1998	n/a	n/a	1998	n/a	n/a
Mean	0.09	0.07		0.11	0.15		0.10	0.10

Source: Own estimates based on *Forfäs* data.

Table 4.2: The Average Value-added per Employee for R&D and non-R&D Active Plants

Year	Value-Added per employee ¹	
	Non-R&D	R&D
	Firms £	Firms £
1984	21,100	37,900
1985	21,600	35,600
1986	22,700	38,400
1987	24,300	47,400
1988	26,600	59,300
1989	27,000	45,100
1990	25,900	47,800
1991	22,900	46,400
1992	23,200	58,500
1993	24,000	69,000
1994	27,000	72,400
1995	26,300	52,200
1996	26,600	52,200
1997	29,100	68,900
Mean	24,879	52,221

Source: own estimates based on *Forfäs* data.

Note: ¹ Deflated using 2-digit sectoral deflators. See CSO (1989, 1993, 1996, 1998d).

Table 4.3: Summary Statistics for Regression Variables

<i>Variable</i>	Number of Observations	R&D Active	Non-R&D Active	All Firms
		Mean (Standard deviation)		
L_{it}	101,682	72.7 (135.12)	12.6 (38.3)	14.7 (46.58)
w_{it} (£'000s)	7,643	19.7 (33.7)	11.3 (15.3)	12.52 (19.42)
Y_{it} (£'000s)	7,760	23,401.67 (59,890.77)	4895.8 (13912.35)	7633.5 (27172.34)
L_{it-1}	101,682	71.4 (139.0)	12.7 (38.7)	14.69 (47.25)
L_{it-2}	101,682	70.2 (143.7)	12.7 (39.4)	14.73 (48.17)
$R \& D \text{ Spend}_i$ £'000s	18,928	301.5 (425.1)	0	79.2 (212.86)

Source: Own estimations.

Table 4.4: Econometric results: Dynamic Models of Labour Demand for (i) non-R&D Active and R&D Active firms and (ii) Product innovating and Process Innovating firms

Log Employment	GMM (1)	GMM (2)	GMM (3)	GMM (4)
	Dynamic Model	Dynamic Model	Dynamic Model	Dynamic Model
	<i>Non-R&D active plants only</i>	<i>R&D active plants only</i>	<i>Product Innovating R&D active plants only</i>	<i>Process Innovating R&D active plants only</i>
$Output_{it}$	0.330*** (.053)	0.344*** (.086)	0.457*** (.057)	0.264** (0.113)
$Wage_{it}$	-0.323*** (.059)	-0.386*** (.078)	-0.318*** (0.087)	-0.497*** (.080)
$Employment_{t-1}$	0.485*** (.045)	0.532*** (.068)	0.409*** (0.061)	0.527*** (.084)
$Employment_{t-2}$	0.045*** (.015)	-0.002 (.027)	-0.031 (0.022)	0.046 (0.040)
Time Dummies	Yes	Yes	Yes	Yes
Number of firms	1,027	147	92	55
Number of observations	4,914	884	521	363
<i>Variables Instrumented</i>	Wages, Output, Lags of Employment	Wages, Output, Lags of Employment	Wages, Output, Lags of Employment	Wages, Output, Lags of Employment
Wald (Joint)	2862.00	43310.00	2905.00	752.9
(<i>p</i> – value)	(0.000)	(0.000)	(0.000)	(0.000)
Sargan Test	256.3	126.7	79.50	40.46
(<i>p</i> – value)	(0.088)	(1.000)	(1.000)	(1.000)
AR (1)	-6.844	-6.408	-4.082	-2.709
(<i>p</i> – value)	(0.0000)	(0.0000)	(0.0000)	(0.007)
AR (2)	-0.446	(-0.270)	0.8313	-1.978
(<i>p</i> – value)	(0.656)	(0.787)	(0.406)	(0.048)

Note: *** significant at 1 per cent level, ** significant at 5 per cent level. Standard errors in ().

Table 4.5: The Mean Job Persistence Rates of R&D Active and non-R&D Active Plants Over the Period, 1984-1998

Time (years):	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
	%	%	%	%	%	%	%	%	%	%
Non-R&D Firms	93.8	87.0	80.4	74.4	68.5	61.1	53.7	47.7	41.6	34.8
R&D Firms	99.0	98.9	98.9	98.7	98.6	98.5	98.5	98.5	98.5	98.5

Source: Own estimates based on *Forfás* data.

CHAPTER 5

THE TANGIBLE CONTRIBUTION OF R&D SPENDING FOREIGN-OWNED PLANTS TO A HOST REGION: A PLANT LEVEL STUDY OF THE IRISH MANUFACTURING SECTOR (1980-1996)

5.1 Introduction

Following a period of recession, the Irish economy has enjoyed significant growth over the past decade, earning Ireland its “Celtic Tiger” nickname. This growth, both in employment and output terms, is most marked in the manufacturing sector. The contrast in employment growth is primarily with EU countries, which have seen employment in manufacturing rise by 0.5 per cent since 1986,⁹¹ while employment in the Irish manufacturing sector during the same period has risen by 5.4 per cent. A key feature of Ireland’s growth has been the expansion of foreign-owned plants which now account for 12 per cent of total manufacturing firms in the country and 45.5 per cent of manufacturing employment.⁹² The growth in employment has been concentrated in high-tech sectors, where employment has more than doubled since 1986;⁹³ these sectors in 1996 accounted for 62 per cent and 17.4 per cent of total manufacturing employment in foreign and Irish-owned firms respectively. Output data for 1996 show that output of foreign-owned manufacturing firms accounts for 77.1 per cent of net manufacturing output (CSO, 1998a). In 1995, 65 per cent of national business expenditure on research and development (BERD) in Ireland was

⁹¹ European Commission (1997) and European Commission (1991).

⁹² Unless stated otherwise, all reported figures are based on own calculations of Forfás Employment Survey Data.

⁹³ Employment growth rates in the US and Canadian manufacturing sectors in the same period were 6.2 per cent and 7.5 per cent respectively (OECD, 1996).

accounted for by subsidiaries of foreign multinational firms.⁹⁴ This contrasts sharply with estimates for other European countries: 37 per cent for Great Britain, 16 per cent for Germany and less than 10 per cent for Greece (OECD, 1998).

The rapid growth of the Irish economy over the past decade and the simultaneous increase in (i) the number of foreign-owned plants in the high-tech sectors, and (ii) the research and development (R&D) activities of foreign-owned plants, has given rise to an increased interest in the relationship between foreign direct investment (FDI) and economic growth in Ireland. The issue arises as to whether the growth is linked to the *sectors* in which FDI is taking place or whether the technological performance of *individual plants* is a significant contributory factor. In particular, an important question is whether those foreign-owned plants that are undertaking R&D activities in their Irish plants are contributing more to the host region relative to those plants that undertake no R&D activities.

The exploration of plant-level technological activity in multinational corporation (MNC) plants and their contribution to the host economy is a hybrid of two literature traditions. The first relates to the internationalisation of R&D activity. Many authors in this tradition have debated the true extent of this internationalisation (Belitz and Beise, 1997; Braunerhjelm and Ekholm, 1997; OECD, 1998) and the tangible and intangible effects of this trend on host economies (Blomström and Kokko, 1998; Beise *et al.*, 1998). The second tradition are studies of the attraction of FDI to a host

⁹⁴ See Forfás (1997).

region (Dunning, 1988; Lall, 1993 and Caves, 1996) and specifically to Ireland (Foley and McAleese, 1991; Ruane and Görg, 1996).⁹⁵

In this chapter we undertake a plant-level empirical analysis of the tangible effects of MNC technological activities, focusing on R&D aspects. Specifically, we use our plant-level dataset to explore different measures of R&D activity undertaken by foreign-owned plants in Ireland. These empirical measures, derived from plant-level data, provide a new perspective on the extent of these R&D activities. The central question explored in this chapter is whether the tangible contribution of MNC plants which undertake R&D investment in Ireland is greater than the tangible contribution of MNC plants which undertake no R&D investment, where tangible contribution is measured in terms of plant survival and employment generated. We conclude that R&D active MNC plants in Ireland have (i) a higher probability of remaining operational in Ireland for a given time period,⁹⁶ and (ii) create a higher quantity and quality of employment, relative to non-R&D active MNC plants.

Section 5.2 describes our plant-level dataset. In Section 5.3 we present estimates of the R&D activities of MNCs in Ireland, and compare these with the aggregate statistics provided by the OECD. In Section 5.4 we outline our expectations concerning the relationship between investment in R&D and the subsequent performance of MNC subsidiaries in Ireland. In Sections 5.5 and 5.6 we compare the survival experiences and the employment performance respectively of R&D active

⁹⁵ Studies of its subsequent effects on the Irish economy include McAleese and MacDonald, 1978; O'Farrell and O'Loughlin, 1981; Barry and Bradley, 1997 and Ruane and Görg, 1999.

⁹⁶ We do not test the alternative hypothesis that the probability of a given plant undertaking R&D expenditures is increasing in the plant's age, i. e., that survival affects R&D expenditure rather than vice versa. See Beise *et al.* (1998).

MNCs, relative to non-R&D active MNCs. The final section contains a short summary and some conclusions.

5.2 Data & Sectoral Classification

The data set explored here is a unique combination of two sources. The R&D data are drawn from a series of surveys of R&D performing plants, undertaken by Forfás, the policy and advisory board for industrial development in Ireland. This organisation has statutory responsibility for R&D statistics in Ireland. For the years 1986 to 1995, the biannual surveys reported data on the population of R&D performers with ten or more employees in the manufacturing and internationally-traded services sectors.⁹⁷ The employment data (1980-1996) are drawn from the annual employment surveys undertaken by the same agency. Similar to the R&D data, these employment surveys cover the population of plants in the manufacturing and internationally traded service sectors.⁹⁸ The employment survey data cover all plants and in matching the two Forfás surveys, we have excluded any plant with less than ten employees through the period 1980 to 1996.⁹⁹ In the analysis that follows, where a variable is not available for all of the surveys of technology in industry, we report the last year for which that variable is available. For example, when estimating the percentage of R&D spend that is invested in experimental development, we note that this information is available for the period 1986-1993 only.

⁹⁷ The biannual surveys switched to odd number years in 1991, thereby following immediately after the 1990 survey of technology in industry. Forfás estimates a response rate close to 100% for this survey. There is an additional survey of innovation in Irish manufacturing in 1992.

⁹⁸ The response rate is greater than 90% for this survey (Strobl, 1996).

⁹⁹ Forfás was established in 1993 and involved the merger of the planning division of the Industrial Development Authority (IDA) which began its employment surveys in 1973 and the Science and Technology Division of Eolas, which began its R&D surveys in 1967.

We define an MNC plant or a foreign-owned plant as any plant where in excess of fifty percent of the equity is held by non-Irish residents - this is the classification used in both surveys. Because a plant's current (i.e., 1996) nationality only is maintained in the dataset, we are unable to take account of any changes in ownership during the period 1980-1996.¹⁰⁰

Throughout this chapter we use the OECD sectoral classification to aggregate sectors into four groups:¹⁰¹

- **High-tech:** Aerospace, Computers & Office machinery, Electronics & Communications, Pharmaceuticals;
- **Medium-High-tech:** Scientific Instruments, Electrical Machinery, Motor Vehicles, Chemicals, Non-electrical machinery;
- **Medium-low-tech:** Shipbuilding, Rubber & plastic equipment, Other transport equipment, Stone, clay & glass, Non-ferrous metals, Other manufacturing, Fabricated metal products;
- **Low-tech:** Petroleum refining, Ferrous metals, Paper & printing, Textiles & clothing, Wood & furniture, Food & beverages.

We use higher-tech or higher technology sectors as a term encompassing both the high-tech and medium high-tech sectors. The use of lower-tech as a summary term refers to both the low-tech and medium low-tech sectors.

We classify a plant as being "R&D active" where that plant has reported at minimum an average annual R&D investment of £25,000 over the period 1986-1995. Plants with an annual mean of £100,000 or over in R&D spend over this period are classified as "large R&D spenders".

¹⁰⁰ The effect of this is that some indigenous firms which are taken over by foreign-owned firms during that period are classified as foreign firms.

¹⁰¹ For the ISIC equivalent classification, see Appendix B in Klette and Johansen (1995).

5.3 The evolution of Irish Industrial Policy towards FDI

Gray (1997) provides the most optimistic evaluation of the importance of FDI in the Irish economy, “[i]t is probably not an exaggeration to say that the growth in foreign investment is at the heart of the Irish economic miracle.” Ruane and Görg (1999) summarise the evolution of Irish FDI policy in three steps:

(i) An active policy of attracting FDI came into operation initially in the 1950s. Before this time FDI had been legislatively prohibited.¹⁰² The objectives of embracing a pro-FDI policy were to generate a viable manufacturing sector and to provide employment. Export-orientated foreign-owned projects in all sectors of manufacturing were eligible for fiscal and financial support, on the same basis as indigenous projects, if they located in Ireland.¹⁰³

(ii) The second step occurred in the 1970s. The national industrial development agency, the IDA, became increasingly selective about the industries in which potential FDI projects should be sought. The electronics and pharmaceutical sectors were singled out as having the best global prospects for fast and sustained growth. In particular US companies were targeted as sources of these projects.

(iii) The third step involved the promotion of linkages between foreign and indigenous industry in these key sectors, and the promotion of Ireland as the European base for head-quarter and R&D functions of MNCs. Those plants which locate these functions locally are believed to have a higher commitment to Ireland, reflected in the generation of a higher quantity and quality of employment relative to plants which

locate only their production facilities in Ireland. Global companies operating in the higher technology sectors were perceived as having a larger probability of undertaking significant R&D activities relative to companies operating in the lower technology sectors,¹⁰⁴ where R&D activities are not perceived as being as important globally.¹⁰⁵

These refinements to FDI policy over time have manifested themselves in (i) a concentration of current FDI in high-tech sectors, and (ii) an increased propensity for foreign-owned plants to undertake R&D activities in Ireland. We now turn to look at one explanation for the increasing concentration of FDI in high-tech sectors, namely, the higher rate of entry of foreign-owned plants into the high-tech sector.

5.3.1 Plant Entry into High-tech Sectors

As we can see from Table 5.1, there was an increase of over 50 per cent in the number of foreign-owned manufacturing plants in Ireland over the period 1980-1996. This increase disguises the extensive net change in plant numbers in different sectors; ranging from over 150 per cent in the high-tech sector to less than 10 per cent in the low-tech sector. In terms of net job creation, this change in plant numbers accompanied a net increase of 22,505 (32.5 per cent) jobs in the foreign-owned plants. Mirroring the experience in plant numbers, this net increase resulted from a combination of 27,683 additional jobs created in both higher-tech sectors with a loss

¹⁰² This prohibition was supported by the public perception of a link between economic dependence and the country's colonial past.

¹⁰³ For a discussion of policy development see White (1982) and Killeen (1975).

¹⁰⁴ One exception here is the food sector, which although classified by the OECD as a relatively low-tech sector, has a high level of R&D expenditure in Ireland.

¹⁰⁵ de Arcos *et al.* (1997) summarise step one as dependent FDI (an emphasis on assembly plants) and the following two steps as an evolution towards developmental FDI (an emphasis on plants which can forge linkages with indigenous industry and create high skilled employment).

of 5,358 in both lower-tech sectors. In terms of the number of employees, the period 1980-1996 saw FDI in the higher technology sectors become the dominant form of FDI in Ireland, as the share of employment in high-tech MNCs rose from almost 15 per cent to over 30 per cent.

The overall change in the number of plants is the net result of plant entry and exit. We summarise in Table 5.2 the entry pattern of foreign-owned plants into the Irish manufacturing sector over the period 1980-1996. A mean annual entry rate is calculated using methodology outlined in Davis and Haltiwanger (1990).

The plant population size is defined in the manufacturing sector as

$$a_{Et} = \frac{P_{Et} + P_{Et-1}}{2} \quad (1)$$

where P_{Et} is the number of plants in category¹⁰⁶ E at time t and a_{Et} is the average number of plants in this category over the period t-1 to t. The number of births is calculated as the number of plants alive in category E at time t that were not alive in category E at time t-1. The birth rate is defined as follows

$$B_{Et} = \frac{b_{Et}}{a_{Et}} \quad (2)$$

¹⁰⁶ Examples of these categories could be sector, age category or size category.

where B_{Et} , the birth rate, is a measure of the extent of entry into an industry (1980-1996). Over this period, there was a mean annual birth rate for all plants of 4.6 per cent. Disaggregating these plants by sector, we find that the mean annual entry rate in the high-tech sector is significantly higher than those in the less technologically-sophisticated sectors.

