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ESSAYS ON LABOUR PRODUCTIVITY, TECHNICAL EFFICIENCY AND FOREIGN DIRECT INVESTMENT IN IRISH MANUFACTURING INDUSTRY

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May 2003

DECLARATION

I declare that this thesis, submitted to Trinity College for the degree of Doctor in Philosophy (Ph. D.) 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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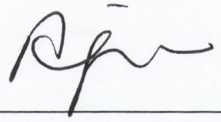
Signature 

SUMMARY

The aim of this thesis is to investigate the structural change that took place in the Irish manufacturing sector during the 1990s

Chapter 2 examines the patterns and growth of labour productivity and employment in Irish manufacturing industry over the 1990s for both domestic and foreign firms separately using 2-digit industry level data. We show that over the period overall labour productivity growth was 158 per cent. An examination of this growth by nationality of ownership shows that labour productivity growth has been much higher in foreign firms than it has been in their domestic counterparts, 185 per cent and 37 per cent for foreign and domestic firms, respectively which shows evidence of divergence of labour productivity in the Irish manufacturing sector between foreign and domestic firms. Our analysis of the sectoral growth rates in productivity between 1991 and 1999 shows that the sectors that are experiencing greater productivity growth are not the same for foreign as for Irish firms. Thus there is little evidence of convergence in productivity levels between domestic and foreign firms across sectors during the 1990s.

In Chapter 3 we examine the factors that affect the growth of labour productivity in Irish manufacturing sector using a decomposition analysis. The results for all manufacturing firms indicate that productivity increases within the continuing firms and the entry of firms which displayed productivity more than the industry average, have contributed significantly to the labour productivity growth in Irish manufacturing over the period 1991-1999. These results are in line with the findings from other studies where we see the dominance of within and entry effects on the overall productivity growth. In addition to the usual approach utilised in the literature we provide labour productivity decomposition results for both foreign and indigenous firms, as well as four different nationality groups. Results for foreign and domestic firms showed that overall within firm

productivity improvements were the main drivers of labour productivity growth for both groups. Results for four OECD sectors show that within-effect contributes most to overall labour productivity growth in all but one sector, namely high-tech sector in which net entry that is mainly driven by entry effect and cross term contribute most. This shows that in high-tech sector, the entry of above average firms and employment expansion in the high productivity firms has been the main drivers of the productivity growth.

In Chapter 4 we investigates the technical efficiency levels in the Electrical and Optical Equipment industry in Irish manufacturing sector and the factors that could affect these levels utilising a stochastic production frontier approach over the period 1991-99 using firm-level panel data. We find that investment intensity plays an important role in explaining technical inefficiency levels in all sub-sectors of the Electrical and Optical Equipment industry. We find some significant relationship between export intensity and labour quality and the technical inefficiency levels of individual firms.

We investigate the effect of foreign firms' entry or presence in the Irish manufacturing sector on both the levels and growth of labour productivity in domestic firms in Chapter 5. Our analysis, using panel data on all companies in the Irish manufacturing sector and covering the period 1991-98, finds no evidence of positive productivity spillovers from foreign to domestic firms when the standard measure of foreign presence adopted in most of the literature is used, namely, MNC employment as a percentage of total employment. However, when we use an alternative measure, which is employment in foreign companies in the relevant sector, a different picture emerges – at both the 2- and 4-digit NACE sector levels, the coefficient of foreign presence measure is positive and significant which shows that there are positive productivity spillovers from FDI in Irish manufacturing industry over the period 1991-99.

We present a brief review of the results from each chapter, policy implications and issues for further research are presented in Chapter 6.

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TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION 1

1.1 THESIS INTRODUCTION 1

1.2 AIMS OF THE THESIS 2

1.3 DATA SOURCE 5

1.4 STRUCTURE OF THE THESIS 7

1A TABLES 9

CHAPTER 2 LABOUR PRODUCTIVITY AND EMPLOYMENT IN IRISH MANUFACTURING INDUSTRY 10

2.1 INTRODUCTION 10

2.2 LABOUR PRODUCTIVITY AND EMPLOYMENT IN IRISH FIRMS IN THE IRISH MANUFACTURING SECTOR 12

2.3 LABOUR PRODUCTIVITY AND EMPLOYMENT IN FOREIGN-OWNED FIRMS IN THE IRISH MANUFACTURING SECTOR 17

2.4 PRODUCTIVITY AND EMPLOYMENT COMPARISONS ACROSS FOREIGN-OWNED AND IRISH-OWNED FIRMS IN THE IRISH MANUFACTURING SECTOR, 1991-1999 22

2. 5 CONCLUSION 27

2.A TABLES 29

2.B FIGURES 40

2.C APPENDIX 42

CHAPTER 3 DECOMPOSITION OF LABOUR PRODUCTIVITY GROWTH IN IRISH MANUFACTURING INDUSTRY 45

3.1 INTRODUCTION 45

3.2 DECOMPOSING PRODUCTIVITY CHANGE-METHODS AND REVIEW 47

3.3 DECOMPOSING LABOUR PRODUCTIVITY CHANGE IN IRISH MANUFACTURING 59

3.3.1 Approach of Decomposition 59

3.3.2 Methodology and Data 61

3.4 Decomposition of Productivity Growth by Ownership 63
3.4.1 Ownership Decomposition, 1991-1999 63
3.4.2 Ownership Decomposition, 1991-1995,1995-1999 67
3.5 Sectoral Decomposition 70
3.5.1 OECD Classification 70
3.5.2 NACE 2 Digit Sectors 75
3.6 Conclusion 82
3A Tables 84
3.B Appendix 93

CHAPTER 4 TECHNICAL EFFICIENCY IN IRISH MANUFACTURING INDUSTRY, 1991-1999 95
4.1 Introduction 95
4.2 Determining Inefficiency: Methodology and Literature 96
4.2.1 Methodology 96
4.2.2 Early Applications 105
4.2.3 Applications to Manufacturing Sector 106
4.3 Measuring Technical Efficiency in Irish Manufacturing Industry 110
4.4 Empirical Results 116
4.5 Summary and Conclusion 122

CHAPTER 5 FOREIGN DIRECT INVESTMENT AND PRODUCTIVITY SPILLOVERS IN IRISH MANUFACTURING INDUSTRY: EVIDENCE FROM PLANT LEVEL PANEL DATA 130
5.1 Introduction 130
5.2 International Evidence on Productivity Spillovers 134
5.4 Empirical Model and Methodology 141
5.5 Productivity Spillovers in Ireland- An Alternative Approach 145
5.6 Summary and Conclusions 147
5.A Tables 150

CHAPTER 6 CONCLUSION 155
6.1 OVERVIEW 155
6.2 CONCLUDING COMMENTS AND FUTURE WORK 162
BIBLIOGRAPHY 164

LIST OF TABLES

Table 1.1: Real GDP, Percentage Change from Previous Period 9

Table 1.2: Unemployment Rates 9

Table 1.3: Productivity Levels In OECD Countries, 1950-98 9

Table 2.2.1- Net Output, Employment, Labour Productivity and Number of Irish Firms in Irish Manufacturing Industry, 1991-1999 29

Table 2.2.2- Labour Productivity (£000) of Irish Firms by Different Size Groups and Associated Firm Numbers, 1991-1999 30

Table 2.2.3 : Labour Productivity (£000) of Irish Firms in 2-Digit Irish Manufacturing Sectors, 1991-1999 31

Table 2.2.4 : Employment in Irish Firms in 2-Digit Manufacturing Sectors, 1991-1999 32

Table 2.2.5- Labour Productivity (£000), Firm Numbers and Employment by OECD-Sectoral Classification, 1991-1999 33

Table 2.3.1- : Net Output, Employment, Labour Productivity and Number of Foreign Firms in Irish Manufacturing, 1991-1999 34

Table 2.3.2- : Labour Productivity (£000) of Foreign Firms by Different Size Groups and Associated Firm Numbers, 1991-1999 34

Table 2.3.3- : Labour Productivity of Foreign Firms in Irish Manufacturing Industry by 2 Digit-Sector in £000, 1991-1999 35

Table 2.3.4-Employment in Foreign Firms in Irish Manufacturing Industry by 2-Digit Sector, 1991-1999 36

Table 2.3.5- Labour Productivity (£000), Firm Numbers and Employment by OECD-Sectoral Classification, 1991-1999 37

Table 2.4.1- Labour Productivity in Irish Manufacturing Industry, 1991-1999 38

Table 2.4.2 Labour Productivity in Irish Manufacturing Industry by Nationality, 1991-1999 38

Table 2.4.3- Labour Productivity Ratios ff Irish Firms to Foreign Firms by Different Size Groups, 1991-1999 38

Table 2.4.4- Labour Productivity Ratios of Irish Firms to Foreign Firms by OECD Sector Classification, 1991-1999 39

Table 2.4.5- Amended Labour Productivity Ratios of Irish to Foreign Firms by OECD Sector Classification, 1991-1999 39

Table 2.C.1- : Number of Irish Firms in Irish Manufacturing Industry
by 2-Digit Sector, 1991-1999 42

Table 2.C.2- Number of Foreign Firms in Irish Manufacturing Industry
by 2-Digit Sector, 1991-1999 43

Table 2.C.3- OECD-Sectoral Productivity for Foreign Firms, 1991-1999 44

Table 2.C.4- OECD Sectoral Classification 44

Table 3.3.1- Significance of Foreign Firms in The Irish Manufacturing Sector, 1999 84

Table 3.4.1: Labour Productivity Decompositions, 1991-1999 84

Table 3.4.2: Labour Productivity Decompositions for Foreign Firms
by Nationality, 1991-1999 85

Table 3.4.3- Percentage Changes in Net Output and Employment
in Irish Manufacturing Sector, 1991-99 85

Table 3.4.4: Labour Productivity Decompositions, 1991-1995 86

Table 3.4.5: Labour Productivity Decompositions, 1995-1999 86

Table 3.5.1- - Labour Productivity Decompositions by OECD Sectoral Classification,
High-Tech 1991-1999 87

Table 3.5.2- Labour Productivity Decompositions by OECD Sectoral Classification,
Medium-High Tech 1991-1999 87

Table 3.5.3- Labour Productivity Decompositions by OECD Sectoral Classification,
Medium-Low Tech 1991-1999 88

Table 3.5.4- Labour Productivity Decompositions by OECD Sectoral Classification,
Low Tech 1991-1999 88

Table 3.5.5: Labour Productivity Decompositions, Irish Firms, 1991-1995 89

Table 3.5.6: Labour Productivity Decompositions, Irish Firms, 1995-1999 90

Table 3.5.7: Labour Productivity Decompositions, Foreign Firms, 1991-1995 91

Table 3.5.8: Labour Productivity Decompositions, Foreign Firms, 1995-1999 92

Table 3.B.1: Labour Productivity Decompositions, Irish Firms, 1991-1999 93

Table 3.B.2: Labour Productivity Decompositions, Foreign Firms, 1991-1999 94

Table 4.3.1- Employment Levels in Electrical and Optical Equipments Industry
and Its Share in Total Manufacturing Employment 124

Table 4.3.2- Employment Levels of Irish Firms in Electrical and Optical Equipments Industry
and Their Share in the Sector 124

Table 4.3.3- Labour Productivity Levels of Irish Firm in Electrical and Optical Instruments Industry, 1991-1999 125

Table 4.3.4- Sub-Sectors of Electrical and Optical Equipment Industry and Corresponding Nace Codes 125

Table 4.4.1- Generalised Likelihood-Ratio Tests of Hypotheses for Parameters of the Stochastic Production Functions 126

Table 4.4.2- Maximum-Likelihood Estimates for Parameters of the Stochastic Frontier Inefficiency Models 127

Table 4.4.3- Technical Efficiency Levels 128

Table 5.3.1- Changes in Irish Manufacturing Sector 1991-1998 150

Table 5.4.1- Descriptive Statistics for Regression Variables 151

Table 5.4.2- Sensitivity ff Productivity Spillovers to Sectoral Aggregation 151

Table 5.4.3- Sensitivity of Productivity Spillovers to Sectoral Aggregation (Growth) 152

Table 5.5.1- Sensitivity of Productivity Spillovers to Sectoral Aggregation 153

Table 5.5.2- Sensitivity of Productivity Spillovers to Sectoral Aggregation (Growth) 154

LIST OF FIGURES

Figure 2.2.1- Labour Productivity and Emploiment in Irish Firms
in Irish Manufacturing Industry 40

Figure 2.3.1- Labour Productivity and Employment in Foreign Firms
in Irish Manufacturing Industry 40

Figure 2.4.1- Labour Productivity in Irish Manufacturing Industry
by Nationality, 1991-1999 41

Figure 4.1- Production Frontiers and Technical Efficiency 129

Figure 4.2- Productivity and Technical Efficiency 129

CHAPTER 1 INTRODUCTION

1.1 Thesis Introduction

During the past decade, the Irish economy has been characterised by high rates of economic growth and low unemployment rates relative to other European Union (EU) and OECD countries. The increase in the real Gross Domestic Product (GDP) reached double-digits in the period 1995-2000 compared to growth rates of between 2 and 3 per cent in the EU and OECD countries.[1] Once associated with the high unemployment rates, especially in the 1980s and early 1990s, this growth in the output levels of the Irish economy has brought down unemployment levels from 15 per cent in 1992 to 3.9 per cent in 2001. Table 1.2 shows that the unemployment level in the Irish economy in 2001 was well below the average rates in EU and OECD countries. This success in achieving high growth rates of output and employment has been accompanied by substantial increases in the general labour productivity level of the economy, due to higher growth rates obtained in output relative to the growth in employment levels. We can see from Table 1.3 that the productivity level in Irish economy, which has been persistently behind those of industrialised countries, has now either caught up or surpassed these countries' productivity levels.

One of the main contributors to this overall high rates of growth in the Irish economy has been the Irish manufacturing sector, which experienced exceptionally high growth rates in terms of both employment and output during the period. Total net

[1] See Table 1.1.

output[2] has increased by over 200 per cent during the 1991-1999 period accompanied by a 26 per cent rise in the employment levels. Foreign Direct Investment (FDI), which has played a major role in achieving these growth rates in terms of both output and employment, has also facilitated considerable restructuring in Irish manufacturing industry and this role has been well documented in the literature.[3] The scale of such FDI is evident in data from Central Statistics Office (CSO), which show that in 1999, foreign firms accounted for 83 per cent of net output and 49 per cent of employment in the Irish manufacturing sector. In 1999 these foreign firms exported approximately 93 per cent of their output, which in turn accounted for 90 per cent of all manufactured exports from Ireland.

While employment creation has been the main focus of attention in Ireland for most of the past forty years, since the mid-1990s, especially as unemployment rates have declined, there has been a shift of emphasis towards focusing on labour productivity of Irish firms and creating linkages between foreign and domestic firms[4] as well as employment. Growth in living standards is seen as being crucially dependent on increasing labour productivity, especially in the manufacturing sector.

1.2 Aims of the Thesis

The aim of this thesis is to investigate the structural change that took place in the Irish manufacturing sector during the 1990s. Although a large body of literature has evolved over the last few years documenting this structural change, most studies focused on employment side of this change using firm level data sets or on labour

[2] Measured in 1985 prices.
[3] For a detailed discussion see Ruane and Görg (1996,1997), Gray (1997), Barry (1999),
[4] The focus on linkages has been primarily in the electronics and healthcare products industries. See Görg and Ruane (2001).

productivity using highly aggregated industry data[5], which can hide the underlying dynamics of change. In this thesis we try to shed more light into the understanding of the changes that took place in Irish manufacturing industry over the 1990 utilising a firm level panel data set. Specifically we focus on the changes in labour productivity and technical efficiency levels and the productivity effects of foreign firms in Irish manufacturing industry.

The first two chapters examine the changes in the labour productivity levels across the manufacturing sector. We begin by providing a detailed picture of the productivity changes that took place in Irish manufacturing industry at 2-digit industry level over the period. First we investigate employment and labour productivity growth both in indigenous and foreign companies in the Irish manufacturing sector and try to ascertain whether the differences in labour productivity at industry level are related to firm size or sector structure in each of them. Next we make comparisons of differences between the labour productivity levels of foreign and domestic firms and investigate whether the differences in productivity levels were increasing or decreasing over the 1990s. The distinguishing feature of this part of our study from other studies in the literature on investigation of labour productivity differences between foreign and domestic firms is that we provide analysis of the differences in labour productivity for different size groups of firms using a more disaggregated sectoral level.

Investigation of growth patterns in employment and output at aggregate level are important in examining productivity growth, but much of this change takes place within individual firms; hence an understanding of the changes taking place at the

[5] Some examples are Barry *et al.* (1999), Kearns (2000) and O'Muircheartaigh (2000).

individual firm level is important. It is often argued in the literature that even in the same narrowly defined industries it is not unusual to observe new or expanding producers as well as exiting or contracting ones, which play a major role in determining overall industry productivity change.[6] In order to investigate the contribution of continuing, entering and exiting firms to the overall labour productivity growth in Irish manufacturing industry we apply decomposition techniques widely used in the literature at plant level. We recognise that overall productivity reflects the balance between foreign and domestic firms but in order to reveal the different patterns that exist in Irish manufacturing industry we separate out the labour productivity levels as between foreign and indigenous companies.

Although labour productivity is one of the most commonly used measures in analysing performance of firms or industries, it only gives a partial picture of performance. Production function estimations have long been used in the literature in order to provide alternative measures, such as Total Factor Productivity (TFP), in examining firms' performance. An assumption commonly used in estimating production functions is that producers operate on their production functions, i.e., that all producers are technically efficient. An alternative approach suggested is to start with the presumption that not all producers are technically efficient and involves the estimation of frontier production functions. This approach is known as stochastic production frontier analysis and it describes the best practice technology in use on the technically efficient firms in an industry. Using this method elative technical efficiency of each firm to the frontier can be calculated and it also allows for examination of factors that can affect the technical efficiency levels of firms in a sector. Our next analysis uses a stochastic production frontier approach to measure

[6] See Foster *et al.* (1998) and Bartelsman *et al.* (2002).

technical efficiency in domestic manufacturing firms in Ireland and examine the factors, such as export intensity, labour quality and investment intensity, which can affect the changes in technical efficiency levels.

In terms of FDI, Ireland is one of the most globalised economies in the world, having pursued a strategy of promoting green-field investment in the manufacturing sector by foreign companies for over forty years. It is often argued in the literature that the investments of MNCs generate important externalities that enhance the productivity of indigenous firms in the economy. These externalities, which are typically referred to as "positive productivity spillovers", are seen as helping to improve the comparative advantage of the economy over time. Recognising the importance of foreign firms in Irish manufacturing industry, in our final analysis, we investigate whether domestic firms benefit from the entry or presence of MNCs in Irish manufacturing industry in terms of increased productivity levels.

1.3 Data Source

The data used in this thesis are from the Irish Census of Industrial Production (CIP).[7] This census is carried out annually by the Central Statistics Office in Ireland and covers all industrial local units with 3 or more persons engaged. As such it is the only fully representative survey of manufacturing plants in Ireland.