5.3.2 R&D Activity and Foreign-owned Plants in Ireland

A key question is whether this increase in the number of plants in the high-tech sectors was accompanied by an increase in the R&D activities of foreign-owned plants. The latest OECD report (June 1998) on the internationalisation of industrial R&D provides estimates of the importance of R&D expenditure of foreign affiliates as a percentage of total industrial R&D in a range of host economies.

Amongst a selection of OECD countries, Ireland has the largest share of industrial R&D accounted for by foreign affiliates as shown in Table 5.3, by a factor of almost two. The country's unique position in terms of the scale of R&D activity accounted for by MNCs is attributed by the OECD to the combination of (i) very low levels of R&D spend by indigenous plants in the Irish manufacturing sector and (ii) the relatively large presence of foreign multinationals in the Irish manufacturing sector generally (OECD, 1998, p.18). The OECD also estimates the intensity of the R&D investment by MNCs across countries. We note from Table 5.3 that Ireland has a lower R&D intensity than many of the other countries, with the exception of the Netherlands (OECD, 1998, p.22).¹⁰⁷ There are two possible explanations for this low intensity. Firstly, the small numbers of foreign-owned plants undertaking R&D

relative to the total number of such plants in Ireland. Thus, when all foreign-owned plants are aggregated, we arrive at a relatively high total for manufacturing turnover and a relatively smaller total for R&D spend. An alternative measure of R&D intensity would involve aggregating over only those plants that undertake R&D expenditure. Secondly, the turnover figures reported by MNCs in Ireland may be artificially high relative to the true level of value added and production that takes place in Irish plants, to the extent that foreign subsidiaries engage in profit-switching transfer pricing.¹⁰⁸ If this is the case, our estimates of R&D intensity would be underestimated. We do not have the same concerns regarding the R&D figures reported by MNCs in Ireland. Indeed, the low corporation tax rate, which limits the value to foreign-owned plants of write offs against R&D expenditures, reduces the incentive for foreign-owned plants to undertake R&D expenditures in Ireland, and may itself explain the relatively low rate.

To look at the dispersal of foreign affiliate R&D spend in Irish manufacturing, we disaggregate by sector. Table 5.4 compares the national share of R&D spend (both manufacturing and some non-manufacturing) 1986 and 1995 (Forfás, 1997¹⁰⁹). R&D spend by MNCs is predominantly in the higher technology sectors. In 1986 all foreign plants accounted for 66 per cent of total business expenditure on research and development in Ireland. Of this 66 per cent, two thirds was expended in both of the higher-technology sectors. Again in 1995, the pattern is similar, as real rates of growth were almost identical across all sectors over the period 1986-1995. The

¹⁰⁷ R&D intensity is calculated as total R&D spend of all foreign affiliates divided by the sum of manufacturing turnover produced by all foreign affiliates.

¹⁰⁸ Profit-switching transfer pricing is a mechanism whereby foreign subsidiaries report a higher value of their sales (profits) in Ireland to avail of the low corporation tax rate as discussed in Stewart (1989) and Murphy (1998).

OECD, on the basis of a further (unpublished) disaggregation of the Irish high-tech sector into sub-sectors, reports that foreign affiliates were responsible in 1993 for 95 per cent of national R&D spend in the pharmaceutical sector, 78 per cent in the computer software industry and 64 per cent in the car industry (OECD, 1998, p.68).

We use plant-level data to summarise the incidence and intensity of R&D activity in foreign affiliates in Ireland. Tables 5.5 and 5.6 show the percentage of the population of foreign-owned plants with ten or more employees undertaking R&D in 1986 and 1993, the latest year for which the data are available.

Table 5.5 takes the population of 691 foreign-owned plants with ten or more employees in 1986. Approximately 14 per cent of these plants engaged in a minimum amount of R&D spend in 1986 in the Irish manufacturing sector.¹¹⁰ The mean R&D spend per plant was £400,000 and the mean number of R&D personnel employed in R&D was 13 persons per plant.¹¹¹ Of the total population of foreign-owned plants, less than ten per cent had a formal R&D department. Using a subset of the population of R&D spending plants for which sales information is available, we calculated that the mean intensity (R&D Spend / Sales) of the foreign-owned R&D-active plants was 4 per cent. This estimate of R&D intensity for R&D-active foreign-owned plants is significantly higher than the aggregate OECD estimate (which covers all plants) of 1.17 per cent for Ireland reported in Table 5.3.

¹⁰⁹ The dataset used in this table include some non-manufacturing plants (i.e., internationally traded services).

¹¹⁰ This is at least £25,000 Irish punts (the salary for one researcher).

¹¹¹ This figure does not represent full time equivalents. This is the number of people who have some involvement in R&D activities without accounting for the time with which they are involved.

It is possible to disaggregate these totals further by nationality of ownership. We divide our population of plants on the basis of whether their parent plant is located in Europe, North America or Asia-Pacific.¹¹² The European plants comprise the largest single group of foreign-owned plants in the Irish manufacturing sector. However, only 10 per cent of these plants conducted R&D in 1986 compared with almost 20 per cent in the other two categories. In terms of mean R&D spend and R&D intensity (R&D spend as a percentage of sales) per plant, the North American plants had a mean equal to three times that of the Asian-Pacific owned plants and over twice that of the European contingent. Correspondingly the North American plants had the highest mean number of R&D persons per plant. Using this plant level analysis, North American plants appear to be the most R&D active of all foreign-owned plants.¹¹³

Table 5.6 shows the equivalent data for 1993. In 1993, the number of plants with ten or more employees was slightly lower at 686 plants, while the percentage of those plants doing a minimum level of R&D increased to over 24 per cent. The mean R&D spend per plant is £590,000 Irish pounds, a real increase of 47.5 per cent over the equivalent 1986 value.¹¹⁴ The mean number of R&D personnel in these plants increased fourfold from a mean of 13 persons in 1986 to 62 persons in 1993.¹¹⁵ Overall the percentage of plants with a formal R&D department increased to approximately 15 per cent. The mean R&D intensity is 3.9 per cent, similar to the 4 per cent reported in 1986. In summary, the percentage of foreign-owned plants

¹¹² We define Asia-Pacific as a term summarising plants from Australia and Asia.

¹¹³ US R&D investment in Irish subsidiaries accounts for 5.6% of all US R&D investment in Europe. The equivalent share of manufacturing turnover is 2.4%. Calculating R&D investment as a percentage of turnover, the US plants invest a greater percentage of their turnover in R&D in Ireland (2.5%) than in any other European country. The second highest plants are those in Germany which invest 2.0% of their turnover in R&D (OECD, 1998, p.99).

¹¹⁴ The consumer price index is used to deflate the annual R&D investments.

reporting R&D expenditure and the scale of that expenditure has increased over the period.

Similar to the situation outlined in 1986, there are significant differences when we distinguish plants by their nationality of ownership. Both categories of non-European plants have a higher average number of plants undertaking R&D spend. The highest percentage is for North American plants, with almost 30 per cent undertaking some R&D spend. North American plants also undertake a scale of annual R&D investment that is four times the level of European and other Non-European plants. They also have the highest R&D intensity (4.7 per cent) followed by the European plants (3.2 per cent). This slight decrease for the North American plants reflects the fact that their scale of R&D investment has not increased as fast as their sales over this period. The mean R&D personnel is 80 persons for North American plants, a five-fold increase from 1986. The corresponding estimate for European plants is 49 persons, equivalent to over a four-fold increase in personnel from 1986. North American plants are more likely to have a formal R&D department (18 per cent) compared with plants from Europe and Asia-Pacific (14 per cent).

5.4 Tangible Contribution of Foreign-owned Plants to the Host Region

The importance of foreign-owned firms in national R&D activities reflects at least in part state policy in attracting the subsidiaries of companies operating in highly R&D intensive and globally fast-growing industries. The policy of supporting plants in high-tech sectors and the desire for R&D activities in all plants was designed to ensure (i) a deepening of the plant's commitment to Ireland as measured by the lower

¹¹⁵ This measures the number of people who have some involvement in R&D activities without accounting for the time with which they are involved. In other words, it does not measure full time equivalents.

propensity to exit of R&D active relative to non-R&D active plants and (ii) a higher quantity of high income jobs created as measured by a higher level of job persistence in R&D active relative to non-R&D active plants.

Why would an R&D active plant have a higher commitment to the host region than a non-R&D active plant? Essentially much of the investment in R&D is a sunk cost, to which there are two elements. First, there is the percentage of annual R&D investments that are undertaken in capital goods, such as specialised buildings and equipment for research purposes. There is a high probability that these items are location specific, so that if a plant were to withdraw, much of the value of these facilities would be lost. The second element is the employment of R&D personnel. Although labour is considered to be mobile, a certain percentage of R&D personnel in a plant will not move with the plant.¹¹⁶ In effect, R&D active plants face higher costs to exiting from the host region than do non-R&D active MNCs.

Why would foreign-owned plants which undertake R&D in Ireland be expected to create more employment and higher quality employment in Ireland relative to non-R&D-active MNCs? We conjecture that the quantity of employment in a plant is a function of its output and that companies which expand output do so by improving their product and/or increasing the range of products which they produce. Improvements in the product range is achieved by undertaking experimental R&D, facilitating adaptation to meet the requirements of the foreign plants' markets. The Forfás surveys indicates that, on average, 63 per cent of all R&D spend by MNC plants in Ireland is for experimental development. Thus we expect that plants

undertaking experimental R&D to have relatively higher production levels, and, by extension, greater employment than plants which do not.

There are several reasons why the employment generated might be of a higher quality. The first reason is simply that skilled R&D personnel will be employed directly, which will typically not be the case in a non-R&D active plant. The second reason is that plants which undertake R&D in Ireland are hypothesised (confirmed later on) to remain operational in Ireland for longer time periods than plants which do not undertake R&D. Thus there is a higher probability that an individual job that is created today will exist for longer than an equivalent position in a non-R&D active plant. Thirdly, plants which undertake R&D as an input into the innovation process typically also invest heavily in other aspects of innovation. Breathnach and Fitzgerald (1994) noted that R&D expenditures in 1990 amounted to 36 per cent of all expenditure undertaken by foreign-owned plants on innovation. These plants spent a further 3 per cent on patents and licences, 31 per cent on product design, 21 per cent on trial production and 8 per cent on market analysis. Thus plants which engage in R&D activity seem to engage in these other categories of innovative activity, in order to apply the fruits of their R&D activities commercially. All of these activities require highly-skilled individuals, the demand for whom would be much greater than in an assembly plant.

¹¹⁶ de Arcos *et al.* (1997, p.4) cite a MERIT interview where the manager of a plant concluded that key R&D personnel would not be willing to move to the US with the firm, thus the firm would not relocate.

5.5 Duration of MNC's in Irish manufacturing

5.5.1 Lifetable Analysis

Underlying the policy of attracting (a) FDI in higher-technology sectors and (b) R&D spending plants as opposed to non-R&D spending plants, is the belief that these plants will have a higher probability of success and hence a lower propensity to exit the Irish manufacturing sector. Figure 5.1 shows us the probabilities of survival of all MNC's in the Irish manufacturing sector, in the 1980-1996 period.¹¹⁷

The survival function, based on 1,515 MNC's between 1980 and 1996, summarises the survival experiences of foreign-owned plants for each of the four OECD subsectors. This analysis is based on all MNC plants with ten or more employees in 1980 and any new MNC plant which entered between 1981 and 1996. For those plants alive in 1980, we measure their survival time in the number of years they survive post-1980. For those plants which entered post-1980, we measure their survival time as the number of years they existed post-entry. A plant can have remained operational (survived) for a maximum of seventeen years (1980-1996) or a minimum of one year.

We note the growing gap between sectors the longer the time period we consider. The probability of a plant remaining in operation in Ireland for the full seventeen years is positively related to the level of technological sophistication of the sector in which it operates. From the data underlying Figure 5.1, we can derive Table A5.1 (in the appendix) which shows the estimated probabilities that a plant in a given sector will

¹¹⁷ These probabilities have been estimated using lifetable analysis, a technique which permits the estimation of the probability of an event (exit) occurring at different time (years) points. It allows for the fact that not all plants will have exited during the period of observation. Lifetable analysis allows a cohort to be distinguished by one characteristic only and the differing probabilities to be estimated for each group.

survive 5, 10 or 17 years over the period 1980-1996. The longer the time period considered *ex ante*, the lower the probability of the plant remaining operational (surviving) in Ireland for one additional year.¹¹⁸ The probability of all foreign-owned plants surviving 17 years in the Irish manufacturing sector is approximately 47 per cent, compared with 55 and 70 per cent probability respectively for five and ten years between 1980 and 1996. However, these probabilities differ across sectors with the highest probabilities of survival recorded for firms operating in the high tech sector. For example, the probability of foreign plants remaining operational for ten years in Ireland in the high-tech sector is almost 64 per cent in contrast to 48 per cent for foreign plants operating in the low-tech sector.

An equivalent analysis can be undertaken on a cohort of MNC's classified as non-R&D spending plants or as R&D spending plants, but only for the shorter time horizon of 1986-1996, because of the shorter duration which our R&D data cover relative to the employment data in the previous lifetable analysis.

Taking a cohort of plants (ten or more employees in 1986) it is possible to examine whether the average annual R&D spend of a foreign-owned plant had any bearing on the probability that the plant remained operational (survived) in Ireland over the period 1986-1996. Figure 5.2 illustrates the two survival functions graphically, for R&D-spending subsidiaries and non-R&D spending subsidiary plants, respectively. Those foreign-owned plants which engage in R&D spend have a greater probability of remaining in Ireland for a given time period than non-R&D spending plants. The probability of a non-R&D-active MNC remaining ten years is over 60 per cent (Table

¹¹⁸ This result is consistent with the findings of Audretsch (1991,1995) for new entrant plants in the

A5.2) relative to an equivalent probability of almost 90 per cent for R&D spending plants. When we make a distinction within R&D spending plants according to the scale of R&D spend (Figure 5.3), we find that the probability of a plant remaining in Ireland for a given time period increases with the scale of R&D activity. In Table A5.2 we see that the probability of a large R&D spender remaining in Ireland for ten years is over ninety per cent relative to eighty five per cent for a small R&D spender and relative to sixty one per cent for a non-R&D spending MNC.

5.5.2 A Cox Duration Model

A limitation of the lifetable analysis above is its inability to distinguish plants by more than one characteristic; in particular, we are unable to distinguish the R&D spending plants by other characteristics, such as plant size and age. The Cox duration model (1972, 1975) estimates the risk of exit (hazard) facing a plant in our cohort as a function of plant and sectoral explanatory variables. This proportional hazards model takes account of duration heterogeneity, i.e., the differing lengths of time over which our plants remained operational post-1986. The hazard is the conditional probability of a plant leaving the manufacturing sector at duration t . The hazard rate is the rate at which a plant exits during period t given that it has survived until time t , i.e., it measures the risk of exit for a plant during the next year. We obtain a baseline hazard function, $h_0(t)$, which is estimated when all of the explanatory variables (covariates) are set at zero. It is an estimate of the risk of exit facing each plant in the cohort in each year 1986-1996. The Cox model then estimates the influence of each of our explanatory variables on this baseline hazard function, distinguishing whether the hazard of a plant exiting at a moment in time has increased or decreased when an

USA and in Chapter 3 of this thesis for Irish indigenous industry.

explanatory variable is nonzero. A negative (positive) coefficient indicates that this baseline risk of exit at a moment in time is reduced (increased).

In order to use the proportional hazards Cox model, we must assume that the ratio of the baseline hazard function $h_0(t)$ and the estimated hazard function $h(t)$ (when an explanatory variable is included) is proportional across time. This implies the contribution of the explanatory variable to the risk of exit does not vary across time but can vary across sectors. In our case, the contribution of R&D activity to the risk of exit facing a plant is assumed the same in 1986 as it is in 1996.

We express the model to evaluate many independent variables as

$$h(t) = [h_0(t)]e^{(\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_N X_N)} \quad (3)$$

where $h_0(t)$ is the baseline hazard function when all of the covariates are set to zero and $h(t)$ is the estimated hazard function when the value of the covariates $(x_1, x_2 \dots x_n)$ are nonzero.

The emphasis of this chapter is on the probability of survival for a foreign-owned plant, given its characteristics and the external environment. The survival function $S(t)$ is an estimate of the probability of surviving longer than a specified period. The cumulative hazard function $H(t)$ is related to the survival function: $H(t) = -\ln S(t)$, where

$$S_t = [S_0(t)]^p \quad (4)$$

and where $p = e^{\beta x}$. The survival function is obtained by raising the baseline survival function (this is the function when all the explanatory variables are set to zero) to the power of $e^{\beta x}$. The cumulative hazard and the cumulative survival functions approximately add to one, the difference from one being due to the standard error of the cumulative survival estimates. Thus the probability of surviving a given time period is one minus the probability of exiting in that period.