[7] To facilitate the research necessary for this thesis, the Central Statistics Office gave controlled access to anonymised micro data. This access was at all times within the CSO's premises and under stringent and rigorous conditions. Access such as this is provided for in the Statistics Act, 1993 solely for statistical research purposes.

The Census comprises two separate annual inquiries, namely the Census of Industrial Enterprises and the Census of Local Units. An enterprise is defined as the smallest combination of legal units that are wholly or primarily involved in industrial production, whereas a local unit could be an enterprise or part of an enterprise situated in a geographically identified place. The choice between using enterprise or plant level data depends on the aims of the study. It is often argued in the literature that for analysis involving productivity and especially entry and exit of plants, plant level data are more suitable because an enterprise consisting of separate local units can have changes in its employment or output levels in each local unit, which might cancel out at the enterprise level.[8] Also in the Irish manufacturing sector most enterprises consist of single local units.[9] Hence in this thesis we use data from the Census of Local Units and all calculations carried out at the micro level refer to the plant level data.

The data available are those standard for such Censuses – output (gross and net), sales, employment, wages, capital additions, sectoral (NACE 4-digit) and regional (county) classification as well as nationality of ownership. In the case of incomplete responses[10], they are fully estimated even when only a few of the most important variables such as employment, type of industrial activity are known.[11]

---

[8] For example if an enterprise consisting of two local units expand its employment level by 10 in one local unit and decrease it by 10 in the other local unit, this amounts to zero change at the enterprise level, whereas there are changes at the local unit level. See Haskel and Martin (2002) for a detailed discussion.

[9] On the average during the study period of 1991-99 over 98 per cent of enterprises consist of single local units.

[10] Due to the size of Irish manufacturing industry, and to the scrutiny of the CSO, the data are very consistent. For example in the 1999 Census, the share of accounted for by the non-respondents in total employment was only 2 per cent.

[11] If information for non-respondents is available from an alternative source, such as Monthly Production or Prodcom data, then the record is manually estimated; otherwise a computerised estimation procedure is used.

In the CIP the classification by nationality of ownership is determined by the nationality of the owners of 50 per cent or more of the share capital. There are no details recorded on the extent of foreign ownership within a given company and thus it is not possible to determine the impact of different shares of foreign ownership, as done in several panel level data studies for other countries. FDI policy in Ireland does not require minimum domestic equity participation as is the case in many developing countries, and most FDI is in the form of green-field investment with 100% foreign ownership.

1.4 Structure of the Thesis

This thesis contains four essays that examine the structural change that took place in the Irish manufacturing sector. Studies in other countries on productivity typically do not distinguish between foreign and domestic firms in their analysis. In Irish manufacturing industry, as we outlined above, it is well documented that foreign and domestic firms have several different characteristics. So in this study, where data, allowing for confidentiality constraints permit, we carry out our analysis separately for domestic and foreign firms.

Chapter 2 examines the changing patterns of employment, net output and labour productivity in Irish manufacturing industry for both domestic and foreign firms during the 1991-99 period using different size classifications and sectoral disaggregation. In addition to the usual NACE 2-digit classification system we utilise OECD classification system of sectors according to their technology intensity. We

also provide descriptive measures for different nationality groups among foreign firms.

In Chapter 3 we investigate the dynamics of factors underlying the changes in the labour productivity levels in Irish manufacturing industry utilising a decomposition approach. In addition to the usual analyses carried out in the literature, we provide results for both foreign and domestic firms separately as well as different nationality groups among foreign firms.

Chapter 4 uses a stochastic production frontier approach to estimate the technical efficiency levels of Irish manufacturing firms and to investigate the factors that affect these efficiency levels. Our analysis in this chapter focuses on the Electrical and Optical Equipment industry, which played a major role in the industrial policy that, has been followed over the last thirty years in the Irish economy.

We investigate the possible "positive productivity spillovers" from FDI to domestic firms in the Irish manufacturing sector in Chapter 5 to examine whether domestic firms benefited from the entry or presence of foreign firms in increasing their productivity levels.

Each individual chapter contains an appendix including tables, graphs and other appendices referred to in the respective chapter. Finally, a brief review of the results from each chapter, policy implications and issues for further research are presented in Chapter 6.

1A Tables

Table 1.1: Real GDP, Percentage Change from Previous Period

	1991	1993	1995	1997	1998	1999	2000	2001
Ireland	1.9	2.7	10.0	10.8	8.6	10.8	11.5	6.6
Germany	5.0	-1.1	1.7	1.4	2.0	1.8	3.0	0.6
U.K.	-1.4	2.5	2.9	3.4	3.0	2.1	3.0	2.2
Japan	3.1	0.4	1.6	1.8	-1.1	0.7	2.4	-0.4
Australia	-0.7	3.8	3.9	3.5	5.4	4.5	3.4	2.4
U.S.	-0.5	2.7	2.7	4.4	4.3	4.1	4.1	1.2
EU	1.8	-0.3	2.5	2.6	2.9	2.6	3.4	1.7
OECD Area	1.2	1.4	2.5	3.5	2.7	3.1	3.9	1.0

Source: OECD Economic Outlook 71, June (2002)

Table 1.2: Unemployment Rates

	1991	1993	1995	1997	1998	1999	2000	2001
Ireland	14.4	15.7	12.2	10.4	7.6	5.6	4.3	3.9
Germany	5.4	7.6	7.9	9.4	8.9	8.2	7.5	7.4
U.K	8.2	10.3	8.5	6.5	5.9	6	5.5	5.1
Japan	2.1	2.5	3.1	3.4	4.1	4.7	4.7	5.0
Australia	9.2	10.6	8.2	8.2	7.7	6.9	6.3	6.8
U.S	6.8	6.9	5.6	4.9	4.5	4.2	4	4.8
EU	7.7	10.2	10.1	10	9.4	8.7	7.8	7.4
OECD Area	6.3	7.7	7.3	6.9	6.7	6.6	6.1	6.4

Source: OECD Economic Outlook 71, June (2002)

Table 1.3: Productivity Levels in OECD Countries, 1950-98
(GDP per man-hour relative to United States)

	1950	1973	1987	1992	1998
Ireland	32	46	66	77	86
Germany	-	-	-	87	90
United Kingdom	58	68	81	79	82
Japan	15	45	60	67	68
Australia	66	69	77	75	78
United States	100	100	100	100	100

Source: Scarpetta *et al.* (2000)

CHAPTER 2 LABOUR PRODUCTIVITY AND EMPLOYMENT IN IRISH MANUFACTURING INDUSTRY

2.1 Introduction

For many decades employment creation has been the priority for industrial policy in Ireland. This objective stemmed from the major need to restructure the economy, primarily out of the agricultural sector and more recently out of the older sectors within manufacturing and into the newer, higher-value sectors. As the Irish economy has moved closer to full employment in the 1990s, there has been a shift of emphasis towards focusing on labour productivity as well as employment. Growth in living standards is seen as being crucially dependent on increasing labour productivity, especially in the manufacturing sector. It has been argued in the literature that such productivity increases can be the result of a range of factors, such as: the establishment of new enterprises whose labour productivity is higher than that of the average in the sector; the closure of below-average productivity enterprises with low productivity; and increases in the actual productivity of existing firms.[12]

This chapter looks at the changing patterns of labour productivity in Irish manufacturing industry and tries to answer a number of questions that emerge. In particular, we are interested in the productivity differences across different sectors and over various size-classification of firms. In all cases we separate out the labour productivity levels as between foreign and indigenous companies, as to merge these

[12] There are different mechanisms through which these improvements can occur such as training of labour, access to capital or access to export markets where firms can achieve a higher market value for their output.

is often to blur the very different patterns that operate in Irish manufacturing, while recognizing that overall productivity reflects the balance between them.

In Section 2.2 we look at how labour productivity and employment have changed in indigenous companies in the Irish manufacturing sector over the 1990s. We examine differences in productivity as related to size and sector. Section 2.3, examines the productivity of labour and employment in foreign companies in the Irish manufacturing sector, again distinguishing between different size classes of companies and the sector in which they operate. Finally in Sector 2.4 we examine whether there is any apparent relationship between the productivity levels experienced by indigenous companies and by multinational enterprises (MNEs) in the same sectors.

All data used in the analysis cover the period 1991-1999 and come from the Central Statistics Office's Census of Industrial Production (CIP).[13] One of the advantages of this survey is its comprehensive coverage of manufacturing industry where all firms in the sector with three or more employees are included. [14] All value figures expressed in the analysis are in Irish £s and in 1985 prices, where net output is deflated using relevant Producer Price Indices given at 2-digit and 3-digit sector levels.

[13] Details of data are outlined in Chapter 1.

[14] There are similar surveys for the Irish manufacturing industry such as Irish Economy Expenditure surveys carried out by Forfás. Although this survey includes internationally traded sectors as well as manufacturing industry it only covers firms with 10 or more employees which excludes quite a lot of firms in the Irish manufacturing sector given the low average size of firms.

2.2 Labour Productivity And Employment in Irish Firms in the Irish Manufacturing Sector

In this section we look at employment and labour productivity growth in the indigenous companies in the Irish manufacturing sector. Table 2.2.1 shows that net output in Irish manufacturing firms grew by 57 percent in real terms over the 1990s. At the same time total employment rose by 15 percent overall, bringing to an end the long trend decline in manufacturing employment in Irish-owned firms experienced since the 1970s. As is evident from Figure 2.2.1, the most rapid period of employment growth was between 1994 and 1997, with the periods on either side of this being marked by virtually no change in employment.[15] As the number of Irish-owned firms increased by 8 percent, the average employment size of Irish-owned firms increased – again in contrast to the experience of the 1980s. Over the period, labour productivity rose by 37 percent where productivity increased at a steady pace except between 1994 and 1995 when it suffered a slight decline.

In Table 2.2.1 we see that the number of Irish-owned firms in manufacturing increased from 3,792 to 4,095 between 1991 and 1999, resulting in an overall increase of 8 percent. In order to examine the changes in the number of firms and labour productivity across small, medium and large size firms, we follow the CSO classification of size groupings and present the results in Table 2.2.2. Over 40 percent of the firms in 1991 were small (employment at or below 10) and these accounted for a slightly smaller fraction of firms in 1999 (37 percent). These small firms enjoyed very substantial growth in productivity over the period, surpassing the

[15] This earlier period gave rise to the discussion of "jobless growth"[15], a phrase coined to capture the fact that output was increasing rapidly, while employment was not. See Guiomard (1995) for a detailed discussion.

rates of productivity increase in all sectors apart from those with 500+ employees. This would seem to suggest that whereas many smaller (<10 employees) firms in the early 1990s were low productivity firms, in the latter part of the 1990s many of these very small firms had productivity levels that matched or bettered those in the size ranges 10-49.

The exceptionally high growth rates in productivity in the 500+ category has widened the range of labour productivity across the indigenous sector over the 1990s – this category has almost twice the productivity levels of firms with employment below 50. The sharp increase in labour productivity in this group in 1999, combined with the fall in firm numbers from 17 to 11, suggests that at least some of the firms which exited this group (either through closure or to their entering another size category) had productivity levels below the productivity levels of those firms continuing to operate in the sector. While there is a general upward trend in the relationship between productivity levels and firm size, it is clear that this is not uniform, undoubtedly reflecting differences in other characteristics associated with the firms and in particular with the sectors in which they operate.

We now turn to look at the sectoral composition of labour productivity over the 1990s using the familiar two-digit NACE classification and present results in Table 2.2.3. To facilitate discussion, the sectors are ranked according to their productivity levels in 1999. These range from the highest productivity in Pharmaceuticals to the lowest in Motor Vehicles and Transport – a ratio of over 7:1, which is significantly higher than the productivity ratio for the highest (Chemicals) to the lowest (Textiles & Clothing) of 4.5:1 in 1991. This reflects the exceptionally fast growth in

productivity (210%) in the Pharmaceuticals sector (and particularly between 1998 and 1999) and the decline in labour productivity (-2%) in Motor Vehicles and Transport over the period.

Thus the labour productivity growth of 37 percent on average in real terms over the period masks a wide variation in growth patterns in productivity levels across sectors. The average labour productivity for Irish manufacturing firms was £33.5k in 1999. All of the traditional sectors with the exception of Food, Beverages & Tobacco have below average productivity levels and Office Machinery & Computers is the only "high-tech" sector with below average productivity, reflecting the low rate of growth in productivity in that sector over the 1990s. Labour productivity in the Chemicals sector remains high despite the fact that labour productivity in that sector declined over the 1990s. The relationship between labour productivity and employment growth within sectors can be examined by comparing Tables 2.2.3 and 2.2.4.

As in the case of Table 2.2.3, sectors are ranked according to their highest levels of employment in 1999 in Table 2.2.4. Traditional sectors still account for most of the employment in Irish manufacturing firms, with Food, Beverages & Tobacco accounting for the largest share (27.5%) of employment, and more than two and a half times the next largest sector (Printing and Publishing).

Over the period employment grew in all but two sectors – Motor Vehicles & Transport experiencing a 40 per cent decline and Textiles & Clothing showing a 35 per cent drop in the employment levels, the sectors with the two lowest levels of

labour productivity in 1999. The growth rates in many of the high-tech sectors are very impressive, especially in the late 1990s, but this growth starts from a relatively small base. The structural readjustment that is taking place is evident in the differences in the ranking of sectors by employment size between 1991 and 1999. For example, while Textiles & Clothing was the second largest sector in employment terms in 1991, by 1999 it had slipped to seventh place.

Since overall productivity in Irish firms depends on composition, it is important to ask what is happening to employment growth in the sectors in which productivity is growing fastest. We calculate the Pearson rank correlation coefficient for the final two columns in Tables 2.2.3 and 2.2.4 in order to examine the relationship between employment and productivity growth in individual 2-digit sectors. The value of this coefficient is 0.27 indicating a relatively weak correlation between productivity and employment growth rates of domestic establishments over the 1991-1999 period.

While the two-digit sectors show how different productivity levels are across sectors, they are somewhat too diffuse to create a general picture. An alternative sectoral decomposition that is possible uses the OECD classification of firms at the three/four digit level to generate four classes of sectors: high tech, medium high tech, medium low tech, and low tech and we present the results in Table 2.2.5 (The sub-sectors included in the different sectors are listed in Appendix in Table 2.C.4.)

What is most striking from Table 2.2.5 is the small portion of establishments (2.4%) and employment (4.2%) accounted for by Irish-owned firms operating in what the OECD defines as high tech sectors. These low percentages persist despite the fact

that employment in this sector has increased by 92% over the period while the number of firms has increased by 30% compared with an overall increase in employment and firm numbers of 15% and 8 % respectively. This indicates the relatively late move of Irish entrepreneurs into the sectors being promoted by government for over twenty years. If one adds the medium high-tech, then the employment share rises to 20% and establishment share to 19%. However, as we can see from Table 2.2.5, productivity in the high-tech sector is much higher than in the medium high tech, whose productivity grew more slowly (18%) than did productivity for the manufacturing sector as a whole (37%) over the period.

2.3 Labour Productivity and Employment in Foreign-Owned Firms in the Irish Manufacturing Sector

Foreign firms play an important role in Irish manufacturing industry, accounting for 83 per cent of net output and nearly 50 per cent of overall employment in 1999. In this section we examine labour productivity levels across foreign owned firms in different size classifications and sectors. Due to the complex manner in which MNEs do business internationally, the measurement of labour productivity in any individual plant may understate or overstate the true productivity in that plant since statistics are collected on a local rather than a global basis.[16] By contrast, there are no such difficulties with employment data and while there may be difficulties with measuring labour productivity in foreign-owned companies, we do not expect these difficulties to alter the measurement over time.

Table 2.3.1 and Figure 2.3.1 show that there has been a steady upward rise in net output and employment in foreign firms over the 1990s. Labour productivity increased by over 180% as net output grew faster than employment. The growth of employment of 41 percent was exceptional in the context of other EU countries in the same period, and reflected Ireland's significant success in winning FDI manufacturing projects during the 1990s[17]. It is noteworthy that the number of foreign firms operating in the Irish manufacturing sector actually fell by 8 percent over the period, implying that, in terms of employment, average firm size has risen. This contrasts with results from the 1980s, when average firm size fell.

[16] Evidence in Stewart (1989) and Murphy (1998) suggests that foreign firms in certain sectors of Irish manufacturing industry are involved in transfer pricing practices in order to avail of the low corporation tax rate.

[17] For a detailed discussion see Ruane and Görg (1997,1998)

Table 2.3.2 shows that the number of foreign-owned enterprises has fallen in the smallest size category of firms (less than 50 employees), has risen modestly in the intermediate size categories and has risen dramatically (more than doubled) in the size category over 500 employees. One striking feature in the table is that over 37% of foreign-owned firms have less than 50 employees. On further reflection this is not so strange as over this period there was a very high level of new firm formation. These small firms enjoyed very substantial growth in productivity over the period, surpassing the rates of productivity increase in all sectors apart from those in the employment category 250-499. Whereas many of these smaller firms in the early 1990s were low productivity firms, in the latter part of the 1990s many of these had productivity levels that matched or bettered those in the size ranges 50-149.

Table 2.3.2 points to the wide differences in labour productivity across different size categories of firms, ranging in 1999 from the highest productivity (£400k) to the lowest (£90k). In 1991 the size category with the highest labour productivity was the 250-500 range and this remained true throughout the period, during which labour productivity rose by over 342%. While there is a general upward trend in the relationship between productivity levels and firm size, it is clear that this is not uniform, undoubtedly reflecting differences in other characteristics associated with the firms and in particular with the sector in which they operate.[18] The next largest productivity increase occurred among smaller firms – those in the less than 50 employment category, which rose by 211%. Whereas at the start of the 1990s the

[18] A key policy issue is the source of the average productivity increase – to what extent is it due to (a) new high productivity firms which have entered that size category, (b) exiting of lower productivity firms, (c) increased productivity across existing firms in the category, or some combination of all three.

average labour productivity was lowest amongst the smallest firms, by the end of the 1990s this category had higher productivity than firms in the 50-100 and 100-250 ranges. Again the question arises as to what has determined this change – the arrival of higher productivity firms, the departure of low productivity firms, or an increase in the productivity of existing firms?

We now turn to look at the sectoral composition of factor productivity over the 1990s using the familiar two-digit NACE classification. To facilitate subsequent discussion, the sectors are ranked using the same sectoral order as for the indigenous sector in Table 2.3.3. Labour productivity in Chemicals in 1999 at £833k is twenty six times the productivity in the lowest sector (Textiles & Clothing); the corresponding ratio for 1991 was 12:1. This reflects the exceptionally fast growth in productivity (364%) in the Chemicals sector, while labour productivity in Textiles & Clothing grew at over 90%.

In Table 2.3.3 we see that the exceptionally high value added in four sectors in 1999, namely, Chemicals, Pharmaceuticals, Printing & Publishing, and Food & Beverages, is driving the average labour productivity in manufacturing, due to the large relative size of these sectors in terms of total employment. All the remaining sectors have below average labour productivity. The relationship between labour productivity and employment growth within sectors can be examined by comparing Tables 2.3.3 and 2.3.4.