The Cox model is estimated for the population of foreign-owned plants with ten or more employees in 1986. The dependent variable is the length of duration the plant remained operational (survived) post-1986. We include dummy variables to account for each plant's scale of R&D activity over the period 1986-1993, its nationality, the period in which the plant began operating in Ireland, and the sector in which the plant is operating. In addition we include the mean annual entry rate of foreign-owned plants by industrial subsector and the employment size of the plant in 1986. For a general discussion of the factors affecting survival of plants, see Audretsch (1995) and Siegfried and Evans (1992). Specifically for Ireland, see Walsh and Konings (1997) for the effect of exchange rates on foreign plants, and Chapter 3 of this thesis for the role of research and development as it affects the survival rates of indigenous plants.

5.5.3 Results of the Cox Duration Model

The estimated model (Table 5.7) for all plants which had ten or more employees in 1986 is statistically significant.¹¹⁹ We report the hazard ratio for each of our explanatory variables. A ratio of less (greater) than one confirms that for a one unit

increase in a variable, the risk of exit for the plant is reduced (increased). Firm size in 1986 is highly significant: the larger the firm is in 1986, the lower the risk of exit and the higher the probability of survival facing the plant over the period 1986-1996. While nationality of ownership does not affect the hazard ratio, there are sectoral differences. In particular, plants in the low-tech sectors have a significantly lower probability of remaining in Ireland over the period relative to plants in the high-tech sector. While the starting period of entry has no effect on the hazard ratio, the annual entry rate has a significant impact. We find that the greater the extent of entry of foreign subsidiaries into the Irish manufacturing sector, the lower is the probability of existing foreign affiliates remaining operational in Ireland. This is contrary to what one might expect on the basis that greater agglomerations of MNCs would be expected to generate spillovers, which would enhance the profitability of existing plants. One possible explanation for this result may lie in the observation that the industrial restructuring which is taking place on a global scale in many sectors is maybe being replicated within Ireland. Those firms that are currently expanding within an industry will be expanding their FDI while simultaneously their declining competitors will be contracting their FDI.¹²⁰ Plants engaging in both small and large scale R&D investments have a higher probability of remaining in Ireland relative to non-R&D spending plants.

Equations 2 through 7 provide different estimates of the model using alternative measurements of a plant's technological activity. Using these alternative measures we attempt to account not only for the presence of R&D activity but for the scale of

¹¹⁹ A table of descriptive statistics and correlation coefficients for all exogenous variables are in Appendix A (5.C Appendices) in Tables A5.3 and A5.4.

¹²⁰ Two well known examples in Ireland would be the major expansions of Intel and IBM while simultaneously Verbatim and Seagate were withdrawing from Ireland.

activity within a plant. In Equation 2 we observe that large R&D spending plants have a smaller risk of exit relative to both small and non-R&D spending plants. All six measures of the scale of R&D activity are significant and all reduce the risk of exit facing a plant, *ceteris paribus*.

5.6 The Quantity and Quality of Employment Created

The second motive behind government policy towards expanding R&D active plants derives from the expectation that such plants would create a greater quantity and quality of employment than similar non-R&D active plants.

5.6.1 The Quantity of Employment Created

The following tables are based on an analysis of an MNC cohort (foreign affiliates with ten or more employees in 1986). They indicate that job creation (destruction) rates are much higher (lower) in higher tech sectors and are higher (lower) for plants which are described as R&D spenders. Overall there is net job destruction in the cohort of 11.1 per cent over the period 1986-1996. However, as indicated in Table 5.8, there is considerable variability across sectors: net job creation by MNC plants occurs in the two higher tech sectors (3.1 per cent and 2.4 per cent) in comparison with the net job destruction in plants in the two lower tech sectors (-10.4 per cent and -28.8 per cent).

It is also possible to analyse how the overall net job destruction rate of the cohort varies according to whether the plant is or is not an R&D spending plant. Table 5.9 shows that large R&D spenders have a net job creation rate of over 12 per cent compared to the net job destruction rate of over 28 per cent for both small R&D

spending and non-R&D spending plants. They suggest that R&D spend is not associated with significant net job creation unless undertaken on a significant scale.

An extension of the previous analysis is to consider those foreign affiliates in the cohort which are alive in both 1986 and 1996. There are 496 such plants out of a total of 691. This allows us to distinguish the effects of closures on the data. When we remove the plants that have exited, Table 5.10 shows that there is overall net job creation rate of 9.6 per cent. There is a 20 per cent net job creation rate for large R&D spending plants, compared with under 12 per cent for non-R&D spending plants. Small R&D-spending plants have a net job destruction rate of 20 per cent (see Table 5.10). Comparison of Tables 5.9 and 5.10 suggest that firm closures among non-R&D spenders are a significant source of job destruction, and are a much less significant source for small R&D spenders.

5.6.2 The Quality of Employment Created

We can attempt to measure the quality of employment created using measures of job persistence (Davis *et al.*, 1996, p.21-26). We define quality in terms of the duration that a new job will exist, since our data do not allow us to account for quality in terms of the skilled or unskilled nature of the employment. Essentially whenever a quantity of jobs is created, we estimate the percentage of those jobs that still exist in 1,2,3 or 4 years time. A limitation of this analysis is that we cannot be sure that they are precisely the same jobs that survive over a given time period. We are limited to examining to what extent a company maintains the new employment levels which include its newly created jobs. If all of the jobs created survive, we note that there is a 100 per cent job persistence rate. If the plants employment level falls to a level below

that which existed before the jobs were created, we say that there is zero per cent persistence rate.

Table 5.11 is based upon a cohort analysis of all plants with ten or more employees in 1986. In general the average persistence of jobs created is high. After four years almost 95 per cent of jobs persist or survive overall. However, when we look at plants disaggregated by the sector in which they operate, we note that the persistence rates of jobs created in both the high-tech sectors (93.8% and 97.5%) are relatively higher than the job persistence rates in the lower tech sectors (54.7% and 63.2%).¹²¹ This same pattern is observed whether we estimate the one, two or three year persistence rates.

When we consider R&D spenders in Table 5.12, the average persistence rate of jobs created is higher in the majority (although not the case for one year rate) for both the large and small R&D spenders relative to the non-R&D spenders. The persistence rate for the non-R&D spending plants falls off sharply by the second year and by the fourth year (43.7 per cent) is under half that of the equivalent rate for jobs created by large R&D spending plants (99.0 per cent).

5.7 Summary and Conclusions

In this chapter we have examined whether the R&D activities of MNCs in Ireland have any bearing on their contribution to Ireland's economic development. Allowing for plant and sectoral characteristics, we compared the survival experiences and the

¹²¹ Care should be taken in interpreting the overall four year persistence rate for all plants as an average of the above four sectors. In this case the majority weighting determined by the number of jobs created and the stock of employment in each category is predominantly on the higher-tech sectors.

employment performance of R&D active MNCs, relative to non-R&D active MNCs. We found that plant survival was positively related to size, the level of sophistication of the sector of activity, and the plant's being R&D active. Our cohort analysis of employment at plant level in MNCs indicated that job losses were greater and job persistence lower in the low-tech sectors and among non-R&D spenders compared with R&D spenders. Although it has long been recognised that the attraction of FDI to Ireland has been beneficial, the results of this chapter supports the idea that R&D active firms generally provide greater tangible benefits to the host economy. On direct employment grounds alone, our results suggest that policy should favour R&D active plants in high-tech sectors.¹²²

Differences between Irish plant level results in this chapter and those aggregate estimates provided at OECD level point to the importance of plant level studies in assessing the impact of R&D activities in firms on economies. Plant level data allow a distinction between the proportion of R&D active firms in a particular group and the scale of the R&D activity in which they engage. Aggregate statistics can hide the importance of the R&D impact at firm level, if account is not taken of differences in the proportion of firms undertaking R&D in a sector.

¹²² This ignores any spillover or other indirect benefits from R&D spending firms in the economy.

5.A Tables

Table 5.1: Growth in Firm Numbers and Employment in Foreign-Owned Industry in Ireland, 1980-1996¹²³

Sector (OECD)	High-Tech	Medium-High-tech	Medium-Low-tech	Low-Tech	Total
No. of plants 1980	68	129	122	153	472
No. of plants 1996	171	210	163	164	708
% Change	151.5%	62.8%	33.6%	7.2%	50.0%
Employment 1980	10216	18792	10953	29280	69241
Employment 1996	27711	29160	11572	23303	91746
% Change	171.3%	55.2%	5.7%	-20.4%	32.5%

Source: Own estimations based on *Forfás* data.

Table 5.2: Mean Annual Entry Rates of Foreign-Owned Plants, 1980-1996

Sector (OECD) (1980-1996)	High-Tech	Medium High-tech	Medium Low-tech	Low-Tech	Total
Mean Annual Entry Rate	7.2%	4.2%	3.6%	4.0%	4.6%

Source: Own estimations based on *Forfás* data.

Table 5.3: OECD Estimates of the Share of National R&D Accounted for by Foreign Affiliates and the R&D Intensity of that Activity¹²⁴

Country	% Share of Total National Industrial R&D by Foreign Affiliates	Intensity of R&D Activity of Foreign Affiliates ^c	% Share of Total Manufacturing Turnover by Foreign Affiliates
Ireland (1993)	68%	1.17% (6)^a	54.0 (1)^b
United Kingdom(1995)	37%	2.09% (4)	31.0% (3)
Spain (1995)	33%	-	-
Sweden (1995)	21%	2.39% (3)	18.7% (6)
Netherlands (1993)	17%	0.76% (7)	42.4% (2)
Turkey	16.5%	-	-
France (1994)	16%	1.78% (5)	21.0% (5) ^b
Germany (1993)	16%	3.17% (1)	28.1% (4)
Greece (1993)	10%	-	-
Finland (1993)	8%	2.61% (2)	7.59% (7)

Source: OECD (1998, p.4-5).

Note: ^a own estimate, ^b 1990 figure, ^c calculated as (R&D Spend / Turnover).
Ranking relative to column one provided in ()s.

¹²³ This table is based on the population of foreign-owned manufacturing companies with ten or more employees in 1980 and 1996.

¹²⁴ These estimates include R&D undertaken by foreign affiliates in some non-manufacturing industries.

Table 5.4: The Percentage Share of National R&D Spend Accounted for by MNCs by Sector

Foreign-Owned Sector	1986 % Share of Total BERD	1995 % Share of Total BERD	Per Annum Real Rate of Growth %
High-tech	31%	29%	14%
Medium-high-tech	14%	13%	14%
Medium-Low-tech	3%	2%	13%
Low-tech	6%	6%	15%
Non-Manufacturing	12%	14%	17%
All Foreign Plants	66%	64%	15%
All Indigenous Plants	34%	36%	16%
All Manufacturing Plants	100%	100%	15%

Source: Forfás (1997)

Table 5.5: R&D Activities by Nationality of Ownership, 1986

Nationality of Ownership	European	USA & Canada	Asia-Pacific	Total
Population of Foreign Plants 1986	402	263	26	691
Number of R&D Spenders	41	50	5	96
% 1986 Cohort who are R&D Spenders	10.2%	19.0%	19.2%	13.9%
Mean R&D Spend per plant £000s	219	573	142	400
Average R&D Intensity – R&D 1986 / Sales 1986 ^a	2.1% (34)	6.0% (37)	0.9% (4)	4.0% (75)
Mean R&D Personnel of each R&D plant	11	16	8	13
% 1986 Cohort with formal R&D department	7.5%	11.4%	15.3%	9.3%

Source: Own estimations based on *Forfás* data.

Note: ^a We are missing sales information for a number of these foreign plants. The number of plants for which the calculation of mean R&D intensity is made is noted in brackets underneath.

Table 5.6: R&D Activities by Nationality of Ownership, 1993

Nationality of Ownership	European	USA & Canada	Asia-Pacific	Total
Population of Foreign Firms 1993	373	277	36	686
Number of R&D Spenders	75	81	9	165
% 1993 Cohort who are R&D Spenders	20.1%	29.2%	25.0%	24.1%
Mean R&D Spend per plant ^a £000s	213	978	226	590
Average R&D Intensity – R&D 1993 / Sales 1993 ^b	3.2% (64)	4.7% (74)	1.1% (7)	3.9% (145)
Mean R&D Personnel of each R&D plant	49	80	15	62
% 1993 Cohort with formal R&D department	12.9%	17.7%	13.9%	14.9%

Source: Own estimations based on *Forfás* data.

Note: ^a Deflated to 1986 prices using the Consumer Price Index.

^b We are missing sales information for a number of these foreign plants. The number of plants for which the calculation of mean R&D intensity is made is noted in brackets underneath.

Table 5.7: Regression Results for the Cox Duration Model

Variable	Hazard Ratio						
	Eqn (1)	Eqn (2)	Eqn (3)	Eqn (4)	Eqn (5)	Eqn (6)	Eqn (7)
Firm Size in 1986	.998**	0.999*	.998***	.998***	.998***	.998**	.997***
Plant Nationality:							
North American	.896	0.897	.909	.917	.898	.920	.869
Other Non-European	.655	0.647	.665	.791	.689	.636	.685
Sector:							
Medium-High-tech	1.444	1.428	1.469	1.371	1.695*	1.290	1.582
Medium-Low-tech	1.437	1.390	1.610	1.450	1.876**	1.344	1.745**
Low-Tech	2.565***	2.474***	3.073***	2.846***	3.098***	2.662***	3.335***
Started in Ireland:							
1973-1982	0.963	0.971	0.961	0.986	1.015	0.985	.963
Post 1982	1.006	1.021	0.995	1.035	1.045	1.065	.986
Annual MNC Entry	1.132***	1.133***	1.149***	1.124***	1.178***	1.118***	1.151***
R&D Activity:							
1. All R&D Spenders	.288***						
2. Small R&D Spender		0.381***					
Large R&D Spender		0.215***					
3. Average Annual R&D Investment			0.999**				
4. Existence of a formal R&D Department				0.304***			
5. % Sales of Innovative products					.974***		
6. Average Annual R&D Personnel						.883***	
7. Average R&D Intensity (R&D/Sales)							.922**
Log Likelihood	-1196.38	-1195.25	-1213.81	-1204.54	-1198.19	-1200.83	-1215.71
Chi Square (11)	103.04	105.31	68.18	86.72	99.43	94.14	64.39
Prob > Chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	691	691	691	691	691	691	691
Time at risk	6355	6355	6355	6355	6355	6355	6355

Note: Categorical Variables are benchmarked against the omitted categories. The omitted categories for plant nationality, sector, started and R&D activity are European, High-tech, Pre-1973 and Non-R&D spenders respectively.

***significant at the 1% level, **significant at the 5% level, *significant at the 10% level.

Table 5.8: Net Job Change by Sector: A Cohort Analysis

Category	Stock of Employ. '86	Gross Jobs Created	Gross Jobs Destroyed	Stock of Employ. '96	% Jobs Change 1986- 1996
High-tech	14,593	5,926	(5,470)	15,049	3.1%
Medium- High-tech	22,884	7,796	(7,245)	23,435	2.4%
Medium- Low-tech	11,087	2,210	(3,357)	9,940	(10.4%)
Low-tech	29,891	5,980	(14,584)	21,287	(28.8%)
All Plants	78,455	21,912	(30,656)	69,711	(11.1%)

Source: Own estimations based on *Forfäs* data.

Table 5.9: Net Job Change by R&D Activity: A Cohort Analysis

Category	Stock of Employ. '86	Gross Jobs Created	Gross Jobs Destroyed	Stock of Employ. '96	% Jobs Change 1986-1996
Non-R&D Spender	34,854	6,854	(19,912)	24,796	(28.2%)
Small R&D Spender	9,874	1,360	(4,144)	7,090	(28.2%)
Large R&D Spender	33,727	13,698	(9,600)	37,825	12.2%
Total	78,455	21,912	(30,656)	69,711	(11.1%)

Source: Own estimations based on *Forfäs* data.

Table 5.10: Net Job Change by R&D Activity: A Cohort (Survivors) Analysis

Category	Stock of Employ. '86	Gross Jobs Created	Gross Jobs Destroyed	Stock of Employ. '96	% Jobs Change 1986-1996
Non-R&D Spender	22,205	6,854	(4,263)	24,796	11.7%
Small R&D Spender	8,870	1,360	(3,140)	7,090	(20.0%)
Large R&D Spender	31,557	13,698	(7,430)	37,825	19.9%
Total	62,632	21,912	(14,833)	69,711	9.6%

Source: Own estimations based on *Forfäs* data.

Table 5.11: Job Creation Persistence Rates by Sector

Category	Average 1 year persistence Jobs Created	Average 2 Year Persistence Jobs Created	Average 3 Year Persistence Jobs Created	Average 4 Year Persistence Jobs Created
High-Tech	99.57%	99.57%	94.58%	93.81%
Medium- High-tech	99.41%	99.35%	97.80%	97.48%
Medium- Low-tech	88.47%	78.82%	70.45%	54.67%
Low-tech	87.00%	77.69%	63.22%	63.22%
All Plants	99.04%	97.60%	94.70%	93.95%

Source: Own estimations based on *Forfäs* data.