As in the case of Table 2.2.4, sectors in Table 2.3.4 are ranked according to their highest levels of employment in 1999. The modern high-tech sectors account for

most of the employment in foreign-owned firms, and thus it is not surprising the overall labour productivity of foreign firms is high, since these sectors have the highest productivities in Table 2.3.3. The only exception to the dominance of high-tech sectors is Food, Beverages & Tobacco, the fourth largest sector that accounts for 10% of total employment in foreign-owned firms. However, it is noteworthy that employment in this traditional sector declined slightly over the period (-1%) while overall employment in foreign firms increased by 41%.

It is evident that a considerable amount of structural adjustment took place in the foreign component of the manufacturing sector during the 1990s as employment fell in seven out of the seventeen sectors listed. The structural readjustment is evident in the differences in the ranking of sectors by employment size between 1991 and 1999. In order to examine the relationship between employment and productivity growth across sectors in which productivity is growing fastest we calculate the Pearson rank correlation coefficient for the final two columns in Tables 2.3.3 and 2.3.4. We find that for foreign firms, sectors which are experiencing higher productivity growth are not the same as sectors experiencing higher employment growth, as evident by a correlation coefficient value of only 0.07.

In looking at the sectoral composition of manufacturing industry, it is helpful to look at the OECD classification, which is based on its ranking of three/four digit level as being high tech, medium high tech, medium low tech, and low tech. From an employment perspective, what is most striking from Table 2.3.5 is that while the total number of foreign-owned enterprises declined over the 1990s by 8%, this decline did not occur in the high-tech sectors where establishments grew by over

11% and employment by 159%. By 1999 the portions of foreign-owned establishments and employment in the high-tech sectors were 16% and 30% respectively compared with 13% and 16% respectively in 1991. This points to the very significant growth in employment in high-tech sectors, where labour productivity almost doubled over the period.

The most striking feature of this table from, a labour productivity perspective, is that labour productivity in the medium-high tech and low-tech sectors in Ireland actually exceeded that in the high-tech sectors towards the end of the decade. In the case of the foreign sector the low productivity activities are found in the medium low-tech sector, which saw an increase in employment of 25% over the period. From a policy perspective it is important to note that, as in the case of domestically-owned industry, high tech does not necessarily equate to high labour productivity – labour productivity measures value added per unit labour and this can be high because of marketing/patents, etc without any significant technology being embedded in the product or indeed any high physical productivity of labour. In effect what we could be seeing here is that there are activities/niches in the low-tech sectors in Ireland, which have very high productivity. This is especially so in the Food, Beverages & Tobacco sector. We return to this issue in Section 2.4 below.

2.4 Productivity and Employment Comparisons across Foreign-Owned and Irish-Owned Firms in the Irish Manufacturing Sector, 1991-1999

In this section we draw comparisons between the productivity and employment levels of foreign and domestic firms in Irish manufacturing industry. There are three main reasons why one would expect labour productivity levels to be lower in foreign compared with domestically owned firms. First, one would expect the average labour productivity of Irish firms to be lower, as these include many small firms that are at the developmental stage, in contrast with the foreign owned companies many of which are the branches or subsidiaries of well-established MNEs. A review of the numbers of firms alone would indicate this – in 1999 there were over 4,000 Irish-owned firms (compared with under 700 foreign-owned manufacturing firms) and over 37% of these had 10 or fewer employees. However, what is of policy interest is that the productivity levels of Irish firms continue to increase at a slower rate than the productivity of the foreign firm so that the gap is actually widening. Second, because of the complexity of international production methods and the complex accounting systems which accompany them and which are influenced by financing and taxation considerations, measured labour productivity of foreign-owned enterprises may under or overstate the actual labour productivity. In the context of Ireland's tax policy over the past forty years, the expectation would be towards over- rather than under-statement of productivity of the Irish production. Finally, mobile investment is more likely to occur in sectors that have relatively higher labour productivity, as these are sectors where firms are more likely to be able to reap the benefits of international location. Thus we would expect to find a disproportionate representation of foreign-owned firms in high-productivity sectors.

Table 2.4.1 shows that the overall growth of 158% in labour productivity in manufacturing in the period 1991-1999 is a product of very rapid growth in the foreign component (185%) and much more modest growth in the domestic component (37%). Whereas in 1991 labour productivity in Irish companies registered one third that of foreign companies, by 1999 this ratio had been halved to one sixth.

Since the composition of direct foreign investment changed somewhat over the 1990s, with increased extra-EU investment and much less intra-EU investment, it is insightful to look at the differences in productivity growth decomposed into four categories – UK, Other EU, US and Other Non-EU. This is examined in Table 2.4.2.

In terms of nationalities, the productivity of Other EU firms in both 1991 and 1999 was closest to that of Irish firms, with the UK in the next highest place. In the case of both of these categories, labour productivity grew at a faster pace than did productivity in Irish companies, and thus the pattern of a widening gap relates to all nationality categories. The numbers of firms located in Ireland fell over the period - by just over 10 percent in the case of the UK and over 15 percent in the case of Other EU firms, in contrast with the growth in firm number of 8% in the case of Irish firms. US firms were the only foreign nationality group to increase in number over the 1990s - by almost 9 percent (with peak number in 1998); and at the same time their average labour productivity increased at the fastest pace (by 185 percent) – more than three times the rate of average productivity increase experienced by UK firms.

The labour productivity of the "Other non-EU" category increased by over 91 percent during the period, while, in contrast with the US, the number of firms in this category fell steadily from 1996 onwards – by over 30 percent. This suggests that at least some of the increase in average productivity may have been due to the closure of lower productivity companies.

In order to focus on the contrast between Irish and foreign-owned firms over the 1990s, we use the data in Sections 2.2 and 2.3 to generate productivity ratios (Irish to foreign) by size and sector.

Table 2.4.3 shows that the decline in the overall relative productivity of Irish firms is found in all size categories with the exception of the 50-99 size, where Irish average productivity increased faster than foreign productivity though it still remains at only a third of foreign productivity. From a policy perspective the relatively better performance of Irish firms in the 500+ category is consistent with their becoming successful global players, though the overall productivity levels are still less than 40% of foreign productivity levels.

Data in Table 2.4.4 indicate that the relative decline in productivity levels in Irish firms is concentrated in two sectors – the medium-high tech sector and the low-tech sector. By contrast, productivity levels in Irish firms in the medium-low tech sector have grown more quickly than that in foreign firms, reaching over 80 percent of their levels in 1999. The performance in the high-tech sector is not as striking but Irish firms have least have lost no productivity ground in the high-tech sector over the

period. Medium-high and low-tech are falling behind though this is primarily due to the rapid productivity growth of foreign firms in the Chemicals sector, which is in the medium-high-tech group, and in the Food, Beverages & Tobacco and Printing & Publishing sectors, which are in the low-tech sectors.

In order to take account of sectors that are known to have exceptionally high value added in Ireland, we present in Table 2.4.5 amended productivity ratios where foreign firms in the following sectors have been removed from the calculations:

- Pharmaceuticals from the High tech sector
- Chemicals from the Medium high tech sector
- Soft Drinks and Recorded Media publications from the Low-tech sector.

The basis for the foreign productivity data used in calculating the ratios here is presented in Table 2.C.3 in the Appendix, which shows that foreign productivity growth in these excluded sectors was over 650% during the period 1991-1999. The exclusion of Pharmaceuticals has a modest (two-percentage point) negative impact on the labour productivity growth in the High tech sector while the exclusion of Chemicals had a significantly large positive impact on productivity growth in the Medium high tech sector, reflecting the low rate of productivity growth in Chemicals, while having a high absolute level of productivity[19]. The amended Low-tech productivity growth rate dramatically reduced (by more than half) as a consequence of the exclusions of foreign firms producing Soft Drinks and Recorded Media publications.

[19] The growth in the labour productivity of the high-tech sector for foreign firms is 98 per cent in Table 2.3.5 whereas this growth rate decreases to 96 per cent in Table 2.A.3 where pharmaceuticals industry is removed from the calculations.

The impact of removing these sectors is to raise the productivity ratios significantly in all but the Medium-Low tech sector, which is unchanged by the emendation. In the case of the High-tech sector, the amended ratio stays constant over the period, while in the Medium-High it falls by a greater amount and in the Low-tech sector by a lesser amount.

Rather than presenting ratios for each of the 2-digit NACE sectors, we look at the sectoral productivity ranking and calculate the Pearson rank correlation coefficient for productivity levels between Irish and foreign owned firms in 1999 and for the growth in productivity between 1991 and 1999. The Pearson rank correlation coefficient for productivity levels across sectors in 1999 is 0.8. This indicates a close parallel between productivity levels for foreign and Irish firms, i.e., there is a broadly similar, but not identical, ranking of sectors in terms of productivity levels. The situation is quite different for growth rates in productivity. Here we find a correlation coefficient of just 0.28, indicating that the sectors which are experiencing greater productivity growth are not the same for foreign as for Irish firms. Thus there is little evidence of greater convergence in productivity growth rates across sectors during the 1990s. To complete the picture, we include in Table 2.4.5 the ranking of sectors by employment growth. In the case of employment, the growth patterns across sectors are ever less similar than for productivity growth – the Pearson Rank correlation coefficient is 0.25.

2. 5 Conclusion

This chapter shows the patterns of growth in productivity and employment in Irish manufacturing industry over the 1990s. Over the period 1991-99, labour productivity in Irish manufacturing industry increased by 158 per cent and most of this increase came through the foreign firms, which increased their average productivity by 185 per cent while their domestic counterparts enjoyed a more modest increase of 37 per cent.

A detailed analysis of labour productivity levels for both domestic and foreign firms showed that there are striking differences across firm size, 2-digit sectors and geographical regions. Comparison of productivity levels of indigenous and foreign firms at individual 2-digit NACE sectors showed that labour productivity difference between the two has increased over the period, reflecting the fact that domestic firms were not able to catch up with their foreign counterparts.

Recognising the fact that foreign firms in some sectors of Irish manufacturing industry engage in transfer pricing in order to avail of the low corporation tax rates, which results in overstated value added figures, we excluded these sectors in our broad analysis of the four OECD sector groups. Results show that the high divergence between the productivity levels of foreign and domestic firms somewhat reduce or increase at a much slower rate, reflecting the fact that domestic firms have at least lost no productivity ground. Even accounting for the high value-added sectors, this shows that there is still a labour productivity gap between domestic and foreign firms in Irish manufacturing industry.

Examining the growth in productivity this chapter raises a key question – what is the source of the productivity growth where it occurred? Was it within-firm productivity growth, growth in the number of above average productivity firms, growth in the number of firms whose productivity is growing, the entrance of new higher productivity firms or the exit of firms whose productivity was below average? In order to answer these questions we analyse firm-level data to study the decomposition of the productivity growth in Irish manufacturing industry in Chapter 3.

2.A Tables

Table 2.2.1: Net Output, Employment, Labour Productivity and Number of Irish Firms in Irish Manufacturing Industry, 1991-1999

	Total Net Output (£000s)	Total Employment	Labour Productivity	Number of Firms
1991	2,701,387	110,009	24,556	3,792
1992	2,770,028	111,382	24,870	3,782
1993	2,877,324	111,167	25,883	3,827
1994	2,924,290	109,706	26,656	3,855
1995	3,034,622	116,714	26,000	3,858
1996	3,347,314	120,224	27,842	3,858
1997	3,657,263	126,632	28,881	3,998
1998	3,814,947	127,529	29,914	3,968
1999	4,252,372	126,840	33,525	4,095
1991-1999	57%	15%	37%	8%

Note: In this table and all subsequent tables, value figures are in Irish £s and 1985 prices.

Table 2.2.2: Labour Productivity (£000) Of Irish Firms By Different Size Groups And Associated Firm Numbers, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
10 OR LESS	17.6	19.9	19.6	19.8	19.6	21.1	21.9	22.8	26.8	52%
# Firms	1512	1530	1564	1559	1485	1459	1488	1440	1541	
10-19	20.5	20.9	21.1	22.2	21.0	21.4	21.0	23.9	26.2	28%
# Firms	945	884	922	928	925	898	956	930	957	
20-49	23.1	23.1	23.8	24.6	23.1	24.9	25.5	24.4	26.0	13%
# Firms	784	824	808	845	884	921	928	982	999	
50-99	23.5	24.9	24.4	26.1	24.8	24.5	25.8	27.6	34.2	45%
# Firms	299	305	317	325	342	347	363	353	333	
100-199	28.9	27.8	31.2	30.2	31.2	33.0	32.5	35.0	38.8	34%
# Firms	127	124	122	119	145	151	171	177	177	
200-249	34.7	35.9	32.3	39.0	47.1	29.9	42.0	42.0	43.5	25%
# Firms	22	22	25	27	22	24	26	24	31	
250-499	28.8	28.9	30.9	29.8	30.0	38.9	37.1	36.2	35.7	24%
# Firms	30	31	31	28	30	33	33	34	36	
500 AND OVER	24.5	23.7	28.0	28.7	24.1	33.0	36.6	39.5	51.8	112%
# Firms	13	14	12	12	14	14	17	17	11	
All firms	24.5	24.9	25.9	26.7	26.0	27.8	28.9	30.0	33.5	37%
# of All Firms	3,792	3,782	3,827	3,855	3,858	3,858	3,998	3,968	4,095	8%

Table 2.2.3: Labour Productivity (£000) of Irish Firms in 2-Digit Irish Manufacturing Sectors, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Pharmaceuticals	32.5	29.5	20.3	32.6	31.2	35.2	56.0	44.8	100.8	210%
Chemicals	53.9	50.9	47.33	56.3	56.4	72.7	56.0	60.3	52.1	-3%
Other Non-Metallic Minerals	30.5	31.9	37.0	38.9	40.2	40.7	43.7	44.5	48.2	58%
Medical, Precision and Optical	25.5	32.4	36.5	32.7	31.3	37.6	45.3	42.9	43.4	70%
Food, Beverages and Tobacco	31.0	30.4	31.7	31.1	30.7	32.5	32.1	34.9	38.8	25%
Paper and Paper Products	29.1	32.2	34.9	34.5	37.1	33.0	34.3	35.4	38.5	33%
Publishing and Printing	22.8	23.0	22.7	25.0	23.8	25.4	27.3	28.6	35.2	54%
Radio, Television and Communications	19.8	16.7	21.2	19.8	19.2	25.0	25.4	33.0	34.4	74%
Manufacturing n.e.c.	24.9	26.3	25.5	23.3	27.0	26.1	33.5	34.8	31.5	26%
Office Machinery and Computers	28.8	29.6	26.9	28.3	22.6	31.0	26.0	28.0	31.1	8%
Electrical Machinery	17.5	17.8	16.4	18.9	19.9	20.3	20.7	22.3	25.6	46%
Rubber and Plastics	21.1	21.9	22.7	24.6	22.2	23.0	23.6	23.1	24.9	18%
Basic and Fabricated Metals	21.1	20.9	21.4	20.6	21.5	22.0	23.5	23.9	24.8	18%
Machinery and Equipment	20.9	20.2	20.3	22.6	20.8	24.5	27.7	25.3	24.5	17%
Wood and Wood Products	14.1	15.7	15.8	16.4	14.7	16.9	18.2	17.9	21.1	50%
Textiles and Clothing	12.2	13.3	13.9	14.1	14.0	14.1	15.5	15.3	16.9	38%
Motor Vehicles and Transport	16.0	17.9	19.5	20.2	15.5	18.0	16.9	18.1	15.7	-2%
Average	24.6	24.9	25.9	26.7	26.0	27.8	29.2	30.3	33.5	37%

Table 2.2.4: Employment In Irish Firms In 2-Digit Manufacturing Sectors, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Food, Beverages and Tobacco	32064	32768	32628	31540	33109	33710	33971	34383	34933	9%
Printing and Publishing	10292	10782	11660	11460	11219	11140	12095	12841	12729	24%
Basic and Fabricated Metals	9239	9164	8940	9164	9563	10440	10450	10974	11823	28%
Other Non-metallic Minerals	8255	7810	7652	8292	8041	8098	8580	8324	8916	8%
Manufacturing n.e.c.	6746	6620	6742	6581	6923	7256	8252	8976	8745	30%
Machinery and Equipment	5379	5660	5960	6340	6889	7230	8586	7750	7878	46%
Textiles and Clothing	11455	11189	10382	10153	10233	9696	10041	8890	7414	-35%
Rubber and Plastics	3746	3962	3979	4155	4669	5285	5444	5851	6300	68%
Wood and Wood Products	3805	3768	3672	3518	3879	3978	4089	4060	4548	20%
Chemicals	3322	3299	3867	3666	3767	3902	4845	4309	4507	36%
Motor Vehicles and Transport	7350	7189	6235	4866	7300	7048	5785	5824	4438	-40%
Electrical Machinery	2467	2836	2890	3046	3364	3718	4559	4509	4426	79%
Paper and Paper Products	3133	3104	3405	3254	3369	3462	3720	3894	3856	23%
Medical, Precision and Optical	745	818	913	1179	1274	1766	1854	2160	2504	236%
Office Machinery and Computers	1252	1271	1400	1642	2042	1962	2611	3022	2321	85%
Pharmaceuticals	777	791	1156	939	1030	1140	1724	1473	1517	95%
Radio, Television and Communications	759	1142	842	850	1073	1533	1750	1762	1502	98%
Total	110009	111382	111167	109706	116714	120224	126632	127529	126840	15%

Table 2.2.5: Labour Productivity (£000), Firm Numbers And Employment By OECD-Sectoral Classification, 1991-1999.

	Labour Productivity (£000) and Firm Numbers				Total Employment			
	High-tech	Medium-high	Medium-low	Low-tech	High-tech	Medium-high	Medium-low	Low-tech
1991	27.4	25.1	23.3	24.8	2788	13907	24759	68555
# Firms	76	614	967	2135				
1992	25.0	24.7	24.3	25.1	3204	14446	24432	69300
# Firms	75	620	938	2149				
1993	23.3	25.4	26.2	26.0	3398	14459	23731	69579
# Firms	84	621	942	2180				
1994	27.4	27.5	28.8	25.7	3431	15396	23382	67497
# Firms	82	631	958	2184				
1995	23.9	25.9	26.9	25.8	4145	17109	25812	69648
# Firms	84	633	951	2190				
1996	30.0	30.6	27.7	27.0	4635	18228	27341	70020
# Firms	84	641	963	2170				
1997	34.3	30.2	29.5	27.7	6085	20782	27130	72635
# Firms	94	668	992	2244				
1998	33.3	30.3	29.5	29.6	6257	19903	27795	73574
# Firms	92	657	996	2223				
1999	51.8	29.7	32.2	33.6	5340	20625	27950	72925
# Firms	99	678	1068	2250				
1991-1999	89%	18%	38%	35%	92%	48%	13%	6%

Note: The description of OECD classification is outlined in the appendix.