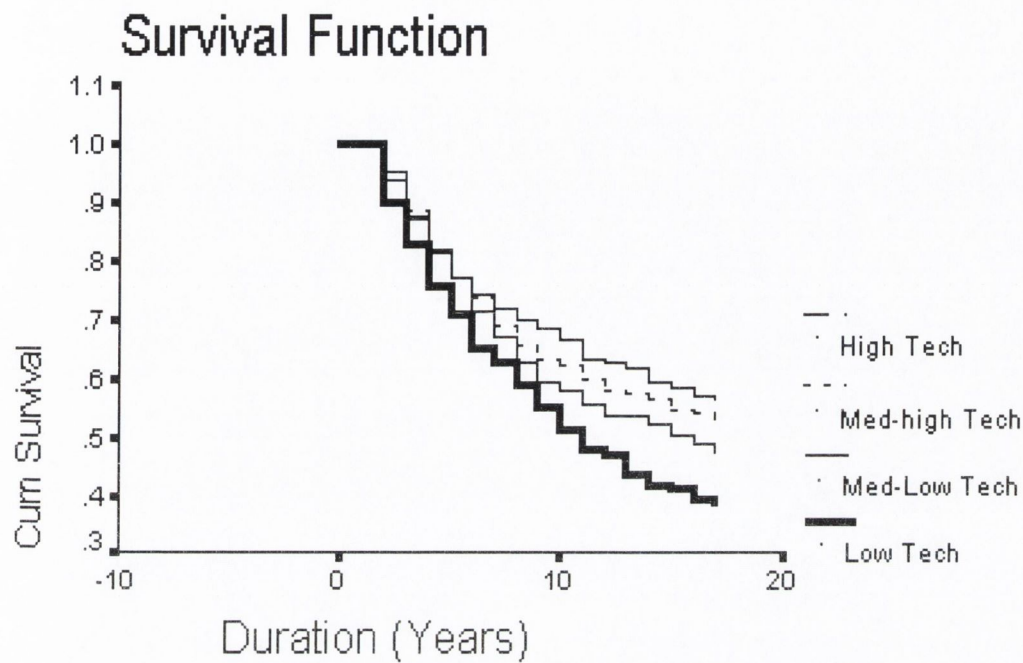
Table 5.12: Job Creation Persistence Rates by R&D Activity

Category	Average 1 year persistence Jobs Created	Average 2 Year Persistence Jobs Created	Average 3 Year Persistence Jobs Created	Average 4 Year Persistence Jobs Created
Non-R&D spender	99.04%	76.65%	60.88%	43.73%
Small R&D spender	86.09%	84.54%	70.72%	52.54%
Large R&D spender	99.08%	99.08%	99.08%	99.08%
All Plants	99.04%	97.60%	94.70%	93.95%

Source: Own estimations based on *Forfäs* data.

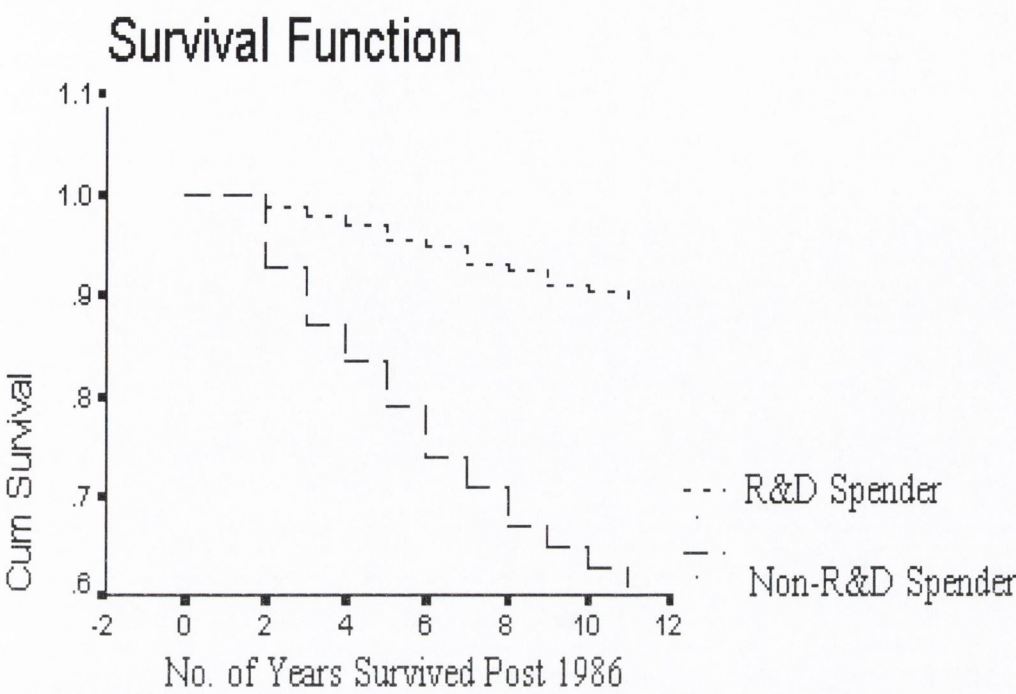
5.B Figures

Figure 5.1: A Survival Function of Foreign-Owned Plants in Ireland by Sector, 1986-1996



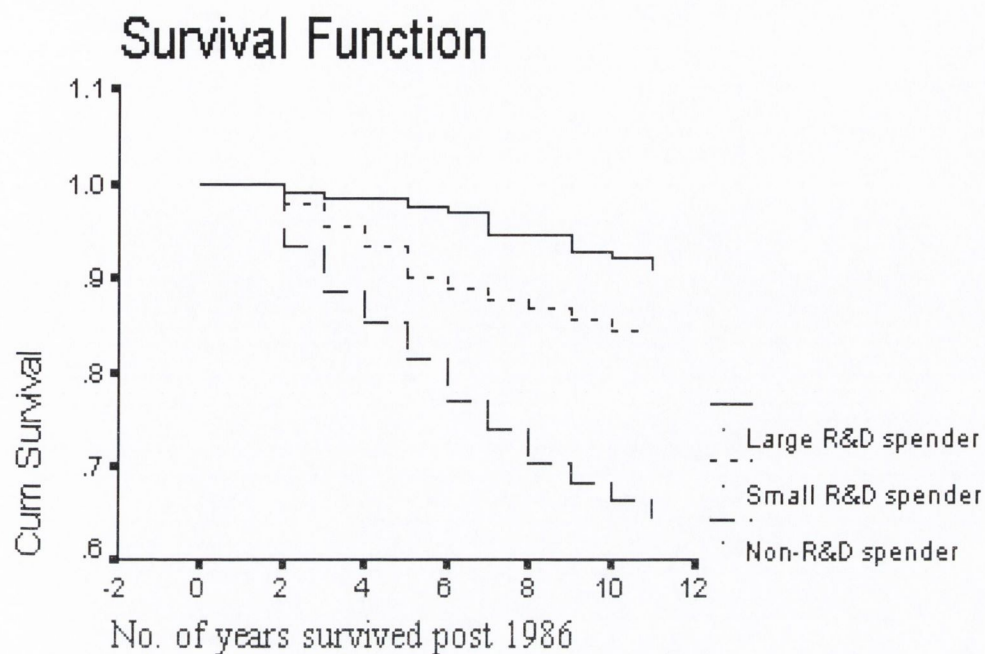
Source: Own estimations based on *Forfás* data.

Figure 5.2: A Survival Function of Foreign-Owned Plants in Ireland by R&D Activity, 1986-1996



Source: Own estimations based on *Forfás* data.

Figure 5.3: A Survival Function of Foreign-Owned Plants in Ireland by Scale of R&D Activity, 1986-1996



Source: Own estimations based on *Forfás* data.

5.C Appendices

Appendix A

Table A5.1: Life-Table Analysis of Foreign-Owned Plants by Sector, 1980-1996

Sector (OECD) Probability of Staying:	High-Tech	Medium- High-tech	Medium- Low-tech	Low-Tech	All Plants
5 years	74.52%	73.59%	71.38%	65.32%	70.36%
10 years	63.47%	59.95%	55.42%	48.07%	55.18%
17 years (1980-1996)	55.97%	52.94%	46.96%	38.89%	47.02%

Source: Own estimations based on *Forfås* data.

Note: Wilcoxon-Gehan statistics show that the difference in probabilities of survival between plants in different sectors are statistically significant at the 1% level.

Table A5.2: Life-Table Analysis of Foreign-Owned Plants by R&D Activity, 1986-1996

Scale of R&D spend Probability of Staying:	non-R&D Spenders	Total R&D Spenders	Small R&D Spenders	Large R&D Spenders
5 years	76.79%	93.55%	88.89%	96.85%
10 years	64.35%	88.02%	84.44%	90.55%

Source: Own estimations based on *Forfås* data.

Note: Wilcoxon-Gehan statistics show that the difference in probabilities of survival between R&D-active and non-R&D active plants and between large and small scale R&D spending plants are statistically significant at the 1% level.

Table A5.3: Summary Statistics for Variables used in Cox Regression

Variable	Description	Mean	Std. Dev	Min	Max
R&D Scale	Based on Average Annual R&D Spend 1986-1993			0	2
Start Period	Prior to 1973, 1973-1982, Post 1982			0	2
Sector	High, Med-High, Med-low or Low Tech			1	4
Entry Rate of Foreign Plants	Average Annual Entry Rate of foreign plants 1986-1996	5.57%	2.59%	3%	14%
Plant Size in 1986	Employment Size of Plant in 1986	113.54	157.94	10	1700
Nationality	North American, European or Other Non-European			0	2
Average Annual R&D Investment	Average Annual R&D based on survey responses ('000s)	378.30	59.79	1.83	11637.17
Formal R&D Department (y/n)?	Ever reported a formal department 1986-1993?			0	1
% Sales of Innovative Prods	% of sales from products developed in last 3-5 yrs?	35.89%	1.60%	0%	100%
Average R&D Personnel	Average Annual R&D Personnel (not FTE)	5.04	.64	.00	229.5
Average R&D Intensity	Mean Annual R&D Spend as a % of Sales	.03	.00	.00	.65

Source: Own estimations.

Table A5.4: Simple Correlation Coefficients for Exogenous Variables (Equation 1) in Table 5.7

	Started			Sector			Nationality			
Variables:	Entry Rate	1973- 1982	Post- 1982	Employ '86	Med- High	Med- Low	Low- Tech	Nth USA	Other Eur.	R&D Active
Entry Rate	1.00									
1973-1982	-0.10	1.00								
Post-1982	-0.22	0.49	1.00							
Employ '86	0.01	0.07	0.18	1.00						
Med-High	0.57	-0.07	-0.06	0.03	1.00					
Med-Low	0.58	-0.04	-0.03	0.08	0.74	1.00				
Low-Tech	0.62	0.00	-0.10	-0.06	0.78	0.80	1.00			
Nth USA	-0.11	-0.17	-0.15	-0.10	0.03	0.07	0.11	1.00		
Other Eur	-0.05	0.00	-0.07	-0.10	0.03	0.01	0.04	0.15	1.00	
R&D Active	0.07	-0.01	-0.03	-0.19	0.05	0.12	0.16	-0.02	0.01	1.00

Source: Own estimations.

CHAPTER 6

FIRM CHARACTERISTICS, PRODUCTIVITY SPILLOVERS AND R&D SPILLOVERS FROM FOREIGN DIRECT INVESTMENT

6.1 Introduction

A key benefit of foreign direct investment (FDI), in addition to increased employment and capital inflows, is the potential spillover of technology from the foreign companies to indigenous companies in the host region. Specifically, in the literature, it has been suggested that the presence of FDI in a host region can improve the productivity of local firms. Such productivity improvements can occur through, for example, the demonstration of new technologies, the training of personnel in foreign plants who may eventually be employed in indigenous industry, and through the technical assistance offered to indigenous suppliers and customers. Indeed some authors suggest that the magnitude and positive effects of spillovers are so significant that they may drive the motivation of host governments to attract FDI: *“[t]he most important reason why countries try to attract foreign investment is perhaps the prospect of acquiring modern technology. By inviting MNC's (Multinational Corporations) to invest within their boundaries, host countries hope to gain access to technologies that they cannot produce themselves”* (Blomström and Kokko, 1998, p.1).

However, existing empirical investigations differ in their estimates of the significance of spillovers. A standard approach of empirical studies has been to estimate how

labour productivity of indigenous plants within a sector is affected by the presence of foreign-owned industry in that sector. Caves (1974) and Globerman (1979) conclude, for Australia and Canada respectively, that the presence of FDI plants within each sector is a significant explanatory factor determining labour productivity in indigenous plants within that sector. Using a similar approach Blomström (1986) concludes that the presence of FDI has increased the structural efficiency of indigenous Mexican industry.¹²⁵ These positive effects of foreign presence were confirmed in recent firm-level studies where Blomström and Kokko (1999), Sjöholm (1999) and Chuang and Lin (1999) estimated positive and statistically significant effects, for Indonesia and Taiwan respectively, which support the hypothesis of productivity spillovers. In contrast, there are firm level studies where the results have indicated negative spillover effects from FDI to indigenous firms. Haddad and Harrison (1993), Aitken and Harrison (1999), Kathuria (2000) and Djankov and Hoekman (2000) find negative effects of FDI for Moroccan, Venezuelan, Indian and Czech indigenous manufacturing firms respectively.¹²⁶

While the earlier studies mentioned above estimate one coefficient for foreign presence across all sectors in the economy, some studies have recognised that the significance of FDI in increasing indigenous productivity is not uniform across all sectors. For example, Blomström (1986) segregated sectors into two groups, according to whether they were *traditional* or *modern*, allowing the significance of foreign presence to be estimated separately for each group. He concluded that the entry of FDI increased structural efficiency only for indigenous plants operating in

¹²⁵ In this study structural efficiency was defined as the deviation of an industry's output from its potential output as measured by an efficiency frontier.

modern as opposed to *traditional* industries. Further evidence for this relationship is found in studies by Cantwell (1989), Haddad & Harrison (1993) and Kokko (1994). All of these studies concluded that the significance of spillover effects might not be identical across different sectors or for plants within a sector operating in the same host region. Thus it has become important to identify the sectoral and firm characteristics that may affect the significance of FDI in explaining the productivity of local firms.

This chapter presents an analysis of how the presence of FDI may impact on labour productivity in indigenous industry and how these effects might be measured. We specifically examine the extent to which firm characteristics affect the type of productivity spillovers from foreign-owned subsidiaries to Irish manufacturing plants. In Section 6.2 we outline in general terms and illustrate, using Irish data, the *productivity approach* to explaining productivity spillovers from FDI. We investigate, replicating the standard analysis of previous studies using firm-level data, whether there are productivity spillovers from FDI in Ireland and outline the results in Section 6.3. In Section 6.4 we discuss three possible extensions to the approach adopted in existing empirical studies and in Section 6.5 we extend this traditional econometric analysis to incorporate these extensions. These extensions focus on the type, and not just the presence, of productivity spillovers from FDI in Ireland. In Section 6.6 we investigate whether R&D productivity spillovers from FDI impacts on the growth of productivity in indigenous plants. Some remaining limitations and possible extensions are outlined in Section 6.7 and some preliminary conclusions are drawn in the final section. We conclude that although there is evidence of productivity spillovers from

¹²⁶ See Görg and Strobl (2000b) for a summary of the methodologies employed by the authors of 18

FDI plants operating in Ireland, there is no evidence to suggest that any of these productivity spillovers are directly linked to research and development spillovers.

6.2 Traditional approaches to measuring productivity spillovers from FDI

Productivity spillovers from FDI enable domestic firms to increase productivity allowing them to improve their efficiency. It is argued that productivity spillovers occur through three channels: (i) the movement of trained staff from FDI plants to indigenous plants, (ii) ‘demonstration effects’ where superior production techniques in FDI plants are demonstrated to local indigenous firms and (iii) through competition with foreign-owned plants which forces indigenous firms to become more productive in order to survive (Blomström and Kokko, 1998).

The productivity approach to estimating the impact of productivity spillovers occurring within a host region has remained popular over time.¹²⁷ In this approach, the productivity of indigenous plants is seen to depend partially on the presence of FDI plants. Thus a measure of productive efficiency for indigenous industry is estimated as a function of the presence of FDI within the sector. A standard measure for productive efficiency is value-added per employee, and foreign presence within a sector is typically measured as the foreign share of employment or value-added within that sector.¹²⁸ In addition, the capital intensity of the indigenous plants, some measure

papers, on the topic of productivity spillovers from FDI, published or forthcoming in academic journals since 1974.