Table 2.3.1: Net Output, Employment, Labour Productivity and Number of Foreign Firms in Irish Manufacturing, 1991-1999

	Total Net Output (£000s)	Total Employment	Labour Productivity	Number of Firms
1991	6,236,887	86,869	71,796	744
1992	6,805,503	87,572	77,713	719
1993	7,374,379	88,836	83,011	687
1994	8,641,788	95,715	90,287	725
1995	10,811,180	103,864	104,090	724
1996	12,047,608	106,410	113,219	728
1997	14,863,904	113,822	130,589	729
1998	19,448,625	115,243	168,762	724
1999	24,946,624	122,131	204,261	688
1991-1999	300%	41%	185%	-8%

Table 2.3.2: Labour Productivity (£000) Of Foreign Firms By Different Size Groups And Associated Firm Numbers, 1991-1999

	Less than 50	50-99	100-249	250-499	Over 500
1991	49.9	78.5	61.3	90.5	66.3
# Firms	345	129	168	74	20
1992	60.0	71.0	71.2	106.2	58.7
# Firms	321	133	162	73	25
1993	69.8	63.8	77.3	129.6	56.1
# Firms	288	132	166	64	31
1994	69.0	72.2	78.1	148.5	63.3
# Firms	304	138	179	68	33
1995	74.0	71.5	80.5	185.2	77.9
# Firms	280	156	171	74	39
1996	60.6	68.6	80.0	193.0	99.8
# Firms	279	153	176	80	40
1997	63.1	160.9	86.8	198.8	112.8
# Firms	287	139	177	84	40
1998	91.2	154.6	135.3	273.5	135.1
# Firms	276	143	176	81	44
1999	155.3	105.8	104.0	399.9	159.2
# Firms	250	129	176	87	44
1991-1999	211%	35%	70%	342%	140%

Table 2.3.3: Labour Productivity of Foreign Firms in Irish Manufacturing Industry by 2 Digit-Sector in £000, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Pharmaceuticals	78.0	87.1	96.8	138.7	158.5	144.5	177.2	223.5	275.8	254%
Chemicals	179.7	218.5	243.9	261.4	291.1	325.0	456.5	717.8	833.0	364%
Other Non-Metallic Minerals	32.5	30.3	34.4	41.3	36.9	35.4	37.6	46.0	55.2	70%
Medical, Precision and Optical	50.2	51.6	53.5	53.7	53.9	58.9	59.3	59.3	75.4	50%
Food, Beverages and Tobacco	108.0	126.2	134.0	140.3	153.2	161.7	177.2	192.9	213.4	98%
Paper and Paper Products	29.9	34.0	41.4	41.4	52.2	49.8	68.2	67.1	77.8	160%
Printing and Publishing	193.7	190.8	215.4	229.9	221.0	252.7	256.6	339.2	416.1	115%
Radio, Television and Communications	45.0	39.6	41.7	40.7	45.8	60.2	85.6	77.7	164.0	265%
Manufacturing n.e.c	41.5	41.5	46.7	49.3	43.0	52.2	51.6	48.5	56.4	36%
Office Machinery and Computers	133.3	126.2	104.4	97.1	151.2	142.2	139.5	167.5	164.7	24%
Electrical Machinery	27.6	30.3	30.2	36.2	44.0	58.1	55.9	47.8	46.0	67%
Rubber and Plastics	28.8	31.1	31.0	34.0	34.2	29.6	32.2	34.1	31.5	10%
Basic and Fabricated	35.6	29.0	38.4	36.6	38.8	36.2	40.5	46.8	45.2	27%
Machinery and Equipment	35.3	35.5	36.2	36.3	42.0	40.3	34.2	39.3	44.0	25%
Wood and Wood Products	38.3	38.8	42.0	43.8	41.7	39.0	36.1	43.5	45.7	19%
Textiles and Clothing	16.7	14.5	18.1	18.1	17.3	18.2	16.8	25.8	31.8	91%
Motor Vehicles and Transport	21.5	18.0	21.0	25.0	29.6	23.8	28.8	34.7	32.9	53%
Average	71.8	77.7	83.0	90.3	104.1	113.2	130.6	168.8	204.3	185%

Table 2.3.4: Employment in Foreign Firms in Irish Manufacturing Industry by 2-Digit Sector, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Chemicals	11346	12022	12413	13793	14391	15560	16157	17123	18462	63%
Office Machinery and Computers	6767	6673	7487	8600	12378	13277	12562	13027	17602	160%
Medical, Precision and Optical	8554	8842	9272	9439	10544	11133	12686	13630	14114	65%
Food, Beverage and Tobacco	12683	11963	11969	12806	12535	12673	12356	11903	12580	-1%
Radio, Television and Communications	4128	4057	5255	6338	6157	6727	11769	11622	11855	187%
Electrical Machinery	7811	7792	7349	7055	9031	8306	9157	10098	10138	30%
Pharmaceuticals	3085	3368	3721	4534	4801	5345	5171	5758	6742	119%
Printing and Publishing	2223	2415	2454	3414	4520	5075	5843	5735	6670	200%
Machinery and Equipment	7001	6969	6552	7238	7331	7104	6460	6602	6616	-5%
Transport Equipment	1590	2453	2529	2811	2291	2453	3638	3462	5146	224%
Rubber and Plastics	4360	4466	4536	4692	4878	5075	4620	4665	4267	-2%
Textiles and Clothing	9573	9421	9196	9552	9046	8280	6794	5680	4215	-56%
Basic and Fabricated Metals	3637	3385	3318	3322	3252	3356	3734	3946	3809	5%
Manufacturing n.e.c.	3755	3848	3830	4212	4488	4255	4390	4238	3130	-17%
Other Non-Metallic	1848	1754	1543	979	1406	1457	1540	1623	1545	-16%
Wood and Wood Products	480	480	446	574	615	617	1086	1032	1094	128%
Paper and Paper products	1113	1032	687	890	1001	1062	1030	857	888	-20%
Total	86869	87572	88836	95715	103864	106410	113822	115243	122131	41%

Table 2.3.5: Labour Productivity (£000), Firm Numbers And Employment By OECD-Sectoral Classification, 1991-1999.

	Labour Productivity and Number Of Firms				Total Employment			
	High-tech	Medium-high	Medium-low	Low tech	High-tech	Medium-high	Medium-low	Low-tech
1991	96.6	73.4	31.6	72.3	13980	32672	10292	29925
# Firms	96	268	143	237				
1992	94.0	85.2	28.2	79.3	14098	33522	10677	29275
# Firms	98	264	130	227				
1993	85.3	93.6	32.3	87.8	16463	33173	10443	28757
# Firms	99	253	126	209				
1994	91.9	101.0	33.9	95.4	19472	34559	9975	31709
# Firms	106	257	126	236				
1995	128.3	107.9	35.9	103.3	23336	38078	10035	32415
# Firms	103	267	117	237				
1996	124.1	124.6	32.3	117.8	25349	38373	10605	32083
# Firms	102	278	116	232				
1997	127.8	160.0	35.6	129.4	29502	40877	11406	32037
# Firms	97	284	117	231				
1998	148.4	226.1	40.2	157.0	30407	43134	11684	30018
# Firms	102	287	124	211				
1999	191.1	265.2	38.4	202.8	36199	43863	12979	29090
# Firms	107	266	121	194				
1991-1999	98%	261%	22%	180%	159%	34%	26%	-3%

Table 2.4.1: Labour Productivity in Irish Manufacturing Industry, 1991-1999

	Overall	Irish	Foreign	Irish/Foreign
1991	45,400	24,556	71,796	0.34
1992	48,129	24,870	77,713	0.32
1993	51,258	25,883	83,011	0.31
1994	56,304	26,656	90,287	0.30
1995	62,771	26,000	104,090	0.25
1996	67,929	27,842	113,219	0.25
1997	77,026	28,881	130,589	0.22
1998	95,825	29,914	168,762	0.18
1999	117,279	33,525	204,261	0.16
1991-99	158%	37%	185%	-52%

Table 2.4.2: Labour Productivity in Irish Manufacturing Industry By Nationality, 1991-1999

	Irish	UK	Other EU	US	Other Non-EU
1991	24,556	56,434	35,123	98,347	70,632
# Firms	3792	132	251	264	97
1992	24,870	65,801	38,727	106,335	71,886
# Firms	3827	121	245	265	88
1993	25,883	59,468	40,646	111,362	84,814
# Firms	3827	112	228	264	87
1994	26,656	64,414	47,127	116,711	99,787
# Firms	3855	123	227	285	92
1995	26,000	68,108	46,214	135,727	111,690
# Firms	3858	117	228	289	90
1996	27,842	69,999	47,580	152,464	115,526
# Firms	3858	117	227	286	98
1997	28,881	86,553	50,480	170,446	146,792
# Firms	3998	122	232	282	93
1998	29,914	93,476	57,018	232,186	127,286
# Firms	3968	121	223	295	85
1999	33,525	87,612	59,921	280,110	134,792
# Firms	4095	118	208	287	75
1991-1999	37%	55%	71%	185%	91%

Table 2.4.3: Labour Productivity Ratios Of Irish Firms To Foreign Firms By Different Size Groups, 1991-1999

	Less than 50	50-99	100-249	250-499	Over 500	Total
1991	0.40	0.30	0.52	0.29	0.39	0.34
1992	0.41	0.37	0.43	0.26	0.42	0.32
1993	0.35	0.40	0.40	0.23	0.47	0.31
1994	0.34	0.36	0.42	0.19	0.44	0.30
1995	0.34	0.36	0.41	0.15	0.34	0.25
1996	0.38	0.35	0.38	0.19	0.35	0.25
1997	0.38	0.18	0.42	0.17	0.32	0.22
1998	0.27	0.20	0.30	0.13	0.30	0.18
1999	0.24	0.33	0.39	0.10	0.37	0.16
1991-99	-40%	10%	-25%	-66%	-5%	53%

Table 2.4.4: Labour Productivity Ratios of Irish Firms to Foreign Firms by OECD Sector Classification, 1991-1999

	High-Tech	Medium-high	Medium-low	Low-Tech	Total
1991	0.29	0.34	0.74	0.34	0.34
1992	0.27	0.29	0.86	0.32	0.32
1993	0.28	0.27	0.81	0.30	0.31
1994	0.31	0.27	0.85	0.27	0.30
1995	0.19	0.24	0.75	0.25	0.25
1996	0.25	0.25	0.86	0.23	0.25
1997	0.28	0.19	0.83	0.21	0.22
1998	0.23	0.13	0.73	0.19	0.18
1999	0.29	0.11	0.84	0.17	0.16
1991-99	0%	-68%	14%	-50%	-53%

Table 2.4.5: Amended Labour Productivity Ratios of Irish to Foreign Firms by OECD Sector Classification, 1991-1999

	High-tech	Medium-high	Medium-low	Low-tech
1991	0.34	n.a.	0.74	0.31
1992	0.27	0.63	0.86	0.37
1993	0.31	0.63	0.81	0.34
1994	0.39	0.65	0.85	0.32
1995	0.21	0.56	0.75	0.31
1996	0.27	0.59	0.86	0.30
1997	0.32	0.59	0.83	0.28
1998	0.28	0.60	0.73	0.26
1999	0.34	0.51	0.84	0.25
1991-99	0%	-19.1%	14%	-20%

2.B Figures

Figure 2.2.1: Labour Productivity and Employment in Irish Firms in Irish Manufacturing Industry, 1991-1999

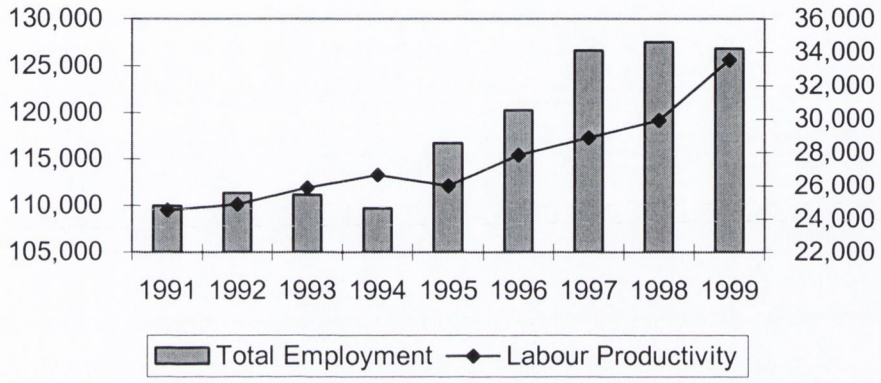


Figure 2.3.1: Labour Productivity and Employment in Foreign Firms in Irish Manufacturing Industry, 1991-1999

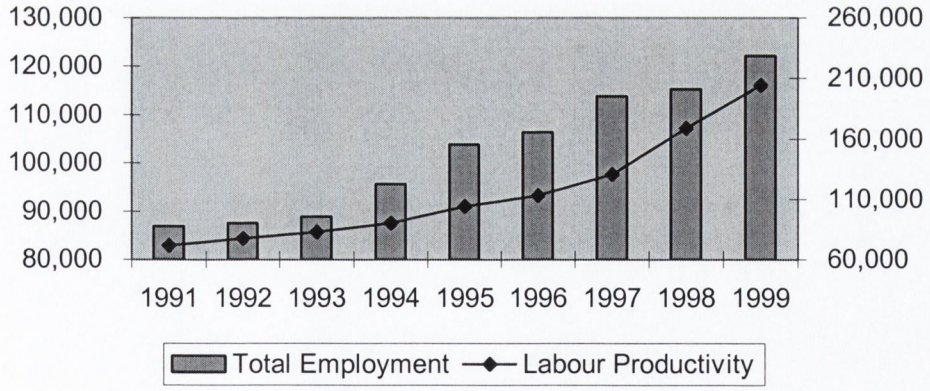
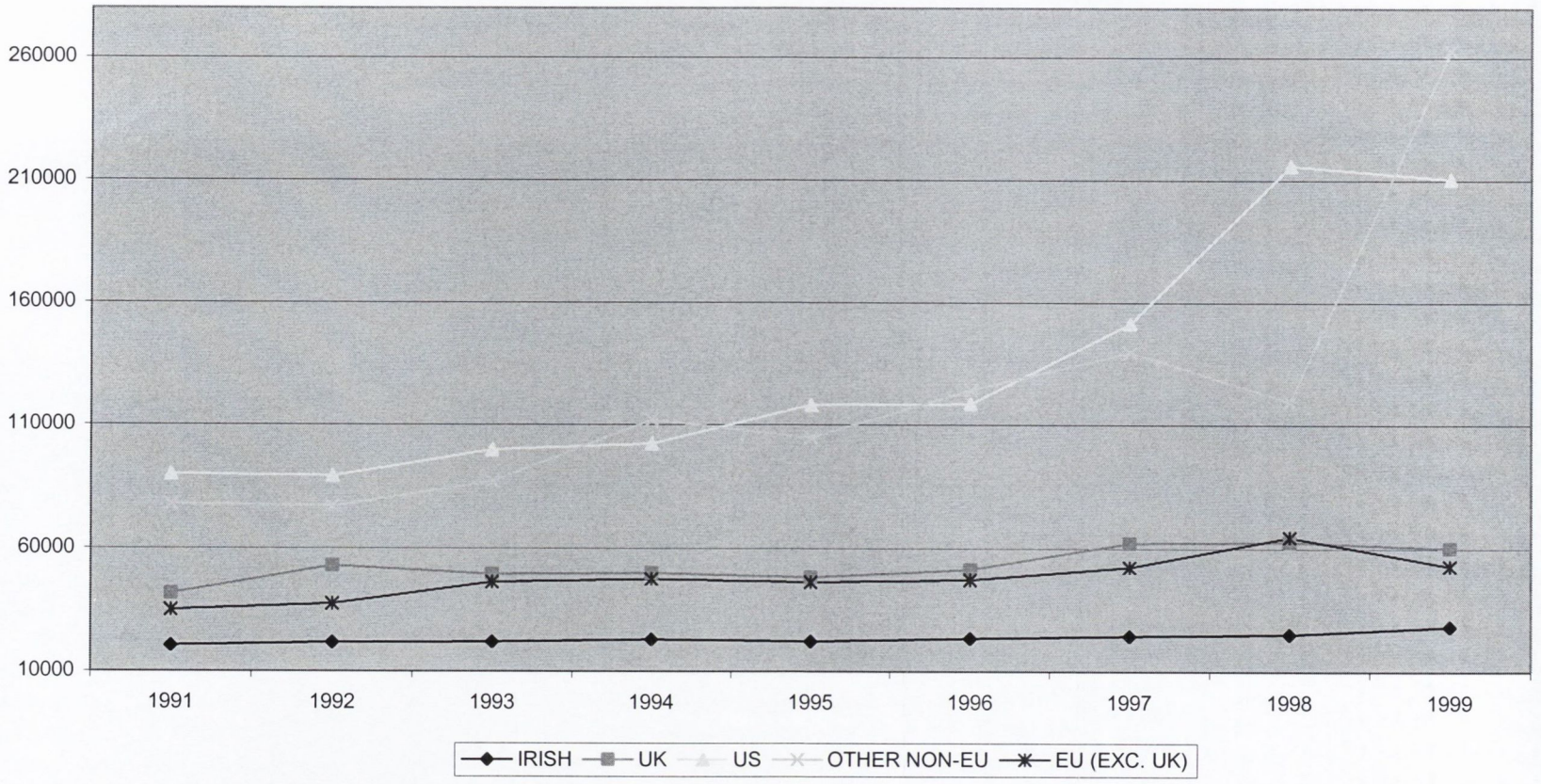


Figure 2.4.1: Labour Productivity in Irish Manufacturing Industry by Nationality,1991-1999



2.C Appendix

Table 2.C.1: Number Of Irish Firms In Irish Manufacturing Industry By 2-Digit Sector, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Food, Beverages and Tobacco	719	723	709	711	737	741	752	725	727	1%
Basic and Fabricated Metals	501	489	491	502	487	488	488	488	540	8%
Printing and Publishing	362	372	402	415	408	402	430	440	444	23%
Manufacturing n.e.c.	369	380	391	393	402	392	410	419	427	16%
Machinery and equipment	250	259	264	271	273	284	309	306	314	26%
Other non-metallic	258	244	250	259	267	266	273	272	286	11%
Textiles and Clothing	367	348	346	342	330	313	322	304	282	-23%
Wood and Wood Products	218	223	215	207	201	208	219	218	242	11%
Rubber and Plastics	184	184	186	184	182	193	212	221	233	27%
Electrical Machinery	96	93	93	97	98	108	119	119	128	33%
Chemicals	136	131	139	138	133	125	132	122	124	-9%
Transport Equipment	126	123	122	120	122	115	102	97	100	-21%
Paper and Paper products	85	88	95	92	88	92	96	98	100	18%
Medical, Precision and Optical	64	66	61	63	66	69	68	70	75	17%
Office Machinery and Computers	32	31	37	35	37	35	39	46	48	50%
Pharmaceuticals	19	16	21	21	20	22	28	23	26	37%
Radio, Television and Communications	25	28	26	26	27	27	27	23	25	0%
Total	3792	3782	3827	3855	3858	3858	3998	3998	3968	8%

Table 2.C.2: Number Of Foreign Firms In Irish Manufacturing Industry By 2-Digit Sector, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Chemicals	100	101	100	107	110	112	117	119	116	16%
Food, Beverages and Tobacco	77	72	69	88	85	85	86	81	76	-1%
Medical, Precision and Optical	69	71	68	68	69	70	71	73	67	-3%
Electrical Machinery	57	57	57	52	58	58	60	62	58	2%
Machinery and Equipment	66	63	59	64	64	68	64	64	57	-14%
Rubber and Plastics	58	54	52	54	49	48	50	53	49	-16%
Basic and Fabricated metals	59	52	50	53	49	46	45	47	47	-20%
Pharmaceuticals	34	37	40	43	43	41	38	41	40	18%
Office Machinery and Computers	35	35	32	36	34	35	31	32	36	3%
Printing and Publishing	22	22	21	26	33	31	33	31	33	50%
Textiles and Clothing	79	77	69	65	59	57	50	40	32	-59%
Radio, Television and Communications	27	26	27	27	26	26	28	29	31	15%
Manufacturing n.e.c.	33	34	32	33	33	34	33	33	28	-15%
Motor Vehicles and Transport	18	18	19	19	18	21	21	21	20	11%
Other Non-metallic	22	19	18	14	16	16	17	19	18	-18%
Paper and Paper products	15	12	9	12	14	14	13	12	12	-20%
Wood and Wood products	7	6	5	7	7	7	10	8	8	14%
Total	744	719	687	725	724	728	729	724	688	-8%

Table 2.C.3 OECD-Sectoral Productivity for Foreign Firms, 1991-1999

	Excluded	High-tech	Medium-high-tech	Medium-low-tech	Low-tech
1991	79.4	83.9	13.3	31.6	79.4
# Firms	123	62	202	143	214
1992	189.6	93.5	38.9	28.2	68.2
# Firms	123	61	200	130	205
1993	206.0	78.5	40.4	32.3	76.0
# Firms	118	59	193	126	191
1994	226.1	73.2	42.4	33.9	79.5
# Firms	135	63	193	126	208
1995	249.1	116.2	46.3	35.9	83.0
# Firms	143	60	200	117	204
1996	268.1	114.6	51.9	32.3	90.8
# Firms	142	61	207	116	202
1997	349.9	113.5	51.1	35.6	99.0
# Firms	148	59	205	117	200
1998	507.3	125.1	50.3	40.2	113.2
# Firms	149	61	209	124	181
1999	597.7	164.4	58.2	38.4	135.3
# Firms	143	67	190	121	167
1991-1999	653%	96%	337%	22%	70%

Note: Excluded sectors are Chemicals, Pharmaceuticals, Recorded Media and Soft Drinks.

Table 2.C.4 OECD Sectoral Classification

High-tech	**Medium high-tech**	**Medium-low-tech**	**Low-tech**
Aerospace	Scientific Instruments	Shipbuilding	Petroleum Refining
Computers and Office Machinery	Electrical Machinery	Rubber and Plastic Equipment	Ferrous Metals
Electronics and Communications	Motor Vehicles	Other Transport Equipment	Paper and Printing
Pharmaceuticals	Chemicals	Stone, Clay and Glass	Textiles and Clothing
	Non-Electrical Machinery	Non-Ferrous Metals	Wood and Furniture
		Fabricated Metal Products	Food and Beverages
		Other Manufacturing	

CHAPTER 3 DECOMPOSITION OF LABOUR PRODUCTIVITY GROWTH IN IRISH MANUFACTURING INDUSTRY

3.1 Introduction

Overall labour productivity in the Irish manufacturing sector increased by 158 per cent from 1991 to 1999. This growth in labour productivity has coincided with growth in both employment and output levels during the same period, which is significantly different from the results experienced in other European countries.[20] Although growth patterns in employment and output at aggregate level are important in examining productivity growth, these changes mainly take place in individual firms; hence an understanding of the changes taking place at the individual firm level is important. There has been a growing body of research into the productivity growth at the firm level, with the increasing availability of data in recent years. Many of these studies examine the origins of productivity growth, by using total factor or labour productivity at the firm level. They conclude that firm performance is heterogeneous and that net changes observed in aggregate data are marked by large increases at some firms and decreases at others.

This chapter examines the factors that affect the growth of labour productivity in the Irish manufacturing sector using a decomposition analysis. In Section 3.2 we review the methods used to analyse the decomposition of productivity growth in the literature. We also present results from studies across a range of developed and

[20] See Scarpetta *et al.* (2000)

developing countries. Section 3.3 outlines the methodology adopted in the decomposition analysis of labour productivity growth in Irish manufacturing sector and the data that are used in the analysis.

A distinguishing feature of the Irish manufacturing sector is the large presence of foreign firms. In 1999 foreign firms accounted for 85 per cent of net output and 49 per cent of employment in the Irish manufacturing sector. In order to account for this, ownership decomposition results are presented in Section 3.4 for both foreign and domestic firms, as well as for four different nationality groups of foreign firms. As we outlined in Chapter 2, overall labour productivity grew by 38 per cent during the 1991-95 period, with increases of 6 per cent and 45 per cent for domestic and foreign firms, respectively. In the second half of the 1990s, during the 1995-99 period, the labour productivity of domestic and foreign firms increased by 29 per cent and 96 per cent, respectively giving rise to a 87 per cent overall increase. In order to account for the differences in these two periods and to test the robustness of overall results to different time periods, we also present results for two sub periods 1991-95 and 1995-99 in this section.

Section 3.5 presents results for four OECD sector classifications in order to explain the contribution of different factors at a more disaggregated sector level. We examine the contribution of different factors to labour productivity growth in the individual 2-digit sectors that make up the aggregated OECD sectors in Section 3.6. Section 3.7 contains a brief summary and some conclusions.

3.2 Decomposing Productivity Change-Methods and Review

The studies within the literature that investigate the role of resource allocations in labour productivity change begin with a decomposition analysis and express the aggregate productivity in a given sector by a weighted average of each firm's productivity in that sector, which is[21]

$$P_t = \sum_{it} S_{it} P_{it} \tag{3.1}$$

where P_t is an aggregate productivity measure, which can be labour productivity (LP) or total factor productivity (TFP) for the sector at time t; S_{it} is the share of firm i in the given sector at time t; and P_{it} is a productivity measure of an individual firm i at time t. In the literature, employment is typically used in weighting labour productivity and output share is used to weight TFP.

In an early empirical study Baily, Hulten and Campbell (1992) explore heterogeneity among plants to see how productivity of individual plants changes within an industry, which plants account for the productivity growth, and how important entry and exit are to productivity growth in the industry. Their decomposition analysis begins with a calculation of total factor productivity (TFP) of each plant. The level of productivity in an industry in year t is the expressed, as an index:

$$\ln TFP_t = \sum_i S_{it} \ln TFP_{it} \tag{3.2}$$

where S_{it} is the share of the i-th plant in industry output in current dollars. The growth of industry TFP over the period t-k to t is then expressed as

[21] Notation used in this chapter follows the corresponding studies that are reviewed.

$$\Delta \ln TFP_t = \ln TFP_t - \ln TFP_{t-k} \quad (3.3)$$

Baily *et al.* (1992) decompose the industry productivity growth into the contributions of the continuing firms (C), the entrants (N) and the exiting firms (X) using

$$\Delta \ln TFP_t = \underbrace{\sum_{i \in C} (S_{it-k} \Delta \ln TFP_{it})}_{within} + \underbrace{\sum_{i \in C} \ln TFP_{it} \Delta S_{it}}_{between} + \underbrace{\sum_{i \in N} S_{it} \ln TFP_{it}}_{entry} - \underbrace{\sum_{i \in X} S_{it-k} \ln TFP_{it-k}}_{exit} \quad (3.4)$$

The contribution of continuing firms can be divided into two parts. The first term is the *within-effect*, which evaluates the contribution of productivity growth in the continuing firms holding their shares constant in the base year. The second term, which is denoted as the *between-effect*, measures the contribution of changes in the shares of firms, holding productivity measure constant in the base year. This value will be positive if there is an increase in the shares of high-productivity firms or a decrease in the shares of low-productivity firms. The last two terms give the contribution of entering and exiting firms to overall productivity growth.

Using data from the Longitudinal Research Database (LRD) for the years 1972,1977 and 1982 they examine the decomposition of productivity growth in US manufacturing industry for 1972-77, 1977-82 and 1982-87 periods. Looking at the contribution of different groups of plants to industry productivity growth, they find that for the 1972-77 and 1982-87 periods, within firm productivity determines the performance of the overall growth, whereas for the 1977-82 period the between-effect accounts for most of the overall productivity growth. The entry and exit terms play only a minor role and the values are small.[22] They find that in the periods of growth in the manufacturing sector (1972-77 and 1982-87), there is a small negative

[22] They report the contribution of entry and exit together as a net entry effect.

effect of entry and exit, whereas in the recession period of 1977-82 they observe a small positive contribution from entry and exit.[23] Baily *et al.* also present results for 23 selected four digit-industries. These results show that in any of the periods analysed, the between-effect has a positive contribution to overall growth in all of the individual industries, whereas within-effect results are mixed.

Griliches and Regev (1995) in their analysis of the productivity growth in the Israeli manufacturing industry propose an alternative method of decomposition. They include the deviation of firm level productivity from the industry average over the base and end years in the between, entry and exit terms.[24] Their decomposition method is given as

$$\Delta P_t = \underbrace{\sum_{i \in C} \overline{S}_i \Delta p_{it}}_{within} + \underbrace{\sum_{i \in C} \Delta S_{it} (\overline{p}_i - \overline{P})}_{between} + \underbrace{\sum_{i \in N} S_{it} (p_{it} - \overline{P})}_{entry} - \underbrace{\sum_{i \in X} S_{it-k} (p_{it-k} - \overline{P})}_{exit} \qquad (3.5)$$

where a bar over a variable indicates the average of the variable over the base and end years, p is firm productivity, P is sector productivity and S is the firm share in the industry.[25] They use labour productivity as their productivity measure and employment as their share measure. Griliches and Regev (1995) find that most of the labour productivity in the Israeli manufacturing sector over the 1979-88 period occurs within firm.

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[23] Although they do not include average industry productivity in their decomposition method they interpret the results of net entry effect in the growth period due to the entrants being below average productivity. Likewise they argue that in the recession period, there was less entry and more exit of low productivity plants leading to a positive contribution of net entry.

[24] It is also argued in later studies that this method is less sensitive to random measurement errors in variables such as employment.

[25] Although Griliches and Regev (1995) include average productivity in the between, entry and exit terms, they do not compare their method to that of Bailey *et al.* (1992). A comparison of the two methods can be found in Foster, Haltiwanger and Krizan (1998) as outlined below.

Foster, Haltiwanger and Krizan (1998), following Baily *et al.* (1992) and Griliches and Regev (1995), apply their decomposition method to the measurement of labour productivity. They argue that the Baily *et al.* method of decomposition could lead to a negative net entry effect, even when the entrants are more productive than exiters, and may not reflect the true net entry contribution, if the market share of entrants is very low and the market share of exiters is very high. They further suggest that within and between effects are obscured in the Griliches and Regev (1995) method. The within-effect involves changes in shares and the between-effect includes changes in productivity because industry averages are used in the deviations, whereas in the Bailey *et al.* specification changes in shares and changes in productivity are held constant for within and between effects respectively. In order to overcome these problems, they propose a modified version of both decompositions.

First they define labour productivity (P) as the sum of value added produced by the firm (VA_i), divided by the sum of employment (L_i) in each firm.

$$P = \frac{\sum VA_i}{\sum L_i} = \frac{\sum VA_i}{L} \tag{3.6}$$

where VA_i is firm's value added, L_i is its employment level and L is total employment in the sector.

Then, they express average labour productivity as the weighted sum of individual firms' labour productivity (P_i), where the weights are each firm's share of employment (L_i/L), defined as S_i.

$$P = \sum \frac{L_i}{L} \frac{VA_i}{L_i} = \sum S_i P_i \tag{3.7}$$

and the change in average labour productivity across time as

$$\Delta P_t = P_t - P_{t-k} = \sum S_{it} P_{it} - \sum S_{it-k} P_{it-k} \tag{3.8}$$

where $S_{it}=L_{it}/L_t$ is a firm's share of employment at time t and P_{it} is a firm's labour productivity at time t. This change in average labour productivity is decomposed into a contribution from firms that continue to operate during the study period (C), from firms that enter (N), and that exit (X).

$$\Delta P_t = \underbrace{\sum_{i \in C} S_{it} P_{it} - \sum_{i \in C} S_{it-k} P_{it-k}}_{continuing-firms} + \underbrace{\sum_{i \in N} S_{it} P_{it}}_{entering-firms} - \underbrace{\sum_{i \in X} S_{it-k} P_{it-k}}_{exiting-firms} \tag{3.9}$$

In this decomposition analysis there are two factors that have to be take into account when examining the contribution of continuing firms, namely, the shift in employment shares and the change in labour productivity within firm level. So while there may not be any change in labour productivity of individual firms, average labour productivity can increase because of the rise in the employment share accounted for by firms with higher labour productivity.

Foster *et al.* (1998) further decompose the first part of the equation for continuing firms in order to measure the contribution of productivity changes at individual firms, holding employment share changes constant, and employment share changes, holding productivity at each firm constant, while taking the contribution of entering and exiting firms into account. In the between, entry and exit terms, they use the

deviation of individual firms' productivity from the base year industry average instead of using the average of base and final year values that was proposed in Griliches and Regev (1995).

$$\Delta P_t = \underbrace{\underbrace{\underbrace{\sum_{i \in C} S_{it-k}\Delta P_{it}}_{within-firm} + \underbrace{\sum_{i \in C}(P_{it-k} - \overline{P_{t-k}})\Delta S_{it}}_{between-firm} + \underbrace{\sum_{i \in C}\Delta S_{it}\Delta P_{it}}_{cross-effect}}_{continuing-firms} + \underbrace{\sum_{i \in N} S_{it}(P_{it} - \overline{P_{t-k}})}_{entering} - \underbrace{\sum_{i \in X} S_{it-k}(P_{it-k} - \overline{P_{t-k}})}_{exiting}}} \qquad (3.10)$$

In Equation 3.10 the *within-effect* captures the contribution from labour productivity changes within existing firms, holding employment shares constant at their base period level. This term removes the contribution to the productivity growth of changes in employment shares, giving a pure interpretation of productivity change within the firm.

The *between-effect* measures the contribution from changes in employment shares, holding constant the labour productivity level of each firm, relative to the group average in the base period. This term will be positive for firms that have above-average labour productivity in the base period and gain employment share and for firms that have below average productivity and lose their share in total employment during the period. On the other hand it will have a negative effect on overall productivity growth if firms with below (above) average labour productivity in the base period gain (lose) employment share.

The *cross-effect* is interpreted as a residual from the specification of the within and between firm effects and it accounts for the interaction of changes in employment shares and labour productivity. If this value is positive then it reflects gains in productivity from firms, which are both gaining market share and increasing their

productivity, or from firms whose productivity levels decrease along with their market share. On the other hand if this value is negative and average productivity growth is positive, it shows that on the average, continuing firms increase their productivity levels while downsizing.

The entry and exit of firms involves a movement of resources including capital and labour. If firms that enter are more productive, on average, than firms that are already in operation, this contributes positively to labour productivity growth. If the firms that exit have lower labour productivity than those that continue to operate, this again improves the average labour productivity.

Using Census of Manufactures plant level data for the US manufacturing industry Foster *et al.* first examine the aggregate productivity change over the ten-year period 1977 to 1987. In their analysis they use both multifactor productivity and labour productivity[26]. For shares, they use plant-level gross output with multifactor productivity measure, and both plant-level employment and gross output with labour productivity measure although they argue that for labour productivity, the appropriate share measure is employment. For the period 1977-1987, their analysis shows that the within component accounts for 48 per cent and 74 per cent of average industry productivity for the multifactor productivity and labour productivity per worker measures respectively[27]. The cross term is positive and accounts for about a third of average industry change when multifactor productivity measure is used whereas it contributes negatively and accounts for 11 per cent of productivity change when the labour productivity measure is used. Net entry accounts for 26 per cent and

[26] They calculate labour productivity both per worker and per hour.
[27] The individual values of the components of decomposition analysis can be greater than 100 per cent due to possible negative contribution from some components.

29 per cent of the average industry change for multifactor and labour productivity measures respectively. They also carry out their analysis in five-year periods for 1977-82, 1982-87 and 1987-92 to test the robustness of their results for a shorter time horizon. They find that cyclical variation in productivity growth plays a dominant role in the overall pattern. Their analysis also shows that the contribution of net entry is greater in cyclical downturns and within firm contribution is large and positive for high productivity growth periods.[28]

Recent studies have followed these studies on the US manufacturing sector, using previously unavailable firm level panel data for a variety of other countries.

Disney, Haskel and Heden (2000), using UK Census of Production data, analyse the determinants of productivity growth in UK manufacturing industry. Their data set covers the period 1980-1992. By using the decomposition methods suggested by Foster et al. (1998) and Griliches and Regev (1995), they examine the contribution of *within, between, cross, entry* and *exit* effects on the overall productivity growth in the UK manufacturing industry. Their measure of productivity is both labour and total factor productivity and they use both employment and gross output alternatively as shares in the decomposition analysis. They find that net entry accounts for around 50 per cent of productivity growth for both labour productivity and total factor productivity measures. They also find that *cross* and *between* terms are important when they use TFP, whereas the *within* term is important for labour productivity, accounting for 48 per cent of productivity growth. They observe that there are strong differences in the *within-effect* results between the findings for the two productivity

[28] Foster *et. al.* also present results for eight 4-digit industries in the auto repairs sector to examine the effects of different factors of productivity decomposition in a service industry.

measures, namely change in TFP and change in labour productivity and argue that most of the difference could be due to measurement error in the construction of the capital variable in measuring TFP. On the other hand entry and exit effects are similar irrespective of the use of TFP or labour productivity. They also consider three sub periods, 1980-82 and 1989-92 as recession periods and 1982-89 as a boom period. Their results show that *within-effect* is more important in the boom period, with net entry becomes less important. For the recession periods, they find that *within* effects are slightly larger and *between* effects smaller.[29]

Hahn (2000) using plant level data on the Korean manufacturing sector for the period 1990-1998, analyses the micro dynamics of entry, exit and productivity growth. He uses the Baily *et al.* method in which *between* and *cross-effect* are combined. Hahn uses TFP as the productivity measure and presents results for 1990-95 and 1995-98 periods separately. The results for 1990-95 show that *within* firm effects account for about 60 per cent of manufacturing productivity growth, while this effect falls slightly below zero during the 1995-98 period.[30] The effect of entry and exit on aggregate productivity growth is more than 40 per cent and around 65 per cent for the 1990-95 and 1995-1998 periods respectively. This effect is consistent with the Foster *et al.* findings that net entry term has a greater effect in downturns. He also presents results for thirteen 2-digit sectors; these show that within-effect is important in six of the industries and that the entry and exit effects play a major role in seven industries. Overall the study shows that the entry and exit effects were the most important factors contributing to the productivity growth in Korean manufacturing

[29] The short recession period makes the interpretation of results sensitive. The authors also note that the recession period of 1980-82 saw very high productivity growth, making the results harder to interpret.