¹²⁷ For a general review of productivity studies see Blomström and Kokko (1998) and Görg and Strobl (2000b).

¹²⁸ We do not suggest that all studies adopt this approach. For example, some studies use total factor productivity instead of labour productivity as a measure of productive efficiency. See Görg and Strobl (2000b) for a survey on the different variables used in different studies.

of labour quality within the plants and a measure of the concentration of plants within the sector are also controlled for in the estimation.

A key development in these studies has been the estimation of indigenous productive efficiency separately for groups of sectors, based on a classification of the technological sophistication of indigenous plants relative to foreign plants within the sector. For example, Kokko (1994) and Kokko *et al.* (1996) group sectors according to whether or not indigenous plants are as technologically developed as FDI plants. They argue that the size of the *technology gap* between indigenous and foreign plants is crucial in explaining the likelihood of spillovers. In these studies the *technology gap* is measured as the ratio of value-added per employee in foreign plants to value-added per employee in indigenous plants within a sector. When this ratio exceeds one, foreign plants are relatively more productive; as the value of this ratio increases above one, the size of the *technology gap* is increasing.

There are two contrasting *ex ante* expectations concerning the impact of this gap on spillovers from FDI. On the one hand it can be argued that, if the technology in FDI plants is too complex relative to that already operating in indigenous plants, the likelihood of spillovers will be low because the FDI technology may be 'inappropriate' for indigenous plants. Kokko *et al.* (1996) provide empirical evidence in support of this argument. They suggest that foreign presence is an insignificant determinant of indigenous labour productivity in sectors where the estimated technology gaps are large, but is a significant determinant of indigenous productivity in sectors with small technology gaps. On the other hand it can be argued that the technological gap must be large enough to provide an incentive for indigenous plants to want to adopt FDI

technology. Indigenous plants may have no desire to obtain technology in use by FDI companies if the technology they already use is comparable. Thus, according to this reasoning, the effect of spillovers on labour productivity is expected to increase with the size of the 'technology gap'.¹²⁹

To illustrate the productivity approach in the Irish context we provide some aggregate estimates of the variables discussed previously in Table 6.1. These estimates are based on Central Statistics Office (1998a) data for the Irish manufacturing sector for 1996. The first column shows labour productivity in indigenous plants. This is measured as net output (value-added) per employee. Productivity is highest in the chemicals sector (£52.5k per employee) and smallest in the wearing apparel sector (£14.8k per employee). The literature suggests that a possible explanation for this divergence in labour productivity across indigenous sectors is the differing presence of foreign plants. In the second column we present the share of employment accounted for by foreign plants in each sector. This figure ranges from 87 per cent of all employment in the case of office machinery/computers to 13.4 per cent in the case of wood/wood products. We provide in Column 4 an estimate of the technology gap between FDI plants and indigenous plants in each sector, namely, the ratio of labour productivity in foreign plants relative to that in indigenous plants in each sector (Column 3 divided by Column 1). In all but one sector (non-metallic minerals) the ratio is greater than one, indicating higher labour productivity in the foreign-owned companies.¹³⁰ At issue here is the relationship between labour productivity and the presence of FDI. We

¹²⁹ Flores *et al.* (1999) suggests that the relationship between labour productivity and the technology gap may be an inverted U-shape.

¹³⁰ There are five sectors in which the ratio is exceptionally high. The practice of profit switching transfer pricing may artificially increase the average value-added per employee in foreign-owned plants. Profit-switching transfer pricing is a mechanism whereby foreign subsidiaries report a higher

present in Table 6.2 the correlation coefficients between labour productivity and foreign presence for all firms taken together and for two groups of indigenous firms, classified according to the relative size of the technology gap between foreign and indigenous firms.

The correlation across all sectors between labour productivity in Irish plants and foreign presence is low, at 0.13. When we classify sectors into those with large and small technology gaps we estimate the correlation between indigenous productivity and foreign presence to be -0.09 and -0.07 respectively. These findings, while based on correlations rather than regressions, may suggest that there is little impact of foreign presence on the level of indigenous labour productivity in Ireland.¹³¹

Some studies have suggested that it is the correlation between changing foreign presence and the *growth* rather than the level of productivity in indigenous plants that should be the focus of attention (Haddad and Harrison, 1993). Changes in foreign presence may not be associated with higher absolute levels of indigenous productivity across sectors but with higher rates of growth of productivity. In Table 6.3 we provide estimates of the change in indigenous productivity and foreign presence between 1991 and 1996.¹³² However, once again, using Irish data we find a weak positive correlation between change in labour productivity and change in foreign presence (0.12). When we classify sectors into those with large and small technology gaps we estimated the correlation between indigenous productivity and foreign presence to be

value of their sales (profits) in Ireland to avail of the low corporation tax rate as discussed in Stewart (1989) and Murphy (1995, 1998).

¹³¹ Of course, there are other factors that impact on indigenous productivity that we have not controlled for. We control for these factors in an econometric analysis in Section 6.3.

0.72 and 0.27 respectively.¹³³ These correlation coefficients are consistent with results found in the literature that the magnitude of productivity spillovers may differ across sectors.

These simple tabulations suggest that there may only be a weak relationship between labour productivity in the indigenous sector and the presence of FDI in Ireland. This is confirmed in a preliminary sectoral study of Irish manufacturing by Ruane and Ugur (2000). They model the labour productivity of indigenous plants at the 2-digit and 4-digit sectoral level. Their preliminary analysis found no evidence of a positive impact of foreign presence on domestic labour productivity using 2 and 4-digit sectoral level data. Aitken and Harrison (1999, p.606) argue that firm-level data are superior to sectoral level data in studies of this kind and that the results of firm-level analyses may be different.

6.3 Measuring the potential impact of productivity spillovers from FDI: replicating the standard analysis of previous studies using firm level data

6.3.1 Data & Econometric Methodology

In this section we conduct a firm-level analysis, attempting to replicate the analysis of earlier studies.¹³⁴ We estimate the labour productivity of over 1,300 indigenous plants in Ireland over the period 1984-1998. Following Kokko (1994, p.282)¹³⁵ we hypothesise that the labour productivity of indigenous firms can be estimated by the function

¹³² This is different to the methodology adopted by Haddad and Harrison (1993) where they regress the change in labour productivity on the level of foreign presence rather than the change in foreign presence.

¹³³ See Table 6.4.

¹³⁴ See Ruane and Ugur (2000) for a preliminary sectoral study of productivity spillovers in the Irish manufacturing sector.

$$(VA/L_d)_{it} = f(LQ_{it}, k_{it}, HERF_{jt}, FOR_{jt}) \quad (1)$$

where i is an individual plant, j is a 4-digit sector and t is an individual year. We estimate the labour productivity of Irish plants $(VA/L_d)_{it}$ as a function of capital intensity (k_{it}), labour quality (LQ_{it}), the sectoral level of producer concentration ($HERF_{jt}$) and the level of foreign presence within the four digit sector (FOR_{jt}).

This equation is estimated separately for two subsets of sectors, namely those sectors where indigenous plants have small or large productivity gaps ($PGAP_{jt}$) relative to foreign-owned plants.

We measure these variables in the following manner:¹³⁶

$(VA/L_d)_{it}$: We measure labour productivity as value added per employee in each plant. Value added is calculated as sales minus the input cost of materials, fuel and electricity.¹³⁷

$(k)_{it}$: A standard measure of capital intensity is a ratio of assets per employee (Blomström, 1979; Kokko, 1994). However, due to data limitations we cannot measure total assets per firm. Jenkins (1990, p.209) suggests using some physical indicator such as electricity consumption as a proxy for capital. Following Jenkins, we

¹³⁵ Kokko (1994) estimated this equation with sectoral level data.

¹³⁶ Summary statistics are presented in Table 6.11.

therefore proxy capital intensity by the share of a firm's non-labour costs (i.e. electricity, fuel, materials etc) in total input costs.¹³⁸ This measure implicitly assumes that a more capital-intensive firm spends a relatively lower share of all input costs on labour. We expect value added per employee to be increasing in capital intensity.

$(LQ)_{it}$: Labour quality is proxied by the ratio of the average wage per employee in each local firm relative to the industry average wage per employee. This industry average is calculated for other indigenous plants only. We infer the relative quality of labour of any domestic firm by this ratio. A firm that offers a higher average wage relative to the industry average is assumed to employ a relatively higher quality of labour. We did not include the average wage per employee for each plant directly into the estimation because of the problem of simultaneity with the dependent variable (Blomström, 1979, p.47; Kokko, 1994, p.283). Ideally we would use some proxy of labour quality that is not correlated with the average wage per employee in the firm (i.e., the ratio of white to blue collar workers in each plant). However, no such alternative existed in our dataset. It is expected that value added per employee in a firm will increase in the quality of labour that it employs.

$(HERF)_{jt}$: The Herfindahl index is a measure of producer concentration in each sector and is expected to capture the effect of market structure on the value of

¹³⁷ This is the definition adopted by the Irish Central Statistics Office for calculating net output or value added.

¹³⁸ Ideally we would have used only costs incurred from electricity and fuel consumption as our measure of capital intensity. However, due to data limitations we use all non-labour costs instead.

output.¹³⁹ Labour productivity is increasing in the level of producer concentration because higher price cost margins and hence higher values of output (i.e., value added) are associated with more concentrated industries. In general labour productivity is expected to be higher in more concentrated sectors. However, we suggest that this expectation may not apply in the case of a small open economy such as Ireland where there are high export and import ratios. The large presence of foreign-owned plants within many sectors weakens the notion of concentration in the Irish manufacturing sector. There are significant differences between foreign and domestic firms with regards to size and market orientation.¹⁴⁰ Consequently, measuring the Herfindahl index for 4-digit NACE industries may not reflect the extent of competition faced by (i) indigenous manufacturing plants that are exporting and (ii) by indigenous manufacturing plants competing against foreign-owned subsidiaries within Ireland.

$(FOR)_j$: The share of all industry employment in foreign-owned plants is our measure of foreign presence in each sector. A significantly positive coefficient on foreign presence can be interpreted as follows; “*[i]f foreign presence has been found to have a significant positive effect on local labour productivity (after the effects of other variables have been accounted for), it has been concluded that spillovers take place*” (Kokko, 1994, p.282).

¹³⁹ The Herfindahl index in sector j is calculated as $H_j = \sum_{i=1}^n \left(\frac{x_i}{X} \right)^2$ where x_i is the employment of n individual firms in sector j and X is the total employment in the same sector (Kokko, 1994, p.283).

¹⁴⁰ See Ruane and Görg (1997).

We include 4-digit sectoral dummies to control for sectoral differences and time dummies to account for macroeconomic changes.

$(PGAP)_j$: The sectoral productivity gap is measured as the ratio of average value added per employee in foreign plants to the average value added per employee in indigenous plants for each sector. This productivity gap measure is expected to proxy the appropriateness of the technology in FDI plants for indigenous plants. It is used to classify sectors into two groups, namely those sectors with small and large technology gaps.¹⁴¹ The impact of foreign presence is expected to differ across these two subsets of sectors.

We estimate this relationship for 1,307 plants using a random effects model, in order to make full use of the panel dimension of the dataset. Random effects estimators can be expected to be superior to fixed effects models in this situation given that our subset of firms is a sample of plants drawn from the population of manufacturing plants and as Verbeek (2000, p.318) notes “[t]he random effects approach allows one to make inference with respect to the population characteristics.” Finally, we can include our time invariant sectoral dummies in random effects estimation whereas fixed effects estimators would drop these time invariant variables. Girma *et al.* (1999) note the importance of including sectoral dummies in our regressions. They conclude that modelling labour productivity without sectoral dummies would imply “*that a positive coefficient on the FDI variable can simply reflect the fact that foreign firms invest in industries that pay higher wages and enjoy higher productivity rather than*

¹⁴¹ Kokko (1994, p.288) classifies sectors with small productivity gaps as sectors where the ratio of foreign to indigenous labour productivity is less than two. There is a large productivity gap when this ratio is greater than or equal to 2. We use this rule to divide our sectors into two subgroups.

the existence of any genuine spillovers to domestic firms” (Girma *et al.*, 1999, p.14).

Aitken and Harrison (1999) confirmed that omitting sectoral dummies biased the results of previous studies investigating productivity spillovers from FDI.

6.3.2 Results

Our initial results are outlined in Table 6.5. All of the variables, with the exception of the Herfindahl index, enter with the expected sign and are statistically significant at the 1 per cent level. The level of labour productivity in indigenous plants is increasing in the relative quality of labour employed in the plant and the capital intensity of the firm’s production process. However, the level of producer concentration of the 4-digit sector is statistically insignificant and supports our expectation that the Herfindahl index may not capture the impact of competition on labour productivity in the case of a small open economy such as Ireland.

In particular, indigenous plants have higher productivity levels in those sectors where there is a higher share of foreign employment.¹⁴² In the literature such a finding is interpreted as indicating that there are positive productivity spillovers from foreign to indigenous plants, such as found in sectoral studies (Globerman, 1979; Kokko, 1994) and other firm level studies for Indonesia (Blomström and Sjöholm, 1999; Sjöholm, 1999) and Taiwan (Chuang and Lin, 1999). In contrast, Flores *et al.* (1999) and Ruane and Ugur (2000) reported an insignificant coefficient for foreign presence in sectoral studies of Portuguese and Irish firms respectively, while Haddad and Harrison (1993),

¹⁴² A significant drawback with the random effects approach is the possible correlation between the time invariant individual effects and any of our explanatory variables. A Hausmann test rejected the null hypothesis that the coefficients of a random and fixed effects estimators would be similar. We thus present the corresponding results of the fixed effects estimator in Column 2 in Table 6.5. The results are similar to those obtained for the random effects estimator. The coefficients on labour quality, capital intensity and foreign presence are all statistically significant and positive.

Aitken and Harrison (1999), Kathuria (2000) and Djankov and Hoekman (2000) find negative spillover effects for Moroccan, Venezuelan, Indian and Czechslovakian (Republic) indigenous manufacturing firms respectively.

A common finding of previous studies has been that the positive relationship between foreign presence and domestic labour productivity is influenced by the characteristics of both domestic and foreign firms. The most standard question in the literature has been to examine whether this positive relationship between foreign presence and domestic labour productivity holds in the presence of large productivity gaps (Kokko, 1992; Haddad and Harrison, 1993; Kokko, 1994; Sjöholm, 1997; Flores *et al.*, 1999). It is suggested that foreign presence may have less impact on indigenous plants where the productivity gap between both sets of plants is very large, i.e., indigenous plants have much lower productivity levels relative to foreign plants. This productivity gap has traditionally been interpreted as a technology gap, suggesting that indigenous firms are relatively very backward compared to foreign-owned subsidiaries. We consider this question for the case of Irish industry. We divide our sectors into three groups, those sectors with no, small or large productivity gaps relative to foreign-owned plants within their sector. We observe the presence of a large technology gap whenever the average productivity of all foreign-owned plants within a 4-digit NACE industry is over twice the average productivity for indigenous plants within the same sector. There is a smaller technology gap between FDI and indigenous plants when the ratio of average foreign to average indigenous productivity within each sector is less than 2 and greater than 1.¹⁴³ There is no productivity gap when the average

¹⁴³ This is the methodology adopted by Kokko (1994, p.288) where sectors are divided into two subsets based on whether or not the average value-added in foreign-owned plants is over *twice* as high as the average productivity in indigenous plants.

productivity of indigenous plants is greater than the average productivity of foreign plants (i.e., when the ratio is less than one).

The results are presented in Table 6.6. The estimated coefficients for 60 4-digit industries where there is no productivity gap are presented in Column 1, for 30 4-digit industries where there is a small productivity gap are presented in Column 2 while the results for the remaining 28 4-digit industries where there are large productivity gaps are presented in Column 3. We confirm Kokko's (1994, p.288) conclusion that "*productivity differences per se are apparently not serious obstacles for spillovers.*" We find that foreign presence is statistically significant and positive for those sectors where there are no and large productivity gaps respectively. The elasticity of value-added with respect to foreign presence, estimated at the sample means (Greene 2000, p.359), is higher for sectors with large productivity gaps (0.598) relative to sectors with no productivity gap (0.131).¹⁴⁴ In contrast to our findings, Flores *et al.* (1999, p.11) estimated that the probability of spillovers is lower when the average productivity in foreign plants is over twice the average productivity in indigenous plants. They estimate that domestic labour productivity should be 50 to 80 per cent¹⁴⁵ of labour productivity in foreign-owned plants to maximise the likelihood of spillovers from foreign plants.

¹⁴⁴ The formula used to estimate the elasticities is $\beta_k \left(\frac{\bar{x}}{\bar{y}} \right)$ where β_k is the coefficient on FOR_{jt}

and $\bar{x}$ and $\bar{y}$ are the sample means for FOR_{jt} and value-added per employee respectively.