[30] Hahn points out that 1995-98 period was a downturn in Korean manufacturing industry.

sector over the period 1990-1998, playing a particularly important role in the recession period of 1995-98.

A recent OECD (2001) study, that is part of an ongoing project on firm-level data, analyses labour productivity decompositions for eight countries. The countries included are Canada, Finland, France, Germany, Italy, Netherlands, Portugal, United Kingdom and the United States. The periods of the analysis differ due to data availability across countries, but in general the results cover the period between 1985 and 1995. The study analyses both labour productivity and where available, multifactor productivity growth.[31] They find that for all countries in the analysis, labour productivity growth is largely accounted for by gains within individual firms, where the *within* component accounted for three-quarters of or more of productivity growth. The results show that the *between-effect* varies significantly across countries and over time, but is generally small and in some cases even negative.[32] The net contribution of the entry and exit of firms is positive in most countries, with the exception of West Germany,[33] and accounts for between 10 per cent and 40 per cent of productivity growth. They also find that in cases where the net entry effect is positive and the coefficient is large, exits made most of the contribution. In years of expansion, *within* firm effect makes a stronger contribution to overall productivity growth, while in slowdowns the contribution is mostly from the exit of low-productivity firms. The contribution of entry is significantly influenced by the horizon over which productivity is measured, the contribution becoming greater the longer the horizon considered. They argue that this is due to the increased share of

[31] Due to data availability they carry out the decomposition of multifactor productivity analysis only for Finland, France, Italy, Netherlands and the UK.
[32] Since this study uses the Griliches and Regev (1995) decomposition method, between-effect results are mixed since it reflects both between and cross terms from Foster *et. al.* (1998) method.
[33] Data for Germany refers to West Germany.

activity for entrants in the end year over the time period examined. This confirms the results of studies on US data, where analyses on longer time periods find a higher contribution of entry than those using shorter time periods.[34] Although the components of the decomposition analysis differ significantly across countries, they find that in the industries that are more closely related to information and communication technologies, the entry component makes a stronger contribution to labour productivity growth.[35] The results for multifactor productivity analysis show that the *within* firm contribution is smaller, whereas *between* firm and net entry effects are more important in overall multifactor productivity growth. Combining these two results on labour and multifactor productivity decompositions, OECD (2001) concludes that incumbent firms, in a number of European countries, increased their labour productivity by mainly substituting capital for labour. [36]

Baldwin and Gu (2002) examine the contribution of plant turnover to labour productivity growth in the Canadian manufacturing sector over the three periods, 1973-79, 1979-88 and 1988-97, using Annual Surveys of Manufacturers. They measure labour productivity of a plant as real gross output per worker.[37] They use the decomposition methods proposed by Foster et al (1998) and Griliches and Regev (1995).[38] Their results show that productivity growth within continuing plants is the

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[34] See Baily *et al.* (1992), Haltiwanger (1997) and Foster *et al.* (1998)

[35] Although the study does not give results for the individual sectors, *electrical and optical equipment* sector in the US, *office, accounting and computing machinery* sector in the UK and *precision instruments* industry in France, Italy and Netherlands are given as examples for the importance of net entry.

[36] They support this with results from studies showing that in many European countries high labour productivity growth was accompanied by falls in employment.

[37] They also report results using value added per worker, which are similar.

[38] In addition to the main two methods used in the literature, they use two alternative methods proposed by Baldwin and Gorecki (1991) and Baldwin (1995). They argue that entering firms replace exiting firms and suggest two methods where they replace the average productivity of an industry with that of exiting firms' average productivity in both Foster *et al.* (1998) and Griliches and Regev (1995) methods.

predominant source of labour productivity growth in Canadian manufacturing, where the *within*-plant component of the decomposition ranges from 40 per cent to 100 per cent of aggregate productivity growth. They find that the *between-effect* plays a negligible role after 1979. However this effect, which explains the shift towards more productive plants, accounts for 30-70 per cent of labour productivity growth in the 1973-79 period. The net entry effect contributes 25 per cent of productivity growth in the 1973-79 period, but this contribution declines to 20 per cent in the 1979-88 and to 15 per cent in the 1988-97 periods. The results of the decomposition of productivity growth in 22 manufacturing industries at 2-digit level show that plant turnover, i.e., entry and exit effects, contribute positively to labour productivity growth in nearly all of the industries, though *within-effect* being the most important factor. They also carry out a decomposition analysis for domestic and foreign-controlled plants separately.[39] Results show that the growth of the *within-plant* component is considerably higher in the foreign sector after 1979. It accounts for 40 per cent of overall *within* growth in the 70s and this rises to over 55 per cent of the total in the 1990s. They also show that foreign plants are an important source of net entry, representing 60 per cent of the contribution from the total net entry effect.

Parham (2002) reports findings from an Australian study of the factors contributing to Australia's productivity growth, namely firm entry and exit and resource allocation across firms in manufacturing, construction, wholesale trade, retail trade, accommodation and property sectors. This study uses data from the Business Longitudinal Survey that covers manufacturing as well as mining, construction and

[39] To our knowledge this is the only study in the literature that examines decomposition of productivity growth for foreign and domestic firms separately.

services sectors and covers the period 1994 to 1998.[40] The study finds that growth in average labour productivity is dominated by the contribution from continuing firms, with the *within-effect* accounting for 90 per cent of the overall change. Entry and exit contribute little to change in average labour productivity.[41]

Overall, results from studies on decomposition of productivity growth in the manufacturing sectors in different countries show that the *within-effect* is the most important factor in determining the overall change in labour productivity growth, although this effect is smaller when explaining the change in total factor productivity growth. In comparing results from different countries one has to be alert to differences in data sources, time periods and more, importantly, different decomposition methods used in these studies. These differences make simple direct comparisons very difficult.

3.3 Decomposing Labour Productivity Change in Irish Manufacturing

3.3.1 Approach of Decomposition

The Irish manufacturing industry has experienced exceptional economic performance during the 1990s, both in terms of increasing output and employment levels. Although employment creation and increased output thorough exports has been the priority for industrial policy for many decades, recently the focus has shifted towards labour productivity. In this section we explain how we propose to examine the

[40] Parham notes that the firms included in the sample for the study accounted for only 1.1% of Australia's value added and 1.5% of workers that casts doubt on the represent ability of the population.

[41] In this study results for entry and exit are separated into true and illegitimate parts, which is due to the sample used.

changes in labour productivity using the decomposition methods outlined in Section 2.

Foreign firms, as noted in Chapter 2, mainly drove the growth in the employment and net output levels in Irish manufacturing industry in the 1990s. They accounted for 85 per cent of total manufacturing net output and 49 per cent of total manufacturing employment in 1999. Thus, in the first part of our decomposition analysis, in addition to the overall results, we present results for foreign and indigenous firms separately and also for four different nationality groupings, among foreign firms.

In order to test the robustness of our results for our selected time period, we next decompose labour productivity growth for 1991-95 and 1995-99 periods. The latter half of the 1990s, from 1995, shows persistent output and employment growth for both foreign and domestic firms, whereas in the first half of the period there were both increases and decreases in the values of employment for domestic firms for some years.

An overall examination of Irish manufacturing industry, in terms of decomposing labour productivity growth, gives an understanding of the different factors that contribute to this growth, but it can miss the structural differences that exist in different individual industries that make up the overall. For example, although foreign firms account for 85 per cent of total manufacturing net output in 1999, as can be seen from Table 3.3.1, this share differs considerably across individual 2-digit sectors ranging from 17 per cent in Other Non-Metallic Minerals to 98 per cent in

Chemicals. We can see the same structural difference in terms of the share of employment, with foreign firms accounting for 49 per cent of total manufacturing employment overall, though this value ranges from 15 per cent in Other Non-Metallic Minerals industry to 89 per cent in the Radio, Television and Communications sector. Hence it is necessary to carry out a more detailed examination of labour productivity growth at sectoral level. We carry out this analysis by firstly dividing the individual industries into four main groups, according to OECD classification, namely, high-tech, medium high-tech, medium-low tech and the low-tech industries and then by using the classical 2-digit NACE sectors.

3.3.2 Methodology and Data

We use the Foster *et al.* (1998) method in our analysis of the decomposition of labour productivity growth in the Irish manufacturing sector over the period 1991-1999, since it is the most comprehensive method in terms of analysing the effects of changes in continuing firms and the contribution of entering and exiting firms. Labour productivity is measured as the ratio of net output to total employment in each firm, where value added figures are expressed in real terms using the producer price indices published by the CSO. The classification system of manufacturing industries in these indices is the NACE 70 where sector codes are different than NACE Rev. 1 classification system that the CIP adopted in classifying firms to different industries after 1991. We mapped the available information at 2-digit and where possible at 3-digit level between the NACE 70 and NACE Rev. 1 classifications. Following Haskel and Barnes (2000), we removed all observations where either net output or employment data were missing or had a zero value, in

order to deal with missing or spurious observations.[42] Also the top and bottom percentiles of the net output were dropped to remove potential outliers.[43] In addition to the usual approach, documented in the literature, we examine within, between, cross, entry and exit effects on overall productivity growth for all firms and we distinguish between the foreign and domestic firms in our analysis given the importance of foreign firms in Irish manufacturing industry. The model we use in our analysis takes the following form

$$\Delta P_t = \underbrace{\underbrace{\sum_{i\in C} S_{it-k}\Delta P_{it}}_{within-firm} + \underbrace{\sum_{i\in C}(P_{it-k} - \overline{P_{t-k}})\Delta S_{it}}_{between-firm} + \underbrace{\sum_{i\in C}\Delta S_{it}\Delta P_{it}}_{cross-effect}}_{continuing-firms} + \underbrace{\sum_{i\in N} S_{it}(P_{it} - \overline{P_{t-k}})}_{entering} - \underbrace{\sum_{i\in X} S_{it-k}(P_{it-k} - \overline{P_{t-k}})}_{exiting} \quad (3.11)$$

where i is the i-th firm and t is the time period, C, N and X correspond to continuing, entering and exiting firms respectively. Since our analysis adds another dimension in which we examine the decomposition of labour productivity for different nationality groups, the industry averages that we use in calculating between, entry and exit terms in the decomposition refer to the corresponding groups' mean values of productivity in the industry. So, for example, when calculating the contribution of different components to overall productivity growth in Irish firms, we calculate the industry averages as the average productivity of Irish firms in the corresponding sector. This allows us to compare the individual firm productivity levels from the corresponding sector average for each nationality group which are quite diverse.

[42] This led to a decrease of 169, 163 and 158 in the number of observations for 1991, 1995 and 1999 respectively. This decrease in the number of observation is less than 0.05 per cent of total number of observation in each year.

[43] Removing the top and bottom percentiles of the net output variables resulted in a loss of 80 observations in 1991, 88 observations in 1995 and 92 observations in 1999.

The data used for our analysis comes from the Irish Census of Industrial Production (CIP).[44] This census is carried out annually by the Central Statistics Office of Ireland and covers **all** industrial local units with 3 or more persons engaged. As such it is the only fully representative survey of plants in Ireland. The variables on which data are collected are those standard for such Censuses – output (gross and net), sales, employment, wages, capital additions, sectoral and regional classification as well as nationality of ownership. In the CIP, the classification by nationality of ownership is determined by the nationality of the owners of 50 per cent or more of the share capital[45]. The analysis is for the period 1991-99, and covers an average of 4,600 companies, of which more than 3,800 are Irish-owned[46]. Although the data series relating to company ownership is available pre-1991 we set this year as our start point as prior data is not available to us. Also the start point coincides with the introduction of the new NACE classification.

3.4 Decomposition of Productivity Growth by Ownership

3.4.1 Ownership Decomposition, 1991-1999

Table 3.4.1 presents the results for labour productivity decomposition using Equation 3.11. Labour productivity growth over the period 1991-1999 was 158 %. The results for all manufacturing firms indicate that productivity within the continuing firms and the entry of firms which displayed productivity more than the industry average, have

[44] Because of the small number of companies in Ireland and in line with a strong emphasis on confidentiality in the Irish statistical office, the data can only be accessed under "safe-setting" conditions at the Central Statistics Office.

[45] FDI policy in Ireland does not require minimum domestic equity participation as is the case in many developing countries, and most FDI is in the form of green-field investment with 100% foreign ownership, although CIP does not provide any information on actual foreign ownership levels in individual firms.

[46] Firms that change nationality during the study period are removed from the analysis which amounted to less than 1 per cent of total number of firms.

contributed significantly to the labour productivity growth in Irish manufacturing over the period 1991-1999. Within and entry effects accounted for 55 per cent and 29 per cent of overall growth, respectively. The cross-effect, showing the contribution of firms with above industry productivity and employment growth is also positive, reflecting the overall trend of employment and productivity growth in the manufacturing sector during the period.

Overall results for Irish manufacturing industry show similarities with studies on other country manufacturing sectors where within-effect dominating the overall productivity growth followed by entry effect. It is, however very difficult to make comparisons between these studies due to different decomposition methods and time periods used.

Next we turn to examine labour productivity growth for foreign and domestic firms separately[47]; the results show important differences. We can see from Table 3.4.1 that labour productivity growth has been much higher in foreign firms than it has been in their domestic counterparts, 185 per cent and 37 per cent for foreign and domestic firms, respectively. The contributions to the productivity growth of Irish firms mainly come from the within-firm and entry effects, accounting for 73 per cent and 32 per cent of growth respectively. The positive exit effect shows that the exiting Irish firms had above average productivity, but the effect of this term is negligible overall. The results for foreign firms also show that the main contributors to the productivity growth are the within-firm and entry effects, reflecting the productivity growth in the continuing firms and the entry of above average productivity firms.

[47] Although labour productivity levels of foreign firms are very much affected by the transfer pricing activities of these firms, we do not expect transfer pricing to have any impact on the decomposition of labour productivity in foreign firms.

The within-firm productivity is much higher in domestic firms than it is in foreign firms. The between-term effect, which shows the market share reallocations between continuing firms, has a higher effect for domestic firms than for foreign firms, reflecting the structural change within the domestic part of the manufacturing industry over the period. The net entry effect results, which measure the net contribution of entering firms, which have above industry productivity and exiting firms that have below industry productivity, present slight differences between foreign and indigenous firms. For both domestic and foreign firms the net entry effect, which is slightly higher for foreign firms than for their domestic counterparts, is mainly from the entry of above average productivity firms, although we see that the exit of less productive firms contributes positively to foreign firms whereas, for domestic firms the exit of more productive firms brings a negative contribution to overall productivity growth.

Since the composition of direct foreign investment changed over the 1990s, with increased extra-EU investment and much less intra-EU investment, it is insightful to look at the differences in productivity growth and the factors that contribute to this growth for intra-EU and extra-EU firms. Most of the intra-EU investment in Ireland comes from the UK, and the US accounts for almost all of the extra-EU investment. [48] So we decompose intra and extra-EU investment in Irish manufacturing industry into four categories – UK, Other-EU, US and Other Non-EU.

[48] The differences between the different nationality groups in Irish manufacturing industry are. outlined in Ruane and Gorg (1997). UK firms are mainly engaged in traditional sectors, whereas US firms are mostly in high-tech industries. This forms the basis for our grouping of different nationality of firms.

The results are set out in Table 3.4.2. Productivity growth has been highest in the US firms, followed by Other Non-EU, Other-EU and UK firms. We can see that within firm and net entry effects are substantial across different nationalities although the sizes of these effects, particularly the within-effect, are quite different. It accounts for 25 per cent of overall growth for Other Non-EU firms whereas for UK firms this value is 73 per cent. The net entry term's contribution is also quite different among different nationality groups. For example, although it has a similar effect for UK and US firms, accounting for nearly 30 per cent of overall productivity growth for both groups, the entry term accounts for all of it for US firms whereas for UK firms the exit of less productive firms makes a significant contribution to the net entry term. The net entry and within effects for Other Non-EU firms virtually account for all of the labour productivity increase in this group. The only negative effect coming from the entry term is in the Other-EU category but the size of the contribution is negligible. The cross term has a positive contribution for US firms, reflecting the fact that, on average, US firms increased their productivity with increases in their employment levels, whereas for UK, Other-EU and other Non-EU firms this effect is negative, suggesting that much of the productivity growth in these groups occurred in plants that were downsizing. We also see that in Other EU and Other Non-EU firms the between-effect accounts for 25 and 15 per cent of overall growth, respectively, reflecting the fact that there has been considerable employment share reallocation between firms in these two groups.

Results from Table 3.4.1 and 3.4.2 show considerable differences in the growth of labour productivity between foreign and domestic firms during the 1991-1999 period in Irish manufacturing sector. Although the productivity growth pattern of foreign

firms dominates the overall pattern, close analysis of domestic and foreign firms reveal that within-firm and entry effects account for most of the productivity growth in both domestic and foreign firms. We also see different results for cross and between terms, as we further disaggregate nationality groups. The dominance of within and entry effects on overall productivity growth is in line with the industrial policy that has been followed during the last decade; it focuses on improving performance among continuing firms and encouraging entry of selective successful firms into Irish manufacturing industry.

3.4.2 Ownership Decomposition, 1991-1995, 1995-1999

Foster *et al.* (1998) argue that the time horizon used in productivity decomposition studies can have an effect on the relative contribution of each of the components. To test whether our results are dependant on the time-period selected, we carry out separate decomposition analyses for the periods 1991-95 and 1995-99. Another factor in the choice of these two periods is the growth rates of net output and employment in the Irish manufacturing sector. Table 3.4.3 presents percentage changes of net output and employment for both domestic and foreign firms in Irish manufacturing industry for the 1991-95 and 1995-99 periods. Although the whole 1991-1999 period has shown substantial growth in terms of output and employment, the second half of the 1990s saw a greater increase in values, except for employment in foreign firms. As outlined in Chapter 2, employment levels in Irish firms actually decreased between 1992 and 1994 and in 1999, which is described as the "jobless growth years" in some studies.[49]

[49] See Guiomard(1995)

Tables 3.4.4 and 3.4.5 show the decomposition of labour productivity growth by nationality groups for the 1991-95 and 1995-99 periods respectively. Comparison of the two tables reveals that for both foreign and domestic firms the majority of the labour productivity growth through the 1991-99 period occurred in the second half, i.e., after 1995. Overall labour productivity growth was 40 per cent in the first half of the 1991-99 period and this increased to 84 per cent in the second half. In the case of Irish firms, labour productivity grew by only 8 per cent between 1991-95, whereas we see a 27 per cent increase in the 1995-99 period. Results for foreign firms show a similar pattern where labour productivity grew by 46 per cent in the 1991-95 period, but this growth increased to 95 per cent in 1995-99 period. These results are interesting because employment growth has been quite substantial for both domestic and foreign firms in the 1995-99 period compared to virtually no change in the 1991-95 period, which reflects the fact that both foreign and domestic firms on, average, were able to increase their productivity levels, as well as their employment levels in the 1995-99 period. A closer examination of different nationalities shows that UK firms increased their labour productivity levels by almost the same amount in the two periods, for Other-EU and Other Non-EU firms, 1991-95 period accounted for most of the increase.

Next we turn to examine the decomposition of labour productivity changes and attempt to ascertain these factors behind the growth rates for the two periods. In Table 3.4.4 we see that in the 1991-95 period, the within effect is the most significant contributor to labour productivity growth for both domestic and foreign firms, accounting for 108 and 87 per cent of overall growth, respectively. In line with the results from the 1991-99 period, we see that the foreign firms drive the overall results

in decomposition analysis. An important difference in the 1991-1999 results in Table 3.4.1 is the effect of the entry term, which is negligible overall and negative for Irish firms, as opposed to the strong positive contribution that was seen for the whole period. We also see that for Irish firms, exit of below average productivity firms was the main positive contributor to the net entry term. In this period, among four nationality groups, UK firms had the highest within and entry components followed by US firms and Other-EU firms respectively.

Table 3.4.5 presents the results of the labour productivity decomposition analysis for 1995-99 period. Results from this second period reflect more closely results from the full period, where within and entry terms account for most of the growth in the overall labour productivity growth. We also see that foreign firms dominate the overall results in the 1995-99 period, as was the case in the 1991-95 period. For foreign firms, comparison of the results for the two periods reveals that the cross term had a positive effect in the first period of the analysis, whereas this effect was negative, on average, in the second half of the period. The higher effect of between and entry terms in the second period than in the first period reflects the fact that entry of above average productivity firms and employment share reallocation between firms have been the significant contributors to overall productivity growth after the improvements within the firms. The negative cross term in the second half of the period and its positive effect in the first period for US firms, shows that continuing firms with increasing productivity were able to increase their employment shares in the first half of the analysis whereas, their shares declined in the second half of the period. This can be explained by the much higher contribution of entry of above average productivity firms in this group in the period.

Overall results show that the within-firm and the entry effects play a major role for both foreign and domestic firms in the labour productivity growth in the Irish manufacturing sector over the period 1991-99, with foreign firms dominating the overall results. However a closer analysis of different nationality groups reveals that there are differences in the size of the terms of decomposition; the within component being highest for UK firms and the entry term accounting for the highest contribution in Other Non-EU firms. Among the continuing firms, US firms are the only group that have been able to increase their productivity while expanding their employment levels, showing both employment and high productivity growth trend in these firms during the period.

3.5 Sectoral Decomposition

3.5.1 OECD Classification

In our next analysis, we divide the manufacturing sector into four main groups, based on the OECD classification of firms at the two/three digit level, thus generating four classes of sectors: high tech, medium high tech, medium low tech, and low tech. We then conduct a decomposition analysis in these sectors for different nationality groups since aggregate results for foreign firms can wash out the contribution of different effects in productivity decomposition analysis for different nationality groups, as we saw from the results of the previous section.

High-Tech Sectors:

We can see from Table 3.5.1 that in the high-tech sectors, overall cross and net entry effects are more substantial than the within-effect results from Tables 3.4.1 and 3.4.2.

The positive contribution of cross effect suggests that much of the productivity growth occurred in plants that were upsizing. In terms of nationalities, the cross term's contribution is much higher in foreign firms than in domestic firms, accounting for 40 per cent and 7 per cent of overall growth in productivity, respectively. This effect was higher in US and Other-EU firms than in UK and Other Non-EU firms, suggesting that the former group was more successful in increasing their productivity, while increasing their employment levels. Overall for all manufacturing firms, cross and net entry effects accounted for 80 per cent of productivity growth. The net entry effect plays an important role for both indigenous and foreign firms. However, it is clear that the contribution of this effect is greater for domestic firms, accounting for 66 and 43 per cent of overall growth in labour productivity for domestic and foreign firms respectively. Further to this, it is also clear that virtually all of the net entry effect for both foreign and domestic firms derives from the entry of above average productivity firms.

The within firm effect was highest for Other EU firms, with 79 per cent of productivity growth coming from within firm productivity growth. This effect has a much lower contribution to overall growth in the other nationality groups, compared to the average contribution across all sectors which we present results in Table 3.4.2.

For UK and Other Non-EU firms, the net entry effect was 98 and 114 per cent respectively. Entry accounted for most of the net entry effect showing that the entry of above average firms dominated most of the productivity growth. For the US firms in the high-tech sector, 52 per cent of the overall productivity growth came from the change in the cross-effect that reflects the increase in the productivity and

employment share of continuing firms, and 26 per cent is accounted for by the entry of above average productivity firms. The only negative between-effect is observed for UK firms, suggesting that the employment shares of above average productivity firms declined over the period 1991-99 in this category. Overall, results for the high-tech sector show that as opposed to the dominance of within-effect in the aggregate results, entry term plays a more important role in the high-tech sector. This is in line with the results from the OECD (2001) study. This showed that entry plays a more important role in determining the labour productivity growth in sectors related to information and communication technology.

Medium-High-Tech Sectors:

In the medium-high tech sectors overall productivity growth mainly comes from the within and net entry terms, accounting for 66 per cent and 34 cent of labour productivity growth respectively. Results from Table 3.5.2 show that foreign firms determine the overall average with high presence in medium-high tech industries.

For domestic firms the main contributing factors to productivity growth are the within and net entry effect, the latter mainly coming from the exit of below average productivity firms. For all different groups of foreign firms, the between-effect makes a positive contribution towards their corresponding overall productivity growth, suggesting that the market shares of above-average productivity firms increased and this effect is highest for the Other-EU category. For US firms the main contribution comes from the improvement in productivity within existing firms and the entry of above average productivity firms. In UK firms the net entry effect accounts for nearly all of the productivity growth. The most striking result from this table is for Other Non-EU firms where overall productivity decreased during the period as opposed to substantial increases in other categories. This decrease has been

mainly due to the between-effect[50], which reflects the fact that the employment share of the firms that were above average productivity declined in this category during the period.

Medium-Low-Tech Sectors:

Table 3.5.3 presents results from the analysis of sectors in the medium-low tech group. We see that labour productivity growth has been higher in domestic firms than in foreign firms, increasing 38 per cent and 22 per cent respectively in the 1991-99 period. Also as opposed to domination of foreign firms' in the overall figures in the high-tech and medium-high tech sectors, domestic firms drive the overall results in this category, showing the higher presence of Irish firms. Overall within and net entry effects are the dominant factors in the medium-low tech sector, accounting for 91 and 40 per cent of overall change respectively, the net entry effect being dominated by the entry of above average productivity firms. For both foreign and domestic firms we can see that the within and net entry effects are the main contributors to overall productivity growth. We can see that, for the overall average, the within-effect is much higher for foreign firms whereas the net entry driven by the entry factor is higher for domestic firms. The negative sign of the cross-effect in this sector reflects the fact that productivity growth comes from the downsizing firms for all categories of firms. The between term contributes positively to overall growth for UK and Other-EU firms whereas it has a negative effect for US and Other Non-EU firms. This reflects the fact that above average productivity firms in the former group increased their employment share whereas in the latter group the employment shares of above average productivity firms decreased. In US firms in the medium-low-tech

[50] When overall productivity growth is negative the interpretation of the effects of different factors in the decomposition analysis changes. So a positive sign in this case would be contributing to this decline in productivity whereas a negative sign will be acting in the opposite direction, in other words improving productivity.

sector, as is the case in the previous two sectors, the within and entry effects account for most of the overall productivity growth.

Low-Tech Sectors:

In Table 3.5.4 we present results for the low-tech sector where within-effect and cross effects were the main factors, accounting for 66 per cent and 17 per cent of overall productivity growth, respectively for all manufacturing firms. In the low-tech sector we again observe that foreign firms dominate the pattern of the contribution of different factors to overall productivity growth. As opposed to medium-low-tech sector the sign of cross-effect is negative only for UK and Other-EU firms, reflecting the fact that productivity growth came from firms that were downsizing in this category. On the other hand the positive and significant contribution of the between-effect in US and Other Non-EU firms shows that these two groups enjoyed both productivity and employment growth in the low-tech sectors. In US firms we see that entry does not play a significant role as opposed to its important contribution in the three other OECD sector groups. In Other-EU firms, the within-firm effect is negative, but this is offset by the huge between-effect, suggesting that the decline in the within firm productivity is offset by the increase in the market share of above-average productivity firms. In this category we also see the downsizing in the high productivity firms form the negative cross-effect. The main contributing factor in the productivity growth in Other Non-EU firms mainly come from the entry of above average productivity firms and the expansion in the employment levels of high productivity firms accounting for 80 per cent of overall growth.

Overall:

Overall, results for the four OECD sectors show that the within-effect contributes most to overall labour productivity growth in all but one sector, namely high-tech

sector in which net entry that is mainly driven by entry effect and cross term contribute most. This shows that in high-tech sector, the entry of above average firms and employment expansion in the high productivity firms have been the main drivers of the productivity growth. In the other three categories the results show that within and entry terms, in line with the overall results, account for most of the productivity growth. In different nationality groups we see that there are substantial dissimilarities in the factors contributing to productivity growth. These differences are more prominent between foreign and domestic firms across different sectors. Foreign firms dominate the overall average in all but one sector, medium-low tech sector where we also see that domestic firms' productivity increase has been greater than foreign firms'. The cross term is negative for all nationality groups in medium-high and medium-low sectors, showing that continuing firms, on the average, increased their productivity levels by downsizing.

3.5.2 NACE 2-digit Sectors

In light of the results from previous section which showed that the effects of different factors change significantly once we go into more disaggregated analysis of labour productivity decomposition, in this section we turn to analyse the contribution of within, between, cross, entry and exit terms on labour productivity growth using standard NACE 2-digit classification, grouped by the four OECD sectors. Since our analysis in the previous section showed that there are considerable differences in the results from 1991-95 and 1995-99 periods, we first we carry out our analysis for indigenous firms in 1991-1995 and 1995-99 periods separately. Results for the entire period 1991-99 are presented in the appendix in Table 3.B.1.

Domestic Industry:

Table 3.5.5 presents the results of decomposition of labour productivity in Irish manufacturing sector for domestic firms for the 1991-95 period. Overall productivity growth was 6 per cent during the period and we can see that medium-high, medium-low and low tech sectors contributed positively to this growth, while the contribution of high-tech was negative. The highest contributions to overall growth came from Medical, Precision and Optical in the medium high-tech sector, Other Non-Metallic Minerals in the medium low-tech sector and Paper and Paper Products in the low-tech sector. Most of the negative contribution of high-tech sector came from the decline in the labour productivity of domestic firms in the Office Machinery and Computers sector. Overall results show that the within-effect was the main contributor to labour productivity growth, accounting for 108 per cent of change. This overall result is driven by the within-effect results of the medium high-tech, medium low-tech and low-tech sectors. In these three categories we see that within-effect has been the most important contributor to labour productivity growth accounting for 122 per cent, 101 per cent and 110 per cent of overall growth in the medium high-tech, medium low-tech and low-tech sectors, respectively. Among the medium high-tech sectors, we see that in the chemicals industry within-effect has a large but negative contribution to productivity growth. The only other sector where we see a negative contribution from the within-effect is the Food, Drink and Tobacco industry in which labour productivity declined over the 1991-95 period.

The dominance of the within-effect disappears in the high-tech sectors in which we see that the entry term accounts for nearly the entire decline in the labour productivity of Irish firms in these sectors, showing that the entrants in these sectors had, on the average, lower productivity than the incumbents. Radio, Television and

Communication sector shows the highest entry effect even though there have been large improvements in productivity coming from the within and between effects in this sector.

In Table 3.5.6 we present the labour productivity decomposition results of domestic firms in Irish manufacturing industry for 1995-99 period. Overall results show that labour productivity grew by 29 per cent during the period and the main contributors to this growth were the high-tech sectors increasing their productivity by 117 per cent during the period. In the high-tech sectors, Pharmaceuticals industry saw a 223 per cent increase in the average productivity in contrast to the 4 per cent decline in its productivity level in the 1991-95 period. We also see that Radio, Television and Communications, Office Machinery and Computers in the high-tech sectors, Medical, Precision and Optical in the medium high-tech sectors and Publishing and Printing and Wood and Wood Products industries in the low-tech sectors saw increases in their productivity levels above the overall average productivity growth. The only industry that experienced negative productivity growth during the period is the Chemicals sector,[51]which is mostly due to the cross and entry effects reflecting the fact that the decline in the productivity growth in the Chemicals industry during this period was mainly from the entry of below average productivity firms and the increase in the employment shares of firms whose productivity were declining.

The within effect was the main contributor to average productivity growth in three of the four OECD sectors accounting 62 per cent, 75 per cent and 77 per cent of growth in productivity in high-tech, medium high-tech and low-tech sectors, respectively. In

[51] It has to be noted that this is largely due to a sharp fall in the average productivity of firms in 1999 in this sector.

the medium low-tech sectors the net entry effect accounted for 87 per cent of overall growth in productivity mainly through the entry of above average productivity firms accounting for 62 per cent of the increase in average labour productivity in these sectors. A closer examination of the sectors in this category reveals that, in all sectors but one, namely, Manufacturing n.e.c. industry, within-effect was the main contributor to overall growth. This shows that the analysis of aggregate industries can hide the important changes occurring in the individual industries.

Overall, results from the decomposition of labour productivity of Irish firms at a more disaggregated level shows that within-effect was the main factor determining the productivity changes, although in some sectors we see that entry plays an important role. The most striking result is in the high-tech sectors where we see a decline in the productivity in the 1991-95 period and a sharp increase in the 1995-99 period. The decline in the first half of the 1990s was due to the entry of below-average productivity firms and the increase in the second half was mostly from the improvements within the firms which can be interpreted as a learning effect taking place in these sectors where firms entering below productivity in the early 1990s improved their productivity in the 1995-99 period making the within-effect the main factor behind the growth in labour productivity. This result is also in line with the findings from other country studies, which showed that in high growth periods, the within-effect plays a more important role.[52]

Next we turn to analyse the decomposition of labour productivity in foreign firms in Irish manufacturing industry. We carry out our analysis for 1991-95 and 1995-99

[52] Although other studies can make comparisons of the results of labour productivity decomposition between recession and growth periods, our analysis can not make this comparison directly since the 1990s, overall, was a high growth period in the Irish manufacturing sector.

periods separately and present the results for the 1991-99 period in Table 3.B.2 in the appendix.

Foreign Industry:
Table 3.5.7 presents the results of decomposition analysis of labour productivity in foreign firms for 1991-95 period. Overall productivity growth was 44 per cent during the period where, medium high-tech and low-tech sectors were the main drivers of this growth. They experienced 47 per cent and 43 per cent growth in labour productivity, respectively in which Chemicals in medium high-tech industries and Paper and Paper Products in the low-tech sectors were the main contributors. Although the highest productivity growth was in the Pharmaceuticals industry with a 103 per cent increase, the low productivity increase in the Radio, Television and Communications industry has driven the overall average in the high-tech sectors below the 44 per cent overall growth. In this period, we see that virtually all of the growth in the labour productivity came from the within-effect in the high-tech, medium high-tech and low-tech industries accounting for 95 per cent of growth in high-tech and medium-high-tech and 107 per cent of increase in medium-low-tech sectors. In the low-tech sectors the within-effect, accounting for 67 per cent of increase in average productivity, was the main factor with the cross-effect, which shows the contribution coming from the firms which are increasing both their productivity levels and employment shares, accounting for 24 per cent of productivity growth.

Closer examination of 2-digit sectors reveals some considerable differences in the decomposition of labour productivity growth. For example, we see that within-effect contributed negatively to overall productivity growth in the Radio, Television and

Communications, Machinery and Equipment and Publishing and Printing industries. In the Radio, Television and Communications sector, the between, cross and entry effects contribute positively to productivity growth compensating the negative contribution coming from the within-effect giving rise to a 2 per cent increase in the average productivity growth. In the Machinery and Equipment industry virtually all of the productivity growth came from the exit of below average productivity firms. In the case of the Publishing and Printing industry, the cross-effect accounted for most of the productivity growth, showing the importance of firms, which were able to increase both their employment shares and productivity levels.

In Table 3.5.8 the results for 1995-99 period are presented. Overall productivity growth has been higher in this period with a 96 per cent rise. The medium-high-tech and low-tech sectors were the main contributors to this overall growth experiencing 146 per cent and 96 per cent increases in their productivity levels. As opposed to the very small increase in the 1991-95 period of the labour productivity of Radio, Television and Communications wee see a 258 per cent increase in the 1995-99 period making this sector the highest productivity growth industry among the seventeen 2-digit industries. Chemicals in the medium high-tech category and Paper and Paper Products in the low-tech sectors were the other high productivity growth industries having 146 per cent and 88 per cent increases, respectively.

We see that other than the high-tech sectors, within-effect is dominant in determining the overall productivity growth in the three OECD sectors accounting for 52 per cent of overall growth in the medium high-tech, 120 per cent in medium low-tech and 124 per cent in the low-tech sectors. In the high-tech sectors the between term is the most

important factor accounting for 111 per cent of overall growth, reflecting the fact that above average firms increasing their share of employment played an important role in the labour productivity growth in these sectors. The only negative contribution coming from the within-effect among the 2-digit sectors was in the Office Machinery and Computers and Publishing and Printing industries. In the Office Machinery and Computers sector this negative contribution of within-effect was offset by the large between-effect, which also played a dominant role in the Publishing and Printing industry. We also see that in the Machinery and Equipment sector between-effect accounted for nearly all of the productivity growth. In other words, in these three sectors, the main contribution to productivity growth came from the increases in the employment shares of above average productivity firms. In terms of entry and exit effects we see that entry played an important role in the Pharmaceuticals, Chemicals and Medical, Precision and Optical industries, whereas exit of below average productivity firms were important in the traditional sectors of Rubber and Plastics and Textiles and Clothing.

Overall, we see that the labour productivity growth of foreign firms in the Irish manufacturing industry was mainly driven by the within-effect, showing the importance of the within firm productivity importance for both 1991-95 and 1995-99 periods, though we have to note that, as we also observed from the results of domestic firms, there can be marked differences among the sectors when we analyse the results at a more disaggregated level.

3.6 Conclusion

Studies that examine the origins of productivity growth (using both total factor and labour productivity) at firm level find that firm performance is heterogeneous and that net changes observed in aggregate data are marked by large increases at some firms and decreases at others.

In order to investigate the microeconomic productivity dynamics that took place in Irish manufacturing industry during the 1990s, this chapter utilized a labour productivity decomposition approach. Our analysis showed that productivity increases within the continuing firms and the entry of firms which displayed productivity more than the industry average, have contributed significantly to the overall average labour productivity growth in Irish manufacturing over the period 1991-1999. These results are in line with the findings from other country studies, although it is difficult to make cross-country comparisons due to differences in the data source, methods applied and the time period analysed.

Recognising the fact that there is a large presence of foreign firms in Irish manufacturing industry we carried out labour productivity decomposition analysis separately for both foreign and domestic firms, as well as four different nationality groups of firms. Results showed that although within and entry components are the main drivers of average labour productivity growth in all groups, there are marked differences between the size of the effects across the groups.