¹⁴⁵ Labour productivity in indigenous plants is greater than 50 per cent of productivity in foreign plants when the ratio of foreign to indigenous productivity is less than 2 (the terminology that we used to classify sectors with small productivity gaps).

A limitation of the previous analysis of the productivity gap is the inability to distinguish between indigenous plants within the sector. There will be indigenous plants within each sector that have different productivity gaps relative to foreign-owned plants. We calculate a firm-level version of the productivity gap ($PGAP_i$). This is calculated as the ratio of average value added per employee in foreign plants to the value added per employee *in each indigenous plant*. This allows the productivity gap to vary across indigenous firms within the same sector. We subsequently divided our indigenous plants into three subsets according to whether each indigenous plant's productivity is greater than average foreign productivity (i.e., no productivity gap) or whether average foreign productivity is over twice (i.e., large productivity gap) or less than twice (i.e., small productivity gap) the level of productivity in each indigenous plant within the same sector (Haddad and Harrison, 1993, p.68). The impact of foreign presence is expected to differ across these three subsets of plants within each sector.

The results are presented in Table 6.7. In Column 1, we present the estimated coefficients for 474 plants with no productivity gap relative to foreign plants operating within the same sector. In Column 2 we have the corresponding coefficients for the 417 indigenous plants that report a small technology gap. In Column 3 we have the estimated coefficients for the remaining 452 indigenous plants with large productivity gaps relative to foreign plants within their sector, i.e., there is a large technology gap. The main result is that foreign presence is a significant determinant of productivity levels in all three subsets of plants. The elasticity of value-added with respect to foreign presence, estimated at the sample means, is higher for sectors with large productivity gaps (0.706) relative to sectors with small (0.150) and no

productivity gaps (0.124). Our results are opposite to those in Haddad and Harrison (1993) who found that the significance of foreign presence on indigenous productivity weakens with the size of the technology gap between indigenous and foreign plants.

The interpretation of the results from analysing productivity gaps is ambiguous. If the productivity gap is a poor measure of the technology gap between indigenous and foreign plants, then technology gaps may still be serious obstacles for spillovers. Alternatively, the productivity gap measure may be an accurate measure of technology gaps and we can agree with Kokko's (1994) conclusion that technology gaps may not prevent productivity spillovers between both sets of plants.

6.4 Extensions to Existing Approaches

It has been estimated in Section 6.3, using traditional approaches, that there are positive productivity spillovers from foreign-owned to indigenous manufacturing plants in Ireland. We suggest that this conclusion is limited because this traditional approach has not attempted to identify (i) the types of productivity spillovers from FDI or (ii) the channels through which productivity spillovers might occur, i.e., whether they are occurring through demonstration, linkages or competitive effects. Görg and Strobl (2000b, p.2) comment that “[t]he approach adopted in the empirical literature therefore largely avoids the (arguably difficult to answer) question as to how productivity spillovers actually take place, but focuses on the simpler issue of whether or not the presence of multinationals affects productivity in domestic firms.”

We can be more specific about the types of productivity spillovers that might occur in any host region. de Arcos *et al.* (1997, p.1) comment that “the predicted advantages of

FDI to its host region consist of technology transfer, either intentionally or via leakage, to local suppliers and customers, new organisational methods and management skills that could become available to the host region through labour mobility, demonstration effects in which the foreign firm becomes a model for local firms, and forced upgrading of the technological and organisational capacities of indigenous firms through greater competition." Are the productivity spillovers occurring between foreign and indigenous firms in Ireland primarily management productivity spillovers, organisational productivity spillovers and/or technological productivity spillovers? We focus on the question of whether or not there are technological productivity spillovers in the Irish case.

Griliches (1979, 1991) and Verspagen and Los (2000) identify two types of technological productivity spillovers. There are *rent* spillovers and *knowledge* spillovers, where R&D spillovers is a term used synonymously with knowledge spillovers (Verspagen and Los, 2000). Griliches (1991) defines rent spillovers as technological spillovers that occur when plants purchase R&D intensive inputs from other plants at less than their full "quality" price. Secondly, R&D spillovers occur through the borrowing of ideas between plants. It is described essentially "*as working on similar things and hence benefiting much from each others' research*" (Griliches, 1991, p.13).¹⁴⁶ Verspagen and Los (2000, p.131) argue that a key property that identifies R&D spillovers is "*that relevant knowledge is transferred from one firm to another, without the receiver having to pay for it directly to the producer of the knowledge.*" The question arises as to whether there is any evidence to suggest, that

¹⁴⁶ For a review of R&D spillovers see Griliches (1995) and Mairesse and Sassenou (1991).

some of the productivity spillovers from foreign to indigenous plants estimated earlier, may actually be research and development productivity spillovers.

In this section we identify three extensions to the existing literature. We want to extend the traditional analysis to focus on the type, and not just the presence, of productivity spillovers from FDI.

6.4.1 Assumption of homogeneous indigenous plants

A qualification of the empirical studies to date is the assumption that the impact of foreign presence on labour productivity for all indigenous plants is uniform, i.e., that all indigenous plants in a sector are equally likely to be the beneficiaries of all types of productivity spillovers. However, it is possible and indeed likely that two indigenous plants can absorb different quantities of R&D productivity spillovers. This ‘absorptive capacity’ will be determined by the resources that the indigenous firms expend in order to adopt the technology or use it to improve productivity (Blomström and Kokko, 1999, p.3). Specifically, Cohen and Levinthal (1989, 1990) model the absorptive capacity of a plant as depending on its cumulative R&D investments over time. The essence of their argument is that a plant that does not engage in R&D will have no expertise in identifying a potential R&D spillover, let alone absorbing and commercially exploiting it.

We suggest that as technological capacity within indigenous firms affects their ability to absorb technological spillovers, then it is inappropriate to aggregate across R&D and non-R&D active indigenous plants. Almost by definition, non-R&D active indigenous plants have very limited capability to absorb any technological spillovers.

Thus we would conclude *a priori* that foreign presence might be less important in explaining the labour productivity of non-R&D active indigenous plants.

6.4.2 Assumption of homogeneous FDI

Within the various traditional productivity studies mentioned earlier, the consistent measure of foreign presence used has been the share of employment, gross output or value added within the sector accounted for by foreign-owned plants. While this is a very simple measure of foreign presence, it has a very serious limitation in that it assumes that all FDI is homogeneous. Thus two FDI plants with equal employment are assumed to contribute exactly the same quantity of productivity spillovers in that sector because their shares of sectoral employment are identical. In effect, there is no account taken of the many firm characteristics that distinguish FDI plants operating within the same sector. Consequently, there is no account taken of the different types of productivity spillovers that may spill-over from different types of FDI plants.

We noted earlier that R&D spillovers are a particular focus of this chapter and in this context one of the more serious firm characteristics omitted may be the presence of R&D activity within an FDI plant. A parallel literature, based on case studies, has highlighted the importance of this type of FDI plant in terms of its potential to be a source of spillovers. A distinction is made between *dependent* and *developmental* FDI (de Arcos *et al.*, 1997, p.1). In the former case, many of the channels through which spillovers are believed to take place, such as, demonstration of new technologies, training of personnel, technical assistance to suppliers and customers, will not be present. These are "screwdriver" assembly plants (non-R&D active) that use relatively unskilled labour to assemble components in host regions. In contrast, de Arcos *et al.*

(1997, p.1) note the benefits of *developmental* FDI where “*the foreign investment contributes to the dynamic evolution of the local economy, through the collaboration with local firms to develop new products, the transfer of technology and expertise to local firms, and the creation of high skilled employment. An example of developmental FDI is a fully-integrated subsidiary that encompasses the full range of product development from R&D through manufacturing and marketing.*” This distinction suggests that technological spillovers may be more significant for a host region if the FDI plants undertake R&D,¹⁴⁷ and that in effect there will be relatively fewer R&D productivity spillovers from non-R&D active FDI plants.¹⁴⁸ Thus estimating the labour productivity of indigenous plants within a sector, as determined by the share of all foreign employment, is a very limited measure unless the distribution of R&D activities in foreign-owned subsidiaries across sectors is identical to that of the distribution of employment shares. We suggest that in order to estimate the magnitude of R&D productivity spillovers to indigenous plants, foreign presence should be measured as the share of employment in R&D active FDI plants only.¹⁴⁹

6.4.3 Measure of "technology gap"

The final qualification of existing empirical studies centres on the concept of the 'technology gap'. The measure of the technology gap (i.e., the productivity gap) used

¹⁴⁷ Although it must be admitted that even with substantial R&D investments in FDI plants, we cannot be definite *a priori* that these investments will result in spillovers. Pearce (1995) and Dunning (1994) highlight the motivations of the R&D activity within the FDI plant as the crucial determinant.

¹⁴⁸ In a different context we can note that many authors have estimated spillovers as a function of the R&D investments of other firms. Bernstein & Nadiri (1993) quantify the 'potential spillover pool' for any plant as the unweighted sum of all other plants R&D expenditures in a sector. Acs *et al.* (1994) and Audretsch and Vivarelli (1996) estimate the spillovers to small firms as a function of the R&D expenditures of large firms. Jaffe (1989) models the spillovers to small firms as determined by "spillover pools" which are the cumulative R&D investments of large firms and universities.

¹⁴⁹ We measured foreign presence as the share of each sectors employment in (i) all foreign-owned plants and (ii) R&D active foreign-owned plants only. The correlation coefficient between these two measures is 0.75. A foreign-owned plant is defined as R&D active if it ever once reported R&D investment over the period 1986-1997.

in existing empirical studies may not measure accurately the technology gap between firms. Previous authors have inferred a technology gap occurring when foreign plants are more productive than indigenous plants. Is it correct that a productivity gap such as this also captures any 'technology gap'? A productivity gap can be the result of different management, marketing, distribution, production and technological ideas between foreign and indigenous companies. It may not necessarily follow that measuring the productivity gap captures the technological gap between both sets of firms.

In other literature authors (de Arcos *et al.*, 1997; Jaffe, 1986, 1989) have discussed the appropriateness of one plant's technology (and hence their potential spillovers) for another plant in narrower terms. An example of this is Jaffe's concept of technological proximity. A plant has a "technological position" that derives from the nature and objectives of its R&D program. If there are K technological areas in which a firm can engage in R&D, then the technological position of a firm can be characterised by the fraction of the plant's research budget invested in each area K . We could apply this concept and define technological proximity as the extent to which foreign and domestic plants within a host region undertake similar R&D programs and thus have similar "technological positions". Jaffe (1986) labels these plants as "technological neighbours". Griliches (1991, p.15) suggests that *"rather than using the SIC classifications as is, one could group three-digit SIC categories into clusters based on a priori notions about the extent of commonality in their technological and scientific base."* Using Jaffe's (1986, 1989) notion of technological proximity, we seek to group indigenous and FDI plants together, not solely on the basis of sector, but according to their "technological proximity". Data limitations allow us to compare only those

foreign and indigenous plants with R&D programs rather than to distinguish further between plants with similar and dissimilar R&D programs. We therefore estimate the productivity of R&D active indigenous plants as determined by the presence of R&D active foreign-owned plants. The use of this approach allows us to focus primarily on the probable technological gap rather than on a productivity gap, which might be the result of a range of factors.

In subsequent sections we incorporate these extensions into the traditional approach used in earlier studies. There are two distinct econometric approaches to estimating productivity spillovers in the existing literature: (i) the level of productivity in indigenous plants is determined by foreign presence within the sector and (ii) the growth in productivity in indigenous plants is determined by the growth in foreign presence within the sector. Our extensions are incorporated into both econometric approaches in the next two sections.

6.5 Foreign Presence and the *level* of productivity in indigenous firms: extensions to traditional studies

We re-estimate the earlier productivity analysis (Section 6.3), extending it to include the extensions raised in the last section, with the aim of investigating whether there are any R&D productivity spillovers from foreign-owned to indigenous firms in Ireland.

6.5.1 Indigenous plants: absorptive capacity

A central idea in this chapter is that the productivity gap measure, whether measured at sectoral or firm level, may be a very inadequate proxy for the technological gap

between foreign and indigenous plants. A technology gap occurs when indigenous plants are technologically less advanced relative to foreign plants. The implication of a technology gap may be that indigenous plants have little ability to absorb any R&D spillovers from foreign plants (i.e., little absorptive capacity). In essence the nature of the technological spillover may be too advanced for the domestic plant.

We suggest the presence of R&D investment in a local plant is a good measure of a local plant's absorptive capacity. A domestic plant is classified as an R&D active plant if it invested at least an average of £100,000 annually (measured in 1986 prices) in R&D over the period (1986-1997). A non-R&D active plant invests nothing or less than £100,000 in research and development annually over this period. On the basis of this definition, 161 indigenous plants are classified as R&D active. We re-estimated the productivity equation (Equation 1) for non-R&D active and R&D active plants separately. The estimated coefficients for both subsets of plants are outlined in Table 6.8. We find that foreign presence is positive and statistically significant at the five per cent level for both non-R&D active and R&D-active indigenous plants (Columns 1 and 2). However, the elasticity of labour productivity with respect to foreign presence, evaluated at the sample means, is 0.511 for R&D active plants relative to 0.117 for non-R&D active plants.¹⁵⁰ We suggest that foreign presence appears to have a greater impact on the level of labour productivity in R&D active plants because they are the indigenous plants most likely to possess any 'absorptive capacity' to avail of R&D spillovers.

¹⁵⁰ We tested the sensitivity of this elasticity to alternative classifications of R&D active indigenous plants. Foreign presence is an insignificant determinant of labour productivity in indigenous plants that invest nothing in R&D. In contrast, foreign presence is significant for those indigenous plants investing less than on average £100,000 per annum in R&D. However, the elasticity of labour productivity with respect to foreign presence increases with the scale of the R&D investment. For example, the elasticity

There is only one other study that we are aware of that has attempted a similar investigation. Barrios (2000) uses a sectoral dummy to split a sample of Spanish manufacturing plants into low and high R&D sectors (this measure was based on the ratio of R&D expenditures to value-added for both foreign and indigenous plants in each sector). He estimated value added in indigenous firms as determined by the share of value added produced by foreign firms at the sectoral level. It was found that foreign presence is positive and significant only in high R&D sectors because these are the indigenous plants with more advanced technological capabilities. There was an additional unreported experiment in this study where a distinction was drawn between indigenous Spanish firms with and without R&D expenditures. In contrast to the results that we estimated and presented above, where the magnitude of productivity spillovers differs across R&D active and non-R&D active indigenous Irish plants, Barrios (2000, p.15) concludes for Spanish plants that “*[i]n all these estimates, the dominant outcome is the lack of any significant impact of foreign presence...*”.

6.5.2 Foreign-owned firms: a refined measure of foreign presence

An unfortunate consequence of the standard measure of foreign presence, namely the share of total sector employment in foreign plants, is that two foreign plants of equal employment size are assumed to provide an equal quantity and quality of productivity spillovers. In similar fashion to domestic plants, foreign plants located within a host region may have diverse characteristics. FDI plants operating in Ireland differ in terms of nationality of ownership, age of subsidiary, size of plant in addition to their propensity to undertake R&D activity. We suggest that the presence of R&D activity

is 0.360 for indigenous plants investing on average £50,000 or greater per annum, and 0.392 for

in a foreign subsidiary is an especially significant characteristic in any study of productivity spillovers. This is suggested because we do not expect all foreign plants can provide an equal quantity or quality of R&D spillovers and it is suggested that a prerequisite for R&D spillovers from foreign-owned plants may be for foreign-owned plants to undertake some R&D activities.¹⁵¹ Our definition of foreign presence is amended to account for the number of foreign-owned plants that undertake R&D investment in Ireland.¹⁵²

We suggest an alternative measure of foreign presence to that used in our earlier analysis which replicates earlier studies. The share of all sectoral employment in foreign-owned *R&D active plants only* is calculated for each 4-digit sector. This is to be contrasted to our earlier measure where the share of all sectoral employment in *all foreign-owned plants* was estimated. The estimated coefficients of these alternative measures of foreign presence are presented in Column 1 of Table 6.9. In contrast to our earliest results (Table 6.5), we find that the presence of R&D active foreign-owned plants is insignificant in explaining labour productivity in all indigenous plants. There are no productivity spillovers from R&D active FDI plants to indigenous plants.

indigenous plants investing £75,000 or greater per annum.

¹⁵¹ We classify an FDI plant as R&D active when any positive amount of R&D investment is recorded for that plant over the period 1986-1997. This measure classifies FDI plants as non-R&D active because they undertake no R&D investment in Ireland even though they may receive the innovative output of the R&D investment undertaken by their parent company. We focus specifically on the potential spillovers from FDI plants that undertake R&D investment in their Irish subsidiary.

¹⁵² This is similar to the approach adopted by de Arcos *et al.* (1997) in a different study that investigated the extent to which foreign-owned companies embed themselves in host regions across Europe. They argued that “[t]he R&D capabilities of the foreign subsidiary are crucial to an evaluation of embeddedness because they are an indicator of the ability of the subsidiary to contribute to the local innovative capacity through technology transfer and spillovers...” (p.4).

6.5.3 Foreign-owned and Indigenous firms: technological proximity

The idea of technological proximity was explored earlier in the idea of the productivity gap (i.e., technology gap) between indigenous and foreign-owned plants. It may be important that the domestic plants absorbing R&D spillovers are not too technologically backward relative to the foreign subsidiaries from which those spillovers originate. This may explain why the presence of R&D active foreign subsidiaries does not increase the productivity of all indigenous plants, as estimated above. In Table 6.9 (Column 2) we estimate the labour productivity of R&D active indigenous plants as determined by the presence of R&D active foreign owned plants. We suggest that we are comparing plants that are more technologically similar than would be the case in comparing non-R&D active local firms and R&D active foreign subsidiaries. We find that the share of all sectoral employment in foreign-owned R&D-active plants is an insignificant determinant of the labour productivity of R&D active domestic plants. Thus it appears an insignificant relationship is estimated between foreign presence and domestic labour productivity through being specific about comparing plants that are more likely to be ‘technological neighbours’ (i.e., both undertaking some R&D activities).

We can interpret the insignificant coefficients on R&D active foreign presence in Table 6.9 as indicating that there are either (i) no R&D spillovers from foreign-owned R&D active plants to indigenous plants or (ii) that any R&D spillovers from foreign-owned plants do not impact on the productivity of indigenous plants.¹⁵³ We quoted de Arcos *et al.* (1997) earlier who noted that spillovers could take many forms; technology transfer, advanced management skills and new organisational skills. Our

¹⁵³ We discuss this topic later as a possible limitation of this analysis.

earliest results estimated the productivity of all indigenous plants as determined by the presence of all foreign-owned plants within the sector. We found evidence of productivity spillovers from foreign to indigenous plants (see Table 6.5). However, this analysis did not allow us to determine whether those spillovers are primarily technological, management skills, organisational methods or any other form of spillover. We suggest that estimating the productivity equation for R&D active foreign and R&D active indigenous plants provided a way to test whether the productivity spillovers that occur between foreign and indigenous plants also include R&D productivity spillovers. However, using this approach we found no evidence of research and development spillovers from foreign to indigenous industry in Ireland.

6.6 Foreign Presence and the *growth* of productivity in indigenous firms

Aiken and Harrison (1999) suggest that there may be an identification problem in the traditional approach to investigating the presence of productivity spillovers. If foreign firms only locate in sectors with high levels of domestic productivity then our initial positive coefficients on foreign presence may indicate spillovers when in fact they may not exist. We remedied this potential identification problem by including sectoral dummies in all of our earlier analysis (Girma *et al.*, 1999). In addition to including sectoral dummies, Haddad and Harrison (1993) remedied the identification problem by focusing on productivity changes in domestic firms as opposed to productivity levels. The issue arises as to whether productivity spillovers from FDI increases the growth in addition to the level of labour productivity in indigenous firms in Ireland.

Haddad and Harrison (1993, p.65) estimate a model of productivity growth. We estimate a similar model

$$\Delta(VA/L_d)_{it} = \Delta(LQ)_{it} + \Delta K_{it} + \Delta For_{jt} + C_j + D_t \quad (2)$$

where $\Delta(VA/L_d)_{it}$, $\Delta(LQ)_{it}$, ΔK_{it} and ΔFor_{jt} is the first difference of value added, labour quality, capital intensity and foreign presence respectively.¹⁵⁴ Finally, C_j and D_t are sectoral and time dummies respectively.

We present the coefficients of random effects estimation in Table 6.10. The dependent variable is the annual change in value added per employee over the period 1984-1997. In Column 1 we estimate this model for all indigenous plants and measure foreign presence as the share of sectoral employment in *all* foreign plants. We find that productivity *growth* is insignificantly related to the *growth* in foreign presence. This estimated relationship is in contrast with the positive relationship estimated previously between the same measure of foreign presence and the *level* of local labour productivity. However, it is in line with the findings of Haddad and Harrison (1993). They conclude that “*our tests on the presence of any spillovers from foreign presence show that although domestic firms exhibit higher levels of productivity in sectors with a larger foreign presence, they do not exhibit higher productivity growth in those sectors*” (p.54). In contrast, Sjöholm (1999) records that foreign presence has a positive and significant effect on the growth, in addition to the level, of labour productivity in Indonesian firms.

¹⁵⁴ We do not include the first difference of the Herfindahl index because the index was insignificant as expected in the majority of the earlier estimations.

We re-estimated this relationship for non-R&D and R&D active indigenous plants only. We sought to see to what extent our earlier result of foreign presence significantly determining the labour productivity of R&D active indigenous plants only could be carried forward to an analysis of productivity growth. In contrast to our earlier findings on the level of productivity in indigenous firms (Table 6.8), we report that foreign presence is an insignificant explanatory variable in productivity growth regardless of the R&D active status of the indigenous plants (Columns 2a and 2b).

Finally, we investigated to what extent the presence of *R&D active* foreign-owned plants within a sector determines the productivity growth of indigenous plants. In Column 3 we estimate the productivity growth of all indigenous plants and we measure foreign presence as the share of all sectoral employment in R&D active indigenous plants. It is estimated that R&D active foreign presence has a significantly negative effect (at the 10 per cent level) on indigenous plants. Aitken and Harrison (1999) explain a negative spillover effect, similar to what we have estimated from R&D active foreign-owned plants, through a market stealing effect. The market stealing effect occurs when more efficient foreign firms operating in a host region steal demand from the local firms. In the face of this competition local firms cut production and consequently reduce their productivity. The authors conclude that “*if the productivity decline from this demand effect is large enough, net domestic productivity can decline even if the multinational transfers technology or its own firm-specific asset to domestic firms*” (p.607). We re-estimate Equation 2 for non-R&D active and R&D active plants and present the results in Columns 4a and 4b. However, we find no evidence of this significantly negative spillover effect for either non-R&D or R&D active plants and interpret this as indicating that there are no R&D

productivity spillovers impacting on the growth of productivity in R&D active indigenous plants.

In summary, we find no evidence of general productivity spillovers from foreign-owned firms when the growth in productivity in indigenous firms is regressed on the growth in foreign presence. In addition, there is no evidence to suggest that there are any positive R&D spillovers between both sets of plants.

6.7 Limitations and Possible Extensions

While the analysis here introduced some additions to earlier studies, it suffers also from clear limitations. Firstly, our measure of labour productivity takes no account of differences in hours worked as we measure labour input solely by the number of workers. Globerman (1979) notes the importance of controlling for hours worked in measuring labour productivity. He suggests that “*measured labour productivity differences across domestically owned plants could conceivably be affected by differences across industries in average hours worked*” (p.47). However, due to data limitations we have been unable to control for the influence of hours worked.

Our study has attempted to measure intra-sectoral spillovers only. We have only estimated the labour productivity of indigenous plants as determined by the presence of foreign plants in their 4-digit sector. We have not attempted to estimate inter-sectoral spillovers where the productivity spillovers emanating in one sector may enhance the productivity of indigenous plants in another sector.¹⁵⁵ To the extent that inter-sectoral spillover effects may be more significant than intra-sectoral spillovers,

we will have underestimated the significance of spillovers from foreign-owned plants in Ireland.

Sample selection bias potentially poses serious problems for the estimates presented above. Specifically, Verbeek (2000, p.345) concludes that the fixed effects estimator may be relatively more robust against selection bias than the random effects estimator although sample selection bias can render the fixed effects estimator inconsistent and the random effects estimator both biased and inconsistent. Our panel is unbalanced for two reasons, namely (i) that the Irish economy expenditure surveys record data on different firms for different years and because (ii) firms enter and drop out of the survey as they enter and exit industries (i.e., for non-random reasons). Baltagi (1995, p.190) and Verbeek (2000, p.346) suggest a test for sample selection bias in panel data models based on Verbeek and Nijman (1992). They recommend that three variables should be included in the estimated equation. These variables are (i) the total number of observations on the firm over the period 1984-1998, (ii) a dummy variable indicating whether the firm was observed for the entire 15 years or not and finally, (iii) a second dummy variable indicating whether the firm was observed in the previous year. The null hypothesis is that these three variables should not be significant in explaining our dependent variable. Baltagi (1995, p.190) concludes, *“intuitively one is testing whether the pattern of missing observations affects the underlying regression.”* We included these three variables in our labour productivity equation (Equation 1)¹⁵⁶ and re-estimated using random effects. We find the first and

¹⁵⁵ See Verspagen (1996) who uses patent data to measure inter-sectoral spillovers and Steurs (1995) who presents a theoretical model of inter-sectoral spillovers.

¹⁵⁶ This equation related the level of indigenous productivity to the level of foreign presence within the sector.

second variables are insignificant and the third variable is significant only at the 10 per cent level. Thus we cannot fully reject the null hypothesis of no selection bias.

As in previous studies we acknowledge that labour productivity is only a partial measure of overall productivity (Flores *et al.*, 1999, p.8). However, Globerman (1979) notes that productivity studies generally may understate the true magnitude of the benefits of FDI to local firms because “*indirect benefits contributing to improved output quality or higher wages (and other payments to domestic factors) will not be directly captured by the productivity measure employed*” (p.53). We have not explored different dependent variables such as the percentage of innovative products sold¹⁵⁷ (Jaffe, 1986, 1989) or the survival (Görg and Strobl, 2000a) of indigenous plants as determined by the operation of multinational corporations in Ireland. For example, our mixed results on the presence of foreign plants on the various productivity measures of Irish plants above must be set in the context of the positive coefficient reported for the presence of foreign plants on the survival of local Irish plants (Görg and Strobl, 2000a).

6.8 Summary and Conclusions

In this chapter we have presented a very preliminary analysis of whether the presence of FDI affects labour productivity in indigenous industry and how these effects may be measured. We outlined in broad terms the approaches adopted by many of the existing empirical studies on this issue.

¹⁵⁷ See Kindleberger (1969) and Hymer (1976) for two opposing views on the consequences of the presence of MNCs on the innovation infrastructure of host regions.

Specifically, we have replicated the analysis of previous firm-level productivity studies using data on the Irish manufacturing sector and concluded that there is a positive relationship between foreign presence and the level of productivity in Irish plants. This is in contrast to the results of a preliminary sectoral study on the Irish manufacturing sector where foreign presence is found to be an insignificant determinant of labour productivity in indigenous plants (Ruane and Ugur, 2000).

Following the analysis in Kokko (1994) we distinguished between sectors according to the relative productivity between foreign-owned subsidiaries and Irish companies. A standard question in the literature for over a decade has centred on the extent to which productivity spillovers vary with productivity gaps between foreign and indigenous plants. We found no evidence that productivity gaps, measured at sectoral and firm-level level, implied fewer productivity spillovers to indigenous plants.

Kokko (1994) investigated the extent to which the magnitude of productivity spillovers was related to various market characteristics. Following this literature we have attempted to investigate to what extent productivity spillovers have varied according to firm characteristics in the Irish manufacturing sector. We estimated the productivity of R&D active indigenous plants as determined by the presence of (i) all foreign-owned plants and (ii) only R&D active foreign-owned plants. There were relatively greater productivity spillovers to indigenous R&D active plants, perhaps indicating the importance of R&D investment in enabling local plants to absorb spillovers. However, we found no evidence of significant R&D productivity spillovers from R&D active foreign plants to R&D active indigenous plants.

The robustness of these findings was tested by alternatively measuring the growth rate of productivity rather than the level of productivity in local plants. In summary, we find no evidence of general productivity spillovers or R&D productivity spillovers in this alternative econometric specification.

de Arcos *et al.* (1997, p.128) suggest that technological spillovers are unlikely to occur between foreign and indigenous plants in peripheral regions such as Ireland because “[t]he most innovative FDI, with the greatest potential for technology spillovers and embeddedness, will not willingly locate in peripheral regions but will be attracted to the core regions of Europe.” Their most interesting policy recommendation is based on their observation that the lack of R&D spillovers may be due to the mismatch between the R&D capabilities of foreign-owned plants relative to indigenous firms. They recommend that “[t]he potential of FDI to have a positive effect on its host region depends on an approximate match between the innovative capabilities of the foreign firms and its host region. Therefore, it is more worthwhile to attract low technology firms with integrated R&D to a peripheral area than firms in high technology sectors that only plan to build an assembly plant” (de Arcos *et al.*, 1997, p.128). Further research on the quality and quantity of innovative capabilities in both foreign and indigenous plants is needed to ascertain whether this explains the apparent lack of R&D spillovers in the Irish manufacturing sector.

6.A Tables

Table 6.1: Summary Statistics of Labour Productivity, Foreign Presence, Foreign Productivity and Technology Gaps for Irish Manufacturing Subsectors, 1996

Sectors	Irish Net Output per Employee £'000 (1)	Foreign Presence in Sector (% Share Empl.) (2)	Foreign Net Output per Employee £'000 (3)	"Technology Gap" >1 (4)
Food, Drink, Tobacco	41.5	27.3	209.5	5.0
Textiles	20.4	50.0	28.7	1.4
Wearing Apparel	14.8	43.1	16.2	1.1
Leather / Leather Product	n/a	n/a	n/a	n/a
Wood / Wood Products	23.3	13.4	53.8	2.3
Pulp, Paper, Print Products	42.1	23.5	63.5	1.5
Publishing / Printing	40.5	31.3	401.3	9.9
Chemicals	52.5	80.0	217.7	4.1
Pharmaceuticals	39.7	82.4	163.0	4.1
Rubber / Plastic Products	31.1	49.0	39.5	1.3
Non-Metallic Minerals	45.1	15.2	39.1	0.9
Basic / Fabricated Metals	26.8	24.3	43.2	1.6
Machinery n.e.c.	28.4	49.6	46.6	1.6
Office Machinery / Computers	34.1	87.1	156.6	4.6
Electrical Machinery	22.3	69.1	64.0	2.9
Radio / TV Equipment	27.5	81.4	66.2	2.4
Precision / Optical Equip.	37.6	86.3	58.8	1.6
Motor Vehicles	19.5	37.0	31.7	1.6
Other Transport	28.9	16.3	36.5	1.3
Furniture / Recycling	30.0	38.9	52.2	1.7

Source: Source: Own calculations based on *Central Statistics Office* data (CSO 1998a)

Table 6.2: Correlation Coefficients of Labour Productivity with Foreign Share by Technology Gap

Sector Classification	Column (1) & (2) Correlation Coefficients
All Sectors	0.13
Sectors with large Tech. Gap (Technology gap >2.6) ^a	-0.09
Sectors with Small Tech. Gap (Technology gap <=2.6) ^a	-0.07

Source: Own estimations.

^a 2.6 is the mean technology gap across all sectors

Table 6.3: The Change in Labour Productivity and Foreign Presence, 1991-1996

Sectors	(1) Indigenous Net Output per Employee (% Change 1991-1996)	(2) Foreign Presence in Sector (% Change 1991-1996)
Food, Drink, Tobacco	0.2	0.0
Textiles	0.2	-0.5
Wearing Apparel	0.3	-0.6
Leather / Leather Product	n/a	n/a
Wood / Wood Products	0.4	3.9
Pulp, Paper, Print Products	0.3	1.4
Publishing / Printing	0.3	21.3
Chemicals	0.1	1.4
Pharmaceuticals	0.2	1.0
Rubber / Plastic Products	0.2	-0.3
Non-Metallic Minerals	0.4	1.2
Basic / Fabricated Metals	0.1	0.5
Machinery n.e.c.	0.3	-0.2
Office Machinery / Computers	0.1	0.9
Electrical Machinery	0.2	-0.2
Radio / TV Equipment	0.3	-0.2
Precision / Optical Equip.	0.6	-0.4
Motor Vehicles	0.2	0.2
Other Transport	0.4	2.3
Furniture / Recycling	0.1	0.3

Source: Own calculations based on *Central Statistics Office* data (CSO 1998a, 1998b).

Table 6.4: Correlation Coefficients of Change in Labour Productivity with Change in Foreign Share by Technology Gap

Sector Classification	Column (1) & (2) Correlation Coefficients
All Sectors	0.12
Sectors with large Tech. Gap (Technology gap >2.6) ^a	0.72
Sectors with Small Tech. Gap (Technology gap ≤2.6) ^a	0.27

Source: Own Estimations.

^a 2.6 is the mean technology gap across all sectors.

Table 6.5: Regression Results for Panel Data Estimation of Foreign Presence on Domestic Plants, 1984-1997

<i>Dependent Variable:</i> Value added per employee	(1) Random Effects	(2) Fixed Effects
<i>Independent Variables:</i>		
LQ_{it}	31.022 *** (.528)	29.714 *** (.561)
K_{it}	31.165 *** (5.867)	29.140 *** (6.839)
$HERF_{jt}$	-.002 (.001)	-.002 (.001)
FOR_{jt}	22.212 *** (8.613)	24.000 *** (8.864)
Year Dummies	Yes	Yes
4-Digit Sectoral Dummies	Yes	dropped
R^2 within	.317	.317
R^2 between	.514	.271
R^2 overall	.481	.245
$Prob > \chi^2$	.0000	.0000
No. of observations	7,976	7,976
N	1,343	1,343
Hausmann Test	rejected	

Note *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.6: Regression Results for Random Effects Estimation of Foreign Presence on Domestic Plants, 1984-1997: The Productivity Gap (i)

<i>Dependent Variable:</i> Value added per employee	(1) No Productivity Gap (sectoral measure) i.e., ratio of average foreign to average indigenous productivity within the sector is <1	(2) Small Productivity Gap (sectoral measure) i.e., ratio of average foreign to average indigenous productivity within the sector is >=1 & <2	(3) Large Productivity Gap (sectoral measure) i.e., ratio of average foreign to average indigenous productivity within the sector is >=2
<i>Independent Variables:</i>			
LQ_{it}	30.723 *** (.763)	22.994 *** (.709)	39.408 *** (1.425)
K_{it}	28.045 *** (11.697)	22.458 *** (3.787)	50.999 *** (9.506)
$HERF_{jt}$	.001 (.002)	-.002 * (.001)	-.009 (.003)
FOR_{jt}	38.462 *** (17.474)	8.063 (6.613)	44.391 ** (17.375)
Year Dummies	Yes	Yes	Yes
4-Digit Sectoral Dummies	Yes	Yes	Yes
R^2 within	.327	.305	.302
R^2 between	.550	.597	.484
R^2 overall	.492	.529	.450
$Pr ob > \chi^2$	.0000	.0000	.0000
No. of observations	3,685	2,415	1,876
N (firms)	591	427	325
N (4-Digit Sectors)	60	30	28

NOTE: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.7: Regression Results for Random Effects Estimation of Foreign Presence on Domestic Plants,1984-1997:The Productivity Gap (ii)

<i>Dependent Variable:</i> Value added per employee	(1)	(2)	(3)
	No Productivity Gap (firm measure)	Small Productivity Gap (firm measure)	Large Productivity Gap (Firm Measure)
	i.e. ratio of average foreign productivity to individual indigenous plant's productivity within the sector is <1	i.e. ratio of average foreign productivity to individual indigenous plant's productivity within the sector is >=1 & <2	i.e. ratio of average foreign productivity to individual indigenous plant's productivity within the sector is >=2
<i>Independent Variables:</i>			
LQ_{it}	33.124 *** (1.192)	26.684 *** (0.279)	22.274 *** (.823)
K_{it}	40.270 ** (17.483)	26.922 *** (2.767)	19.509 *** (3.404)
$HERF_{jt}$	-.001 (.002)	-.001 (.001)	-.007 (.001)
FOR_{jt}	44.593 ** (21.160)	10.374 ** (6.076)	34.605 *** (8.802)
Year Dummies	Yes	Yes	Yes
4-Digit Sectoral Dummies	Yes	Yes	Yes
R^2 within	.256	.771	.213
R^2 between	.626	.845	.705
R^2 overall	.595	.839	.547
$Prob > \chi^2$	.0000	.0000	.0000
No. of observations	2,825	2,687	2,464
N	474	417	452

NOTE: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.8: Regression Results for Random Effects Estimation of Foreign Presence on Domestic Plants by Domestic Plant's R&D Active Status, 1984-1997

<i>Dependent Variable:</i> Value added per employee	(1) Non-R&D Active indigenous plants	(2) R&D Active indigenous plants
<i>Independent Variables:</i>		
LQ_{it}	28.261 *** (.274)	57.891 *** (4.799)
K_{it}	25.409 *** (3.212)	93.469 ** (41.774)
$HERF_{jt}$	-.002 ** (.001)	.001 (.005)
FOR_{jt}	10.871 ** (5.013)	84.438 ** (44.993)
Year Dummies	Yes	Yes
4-Digit Sectoral Dummies	Yes	Yes
R^2 within	.640	.229
R^2 between	.589	.498
R^2 overall	.653	.449
$Prob > \chi^2$	.0000	.0000
No. of observations	6,800	1,176
No. of Firms	1,182	161

NOTE: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.9: Regression Results for Random Effects Estimation of R&D active Foreign Presence on the Level of Labour Productivity of Domestic Plants, 1984-1997

<i>Dependent Variable:</i> Value added per employee	(1) All Indigenous Plants	(2) R&D Active Indigenous plants
<i>Independent Variables:</i>		
LQ_{it}	31.025 *** (.528)	58.328 *** (4.801)
K_{it}	31.648 *** (5.867)	92.615 ** (41.894)
$HERF_{jt}$	-.001 (.001)	-.003 (.005)
$R \& DFOR_{jt}$ (share of all employment in foreign R&D active plants)	-14.719 (13.641)	-11.460 (71.430)
Year Dummies	Yes	Yes
4-Digit Sectoral Dummies	Yes	Yes
R^2 within	.316	.163
R^2 between	.515	.719
R^2 overall	.482	.638
$Prob > \chi^2$	0.0000	.0000
No. of observations	7,976	1,176
N	1,343	161

NOTE: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.10: Regression Results for Random Effects Estimation of the Change in Foreign Presence on the Change in Productivity of Domestic Plants, 1984-1997

<i>Dependent Variable:</i> Change in Value added per employee	(1) All local Plants	(2a) Non-R&D active local plants	(2b) R&D active local plants	(3) All Plants	(4a) Non-R&D active local plants	(4b) R&D active local plants
<i>Independent Variables:</i>						
$\Delta(LQ)_{it}$	26.117 ^{***} (.560)	26.310 ^{***} (.420)	20.239 ^{***} (3.558)	26.116 ^{***} (.560)	26.310 ^{***} (.419)	20.249 ^{***} (3.559)
$\Delta(K)_{it}$	26.254 ^{***} (5.733)	34.504 ^{***} (4.430)	-27.810 (28.519)	25.878 ^{***} (5.735)	34.189 ^{***} (4.434)	-26.324 (28.583)
$\Delta(FOR)_{jt}$	9.696 (10.425)	1.164 (8.479)	42.041 (40.791)			
$\Delta(R \& DFOR)_{jt}$				-31.498 [*] (17.719)	-20.444 (14.442)	-59.557 (67.447)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
4-Digit Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2 within	.233	.376	.067	.233	.376	.067
R^2 between	.640	.746	.613	.641	.747	.613
R^2 overall	.309	.444	.300	.309	.444	.300
$Pr\ ob > \chi^2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of observations	6,169	5,207	962	6,169	5,207	962
N	1,281	1,127	154	1,281	1,127	154

NOTE: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in ()s.

Table 6.11: Summary Statistics

	No. of Obs.	Mean	Std. Deviation	Min	Max
$(VA/L_d)_{it}$	7,978	29.41	63.56	-226.50	2204.32
£'000s					
LQ_{it}	7,978	1	0.90	0	19.42
K_{it}	7,978	0.73	0.14	0	1
$HERF_{jt}$	7,978	767.05	1203.31	95.28	10000
FOR_{jt}	7,978	0.28	0.26	0	0.97
%					
$R \text{ \& } DFOR_{jt}$	7,978	0.10	0.17	0	0.97
%					

Source: Own estimations.

CHAPTER 7

SUMMARY AND POLICY IMPLICATIONS

7.1 Overview

It has been suggested that investment in research and development can be the engine that drives growth in both the macroeconomy (Romer, 1986, 1990; Grossman and Helpman, 1991) and individual firms. This thesis aimed at analysing the impact of investment in R&D on indigenous firms and foreign-owned subsidiaries operating in Ireland.

The policy context, aims and structure of the thesis were described in Chapter 1. In contrast to other EU and OECD countries, BERD as a percentage of GDP had increased substantially since 1982. However, the level of investment in R&D in the Irish manufacturing sector was low by international standards. It was argued that this low level of R&D investment could hamper the competitiveness and growth of indigenous plants while multinational corporations might be less committed to the host region. Specifically, on the assumption that R&D improves the growth and competitiveness of indigenous industry and the embeddedness of foreign-owned industry in Ireland, the state proposed to increase the budget for R&D projects from approximately £20 million per annum to £1.9 billion between 2000 and 2006. Hitherto, there had been no firm-level study that investigated whether increasing R&D investment in indigenous firms increased their growth and competitiveness or whether R&D activities in foreign-owned subsidiaries increased their embeddedness in the host region.

In Chapter 2 we examined whether investment in innovation improved the survival and growth of indigenous new entrant plants. In 1998, over 6 per cent of the operating indigenous plants had entered in the previous year but approximately 10 per cent of these entrants will be expected to exit each year in the first three years after 1998. Using a two-stage Heckman (1979) estimator, we find that innovative new entrant plants have a relatively higher probability of survival, but having survived, they enjoy lower annual growth rates relative to non-innovators. We explored why innovating new entrants might survive longer. Based on the theoretical models by Jovanovic (1982) and later extended by Pakes and Ericson (1989, 1998) we find evidence consistent with the idea that innovating plants actively learn to overcome their small initial size as a constraining influence on their future growth. In contrast, non-innovating new entrants do not invest in such learning and consequently their post-entry growth depends significantly on their initial size.

In Chapter 3 we analysed the survival of a cohort of indigenous incumbent plants. Between 1991 and 1998 it appears that for every job created through the entry of new firms, an additional job was destroyed through the simultaneous exit of manufacturing plants. Using a Cox (1972, 1975) duration model, we find that incumbent plants that invest in R&D have superior probabilities of survival relative to plants that do not undertake R&D investment. This result is consistent across a range of variables used to measure a plant's R&D investment, namely, scale of R&D activity, R&D intensity or sales of innovative products developed within the plant.

There may be an ambivalence in the state's attitude to supporting increased R&D in manufacturing firms if the outcome of that investment is reduced labour demand in those firms. We investigated the impact of R&D investment on labour demand in

Chapter 4. Using a general method of moments (GMM) estimator to estimate a dynamic labour demand model, we find that the percentage increase in labour demand for a given rise in output is the same in both R&D active and non-R&D active plants. The data do indicate however that the change in labour demand for a rise in output is substantially greater in product innovating R&D active firms relative to process innovating R&D active firms. Finally, we estimate that job persistence (i.e., the percentage of newly created jobs that survive for a given time period) is significantly higher in R&D active companies. It is estimated that one third of all newly created jobs in non-R&D active companies persist for ten years while almost 100 per cent of newly created jobs in R&D active firms persist for the same period.

The rapid growth of the Irish economy over the past decade and the simultaneous increase in (i) the number of foreign-owned plants in the high-tech sectors and (ii) the research and development (R&D) activities of foreign-owned plants has given rise to an increased interest in the relationship between foreign direct investment (FDI) and economic growth in Ireland. The central question explored in Chapter 5 is whether the tangible contribution of MNC plants that undertake R&D investment in Ireland is greater than the tangible contribution of MNC plants that do not undertake R&D investment. We conclude that the scale of R&D activity in a foreign-owned plant is an important factor in lengthening the duration over which that plant will operate in Ireland and in increasing the quantity and improving the quality of employment created in that plant.

Finally, two central questions concerning productivity spillovers from foreign-owned plants to indigenous plants were explored in Chapter 6. First, we investigated whether there are productivity spillovers from foreign-owned plants. Using the traditional

productivity approach to estimating spillovers from FDI, it was found that there are productivity spillovers to indigenous industry. Second, three extensions to traditional analysis were suggested with the aim of indicating whether it is possible to attribute the productivity spillovers to R&D spillovers in the Irish case. We concluded that there was no evidence of R&D productivity spillovers from foreign-owned R&D active plants to indigenous plants in Ireland.

7.2 Policy Implications

We discuss briefly a number of policy implications that may emerge from the analysis in this thesis.

The overall conclusion for indigenous firms, both new and incumbent, is that investment in R&D has positive consequences. As discussed in Chapter 2 and 3, R&D investment increases the probability of survival of both new and incumbent firms. There are two immediate policy implications. The small fraction of indigenous companies undertaking any R&D investment needs to be increased while the scale of the R&D investment in many existing plants needs to be increased also. Second, non-innovating firms that responded to the surveys of technology in industry (1993), argued that the major factor hampering their efforts to invest in R&D / innovation was lack of finance. There was no suggestion that these plants did not understand the potential benefits of R&D investment. This may suggest that providing access to finance would encourage this cohort of plants to undertake investment in R&D. However, we have provided no evidence in this thesis upon which to suggest that finance from central government causes firms to increase their own R&D activities.¹⁵⁸

¹⁵⁸See Breathnach (1994) for a review of the consequences of R&D grants in Ireland. See also Kauko (1996) for a review of the literature on R&D subsidies, Hall (1996) for a review of the Australian experience on R&D subsidies and Granstrand (1998) for a comment on the design of R&D tax credits.

Employment creation has been a central policy objective of the industrial development authorities for many years. There is the perception that investment in technology increases labour productivity and reduces labour demand by firms. Consequently, the enormous rise in government grants for R&D over 2000-2006 may reduce labour demand in manufacturing firms. The analysis in Chapter 4 found that labour demand was not significantly less in R&D active firms. Our analysis was limited to the extent that we could not control for the skill orientation of the jobs or the hours worked, two factors that could have changed quite considerably due to innovations within the firm. However, it is clear that the most significant difference that we can find between R&D active and non-R&D active companies is the significantly higher job persistence in R&D active firms. This characteristic in manufacturing firms may become important if government policy aims at increasing the quality of jobs created in addition to the quantity.

Irish industrial policy has, for some time, been aimed at attracting multinational corporations to establish subsidiaries in Ireland (Ruane and Görg, 1996; Barry, 1999). The quality of the FDI that is attracted must be a concern. There may be distinguishing characteristics (e.g., R&D activity) that imply that some FDI plants will have a relatively greater positive impact on the host region. An interesting policy question arises as to how to attract this particular type of FDI to Ireland. Specifically, how can R&D investment in foreign-owned plants in Ireland be increased? First, there may be financial incentives needed to counteract Ireland's low corporation tax rate (a financial inducement to FDI plants to establish themselves in Ireland) which acts as a deterrent to R&D investment. R&D active foreign-owned plants are able to write off a much higher percentage of their R&D investment against tax in those European

countries that have higher corporation tax rates. Second, multinational companies may be interested in establishing R&D facilities in Ireland if other multinationals already have similar facilities in Ireland and/or if indigenous firms are undertaking advanced R&D in Ireland. The potential spillover of knowledge from other world-class multinationals could be an important attraction of further R&D investment to Ireland.

An important positive externality for indigenous industry of increasing R&D activities in foreign-owned plants could be productivity spillovers from FDI. However, if indigenous industry is to avail of R&D productivity spillovers, indigenous industry must increase its own R&D investment in order to increase the capability to absorb any spillovers. The absence of evidence of R&D productivity spillovers in Ireland uncovered in the analysis may be due to the fact that too few indigenous manufacturing firms undertake R&D investment and/or their R&D programs may be too dissimilar to those undertaken in foreign affiliates. In addition, spillovers require pathways over which to travel between plants (e.g., through trading relationships). Preliminary indications of our research on spillovers support national policy of building up the technological infrastructure in the country, of developing R&D facilities within indigenous companies and of improving the level of contact between indigenous and foreign subsidiaries.

7.3 Concluding Comments

This thesis has contributed to the expanding literature on the consequences of research and development in manufacturing companies by addressing a number of issues, namely the survival, growth, employment and spillover effects of R&D investment, and providing empirical results for the Irish manufacturing sector. Our analysis has raised a number of issues that require further investigation. The first issue concerns

the impact of government grants for R&D projects on the scale and intensity of R&D activity subsequently undertaken by the recipients. This requires the development of accurate measures of innovative output that can be used to measure the performance of R&D investment. Secondly, in this thesis, we have established that R&D active firms perform better relative to non-R&D active companies. Further research needs to be undertaken to better understand, not just whether, but how R&D helps companies to perform better. Thirdly, the traditional analysis of labour demand, that focuses almost exclusively on the quantity of labour demanded, needs to be expanded to take account of the quality and skill orientation of labour demanded. Fourthly, an in-depth analysis of the determinants of the quantity and quality of R&D activity in FDI plants needs to be undertaken. Finally, there has been much speculation as to how technological spillovers occur from FDI plants to indigenous plants through the movement of trained labour from FDI plants. In a literature where there are few empirical studies of the channels through which productivity spillovers occur, labour mobility would appear to be a relatively easier channel to start collecting data and analysing its significance in terms of spillovers to indigenous plants.

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