In order to see the sensitivity of our decomposition results to the time period we investigated the changes for the 1991-95 and 1995-99 periods separately. The results showed that in the first half of the period within firm productivity was the main

contributor to overall average productivity growth for both foreign and domestic firms, whereas results from the second period reflect the trend from the overall results where both within and entry components played important roles.

Finally we examined the micro dynamics of labour productivity in Irish manufacturing industry using the OECD four-group classification of sectors. The analysis showed that within-effect contributes most to overall labour productivity growth in all but one sector, namely high-tech sector in which net entry that is mainly driven by entry effect and cross term contribute most. This shows that in high-tech sector, the entry of above average firms and employment expansion in the high productivity firms has been the main drivers of the productivity growth. In the other three categories the results show that within and entry terms, in line with the overall results, account for most of the productivity growth.

Overall, we found that the labour productivity growth in the Irish manufacturing industry was mainly driven by the within-effect, showing the importance of the within firm productivity importance during the 1991-1999 period. We have to note that there are marked differences between the decomposition results when data was disaggregated to carry out the analysis, which reflects the fact that aggregate productivity figures hide considerable heterogeneity present at firm level.

3A Tables

Table 3.3.1 Significance of Foreign Firms in the Irish Manufacturing Sector, 1999

	Total Net Output		Total Employment	
	Sectors as % of Total	Foreign as % of Sector	Sectors as % of Total	Foreign as % of Sector
Food, Drink and Tobacco	10.9	66	10.3	26
Textiles and Clothing	0.6	50	3.6	35
Wood and Wood Products	0.2	34	0.9	19
Paper and Paper Products	0.3	32	0.7	19
Publishing and Printing	11.2	86	5.5	34
Pharmaceuticals	7.5	92	5.5	82
Chemicals	39.5	98	9.6	80
Rubber and Plastics	0.5	46	3.5	40
Other non-metallic Minerals	0.3	17	1.3	15
Basic and Fabricated Metals	0.7	37	3.1	24
Machinery and Equipment	1.2	60	5.4	46
Office Machinery and Computers	11.7	98	14.4	88
Electrical Machinery	1.9	80	8.3	70
Radio, Television and Communications	7.9	97	9.7	89
Medical, Precision and Optical	4.3	91	11.6	85
Motor Vehicles and Transport	0.7	71	4.2	54
Manufacturing n.e.c.	0.7	40	2.4	27
Total Manufacturing	100	85	100	49

Table 3.4.1: Labour Productivity Decompositions, 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net Entry
All	158%	55	6	7	29	-2	32
Irish	37%	73	8	-10	32	3	29
Foreign	185%	55	5	10	28	-2	31

Table 3.4.2: Labour Productivity Decompositions for Foreign Firms by Nationality, 1991-1999							
	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net Entry
Foreign	185%	55	5	10	28	-2	31
UK	55%	73	10	-13	20	-10	30
Other EU	71%	63	25	-1	-3	-15	12
US	185%	55	3	14	29	0	29
Other Non-EU	91%	25	15	-15	50	-26	76

Table 3.4.3 Percentage Changes in Net Output and Employment in Irish Manufacturing Sector, 1991-99		
	Net Output	Employment
All		
1991-95	55%	12%
1995-99	111%	13%
1991-99	227%	26%
Irish		
1991-95	12%	6%
1995-99	40%	9%
1991-99	57%	15%
Foreign		
1991-95	73%	20%
1995-99	131%	18%
1991-99	300%	41%

Table 3.4.4: Labour Productivity Decompositions, 1991-1995

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net Entry
All	40	92	8	1	0	1	-1
Irish	8	108	10	-15	-7	-4	-3
Foreign	46	87	8	6	0	1	-1
UK	24	133	-3	-67	20	-17	38
Other EU	34	84	10	-5	4	-7	11
US	40	89	-4	18	2	5	-3
Other Non-EU	53	82	16	-7	6	-3	9

Table 3.4.5: Labour Productivity Decompositions, 1995-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net Entry
All	84	64	24	-22	29	-6	35
Irish	27	57	4	-3	38	-5	43
Foreign	95	62	29	-24	24	-8	33
UK	25	92	8	4	1	5	-3
Other EU	28	121	-15	-8	32	30	2
US	104	68	30	-30	24	-8	32
Other Non-EU	25	10	19	3	40	-28	68

Table 3.5.1- Labour Productivity Decompositions by OECD Sectoral Classification, High-Tech 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
All	98	10	10	40	38	-2	41
Irish	89	28	-1	7	66	0	66
Foreign	101	10	10	37	39	-4	43
UK	606	1	-2	3	96	-1	98
Other EU	104	79	11	11	-1	0	-1
US	74	12	7	52	26	-3	29
Other Non-EU	159	-21	2	5	104	-10	114

Note: The sectors in the high-tech category are Pharmaceuticals, Office Machinery and Computers and Radio, Television and Communications.

Table 3.5.2- Labour Productivity Decompositions by OECD Sectoral Classification, Medium-High Tech 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
All	222	66	5	-9	34	-4	38
Irish	18	59	2	-3	37	-5	42
Foreign	262	65	5	-9	35	-3	39
UK	266	14	1	-13	93	-4	97
Other EU	76	72	4	0	16	-9	24
US	317	69	2	-9	35	-4	38
Other Non-EU	-15	-120	435	-164	-15	36	-50

Note: The sectors in the medium-high-tech category are Chemicals (excluding Pharmaceuticals), Machinery and Equipment, Electrical Machinery and Medical, Precision and Optical.

Table 3.5.3- Labour Productivity Decompositions by OECD Sectoral Classification, Medium-Low Tech 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
All	33	91	0	-32	36	-4	40
Irish	38	73	0	-21	48	-1	48
Foreign	22	127	7	-53	9	-10	19
UK	62	114	22	-56	12	-7	19
Other EU	12	107	52	-72	14	1	13
US	14	67	-9	-8	31	-19	50
Other Non-EU	57	150	-2	-52	-2	-6	4

Note: The sectors in the medium-low-tech category are Rubber and Plastics, Other Non-Metallic Minerals, Basic and Fabricated Metals, Motor Vehicles and Transport and Manufacturing n.e.c.

Table 3.5.4- Labour Productivity Decompositions by OECD Sectoral Classification, Low Tech 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
All	109	66	7	17	10	1	10
Irish	35	76	20	-4	14	5	9
Foreign	180	69	-1	30	1	-1	2
UK	24	93	7	-9	11	1	10
Other EU	81	-5	198	-184	51	-39	90
US	173	67	-4	37	-1	-1	1
Other Non-EU	257	28	-3	27	53	4	49

Note: The sectors in the low-tech category are Food, Beverages and Tobacco, Textiles, Wood and Wood Products, Paper and Paper Products and Printing and Publishing.

Table 3.5.5: Labour Productivity Decompositions, Irish Firms, 1991-1995

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
High -Tech	-13	-19	-10	11	98	-21	118
Radio, Television and Communications	-3	-257	-279	141	567	72	495
Pharmaceuticals	-4	-24	103	37	34	50	-16
Office Machinery and Computers	-22	0	-2	-2	69	-35	104
Medium High-Tech	3	122	7	-49	-4	-24	20
Medical, Precision and Optical	23	87	17	4	-24	-15	-8
Electrical Machinery	14	101	-27	17	68	58	10
Chemicals	5	-1339	853	575	638	628	10
Machinery and Equipment	0	142	99	-107	-45	-11	-34
Medium Low-Tech	15	101	13	-9	-8	-3	-4
Other Non-Metallic	32	107	1	-24	20	5	15
Manufacturing n.e.c.	9	103	-3	7	-11	-4	-7
Rubber and Plastics	5	91	65	-29	-32	-5	-27
Basic and Fabricated Metals	2	121	23	-21	0	22	-23
Motor Vehicles and Transport	-3	-68	-596	816	48	99	-51
Low-Tech	4	110	6	-17	-3	-4	1
Paper and Paper Products	28	104	-3	0	-8	-7	-1
Textiles and Clothing	14	83	28	-7	0	4	-4
Wood and Wood Products	5	78	176	-193	85	46	39
Publishing and Printing	4	148	25	-106	3	-30	32
Food, Drink and Tobacco	-1	218	310	-477	80	32	49
All	6	108	10	-15	-7	-4	-3

Table 3.5.6: Labour Productivity Decompositions, Irish Firms, 1995-1999

	Labour Productivity Growth	*Within*	Between	Cross	Entry	Exit	Net entry
High -Tech	117	62	4	-21	56	1	55
Pharmaceuticals	223	10	-2	4	86	-2	88
Radio, Television and Communications	79	169	7	-81	16	10	6
Office Machinery and Computers	38	40	19	6	33	-2	35
Medium High-Tech	15	75	14	-14	18	-7	25
Medical, Precision and Optical	39	69	12	-14	31	-2	32
Electrical Machinery	28	83	8	-3	14	1	13
Machinery and Equipment	18	70	20	-18	11	-18	29
Chemicals	-8	-66	51	80	92	58	35
Medium Low-Tech	20	13	-6	7	62	-25	87
Other Non-Metallic	20	128	-8	-3	-12	5	-17
Manufacturing n.e.c	16	5	-13	18	77	-14	91
Basic and Fabricated Metals	15	67	81	-71	4	-19	22
Rubber and Plastics	12	76	29	-25	19	-1	20
Motor Vehicles and Transport	1	105	73	-22	62	118	-56
Low-Tech	30	77	8	-4	24	5	19
Publishing and Printing	48	129	2	-34	-1	-4	3
Wood and Wood Products	43	103	5	-17	10	0	9
Food, Drink and Tobacco	26	74	24	-9	3	-8	11
Textiles and Clothing	21	46	5	35	14	0	14
Paper and Paper Products	4	-144	-46	-17	314	8	307
All	29	57	4	-3	38	-5	43

Table 3.5.7: Labour Productivity Decompositions, Foreign Firms, 1991-1995

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
High -Tech	33	95	-18	42	3	22	-20
Pharmaceuticals	103	78	2	0	17	-3	20
Office Machinery and Computers	13	54	-16	60	1	-1	1
Radio, Television and Communications	2	-738	245	476	236	118	118
Medium High-Tech	47	95	19	-22	4	-4	8
Chemicals	62	99	12	-10	-2	-2	-1
Electrical Machinery	59	40	29	-16	28	-19	47
Machinery and Equipment	19	-21	-13	-3	-2	-138	136
Medical, Precision and Optical	7	158	72	-154	24	-1	25
Medium Low-Tech	14	107	-21	-14	6	-22	8
Motor Vehicles and Transport	38	222	35	-161	15	12	3
Rubber and Plastics	19	115	-22	-4	-1	-13	12
Other Non-Metallic	13	51	92	-120	-25	-101	76
Basic and Fabricated Metals	9	286	-246	33	-9	-36	28
Manufacturing n.e.c.	4	251	-82	-65	-4	0	-4
Low-Tech	43	67	13	24	-9	-5	-4
Paper and Paper Products	75	103	10	7	-2	19	-21
Food, Drink and Tobacco	42	94	8	-2	-9	-10	1
Publishing and Printing	14	-43	49	89	-7	-11	5
Wood and Wood Products	9	55	5	4	-31	-67	35
Textiles and Clothing	3	119	-20	65	-27	37	-64
All	44	87	8	6	0	1	-1

Table 3.5.8: Labour Productivity Decompositions, Foreign Firms, 1995-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
High -Tech	49	28	111	-76	18	-18	37
Radio, Television and Communications	258	57	31	0	5	-6	12
Pharmaceuticals	74	27	7	3	55	-8	64
Office Machinery and Computers	9	-98	706	-596	-7	-95	89
Medium High-Tech	146	52	5	-2	40	-5	45
Chemicals	186	50	5	0	41	-5	46
Medical, Precision and Optical	40	65	-5	-17	49	-8	57
Electrical Machinery	5	125	32	-21	-10	25	-35
Machinery and Equipment	5	0	99	-8	-20	-29	9
Medium Low-Tech	7	120	-2	-13	5	10	-5
Other Non-Metallic	50	87	-7	-7	4	-24	27
Manufacturing n.e.c.	31	415	48	-180	2	185	-183
Basic and Fabricated Metals	17	309	-25	-56	-126	2	-128
Motor Vehicles and Transport	11	94	10	-12	13	5	8
Rubber and Plastics	-8	45	-39	-18	-3	-116	113
Low-Tech	96	124	-2	-22	-9	-9	0
Paper and Paper Products	88	139	-6	-37	-2	-6	4
Food, Drink and Tobacco	84	70	11	12	-1	-9	7
Publishing and Printing	49	-7	102	-3	-13	-21	8
Wood and Wood Products	39	123	-3	-9	-11	0	-10
Textiles and Clothing	9	49	-57	-7	26	-88	114
All	96	62	29	-24	24	-8	33

3.B Appendix

Table 3.B.1: Labour Productivity Decompositions, Irish Firms, 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
High -Tech	89	28	-1	7	66	0	66
Pharmaceuticals	210	8	-2	-2	95	-1	96
Radio, Television and Communications	74	71	-9	11	21	-6	27
Office Machinery and Computers	8	36	20	42	18	16	2
Medium High-Tech	18	59	2	-3	37	-5	42
Medical, Precision and Optical	70	48	0	4	46	-1	48
Electrical Machinery	46	54	10	-4	51	11	40
Machinery and Equipment	17	79	10	-9	25	5	20
Chemicals	-3	-80	191	31	99	141	-42
Medium Low-Tech	38	73	0	-21	48	-1	48
Other Non-Metallic	58	113	-3	-27	15	-2	17
Manufacturing n.e.c.	26	63	17	-6	28	3	25
Rubber and Plastics	18	73	16	-3	18	3	14
Basic and Fabricated Metals	18	194	-56	27	2	67	-65
Motor Vehicles and Transport	-2	29	140	-55	48	61	-13
Low-Tech	35	76	20	-4	14	5	9
Publishing and Printing	54	156	-3	-61	3	-5	8
Wood and Wood Products	50	83	6	-2	21	7	14
Textiles and Clothing	38	34	6	27	37	4	33
Paper and Paper Products	33	61	1	-1	43	4	39
Food, Drink and Tobacco	25	44	48	-48	48	-7	55
All	37	55	6	7	29	-3	32

Table 3.B.2: Labour Productivity Decompositions, Foreign Firms, 1991-1999

	Labour Productivity Growth	Within	Between	Cross	Entry	Exit	Net entry
High -Tech	98	10	10	37	39	-4	43
Radio, Television and Communications	265	5	9	46	37	-4	41
Pharmaceuticals	254	22	4	2	68	-4	72
Office Machinery and Computers	24	5	25	86	-8	8	-16
Medium High-Tech	261	65	5	-9	35	-3	39
Chemicals	364	66	3	-9	37	-3	40
Electrical Machinery	67	77	35	-16	-1	-4	4
Medical, Precision and Optical	50	61	5	-21	51	-5	56
Machinery and Equipment	25	37	47	6	-3	-14	10
Medium Low-Tech	22	127	7	-53	9	-10	19
Other Non-Metallic	70	99	14	-39	-2	-28	26
Motor Vehicles and Transport	53	58	28	-13	22	-4	27
Manufacturing n.e.c.	36	263	-301	-124	-6	-268	262
Basic and Fabricated Metals	27	357	-28	-140	-107	-18	-89
Rubber and Plastics	10	92	-86	70	-1	-25	24
Low-Tech	180	69	-1	30	1	-1	2
Paper and Paper Products	160	43	12	35	1	-9	11
Publishing and Printing	115	54	-1	49	5	7	-1
Food, Drink and Tobacco	98	91	3	-3	1	-9	9
Textiles and Clothing	91	49	1	45	6	1	5
Wood and Wood Products	19	86	-2	-21	37	0	37
All	185	55	5	10	28	-2	31

CHAPTER 4 TECHNICAL EFFICIENCY IN IRISH MANUFACTURING INDUSTRY, 1991-1999

4.1 Introduction

The Irish economy has been characterised by high rates of economic growth and low unemployment rates relative to other EU countries during the last decade. One of the main contributors to this overall high rate of growth in the Irish economy has been Irish manufacturing industry, which experienced exceptionally high growth rates in terms of both employment and output during the period. As outlined in Chapters 2 and 3, this success in achieving higher rates of growth in output relative to employment has brought substantial increases in labour productivity of both foreign and domestic firms.

Although labour productivity is one of the most commonly used measures for analysing performance of firms or industries, it only gives a partial picture of performance. Another approach taken in the literature in measuring performance of firms or industries has been to estimate production functions in order to measure general productivity. A common assumption that is used in estimating production functions is that producers operate on their production functions, namely all producers are technically efficient.

The alternative approach that is adopted in the literature starts with the presumption that not all producers are technically efficient and involves the

estimation of production functions, which is known as stochastic production frontier analysis. This chapter uses a stochastic production frontier approach to measure technical efficiency in manufacturing firms in Ireland over the period. Using firm level Census of Production panel data we examine how technical efficiency levels in manufacturing firms in the Electrical and Optical Equipments industry changed over the period 1991-1999. This sector played an important role in the development of Irish manufacturing industry since the 1970s. We also examine the factors that might have affected the changes in the technical efficiency levels of firms in this industry.

This chapter comprises the following: the next section summarises the approach taken in the literature to modelling inefficiency using the stochastic production frontier approach; it also includes a discussion of some of the studies that utilised this approach. Section 4.3 describes the data and outlines the application of stochastic frontier approach in measuring technical efficiency in Irish manufacturing industry. Section 4.4 presents the results from the estimation of technical efficiency of selective manufacturing sectors in this section. We conclude with a summary in Section 4.5.

4.2 Determining Inefficiency: Methodology and Literature

4.2.1 Methodology

Typical models of production function analysis start with a production function and in these models producers are assumed to operate on their production

functions, maximising output using the available inputs. Empirical analysis of production functions have long used different least squares techniques in which error terms were assumed to be symmetrically distributed with zero means and the only source of departure from the estimated function was assumed to be statistical noise. These analyses considered productivity only and did not deal with technical efficiency. However, the pioneering work of Koopmans (1951) provided a definition of technical efficiency suggesting that not all producers were technically efficient and since that time we have seen increasing number of studies modelling production functions with the assumption that not all firms might be operating efficiently.

Before proceeding with the theoretical and empirical studies in the literature that followed Koopmans, it is useful to provide informal definitions of productivity, technical efficiency and technical change, which are widely used in these studies. More importantly it is important to show the differences between productivity and technical efficiency concepts, which are often used interchangeably.[53]

Productivity is defined as the ratio of the output(s) that a firm produces to the input(s). There are different measures of productivity used in empirical studies such as labour productivity and capital productivity, which are known as partial productivity measures since they relate output to a single input such as labour or capital. An alternative measure used in empirical studies is total factor

[53] For more details see O'Neill (2002).

productivity, which relates output to all the inputs used in the production process.

In order to demonstrate the difference between productivity and technical efficiency definitions we can use a simple production process where a single input (x) is used to produce a single output (y).[54]The line OF in Figure 4.1 represents a production frontier, which defines the relationship between input and output. The production frontier represents the maximum output attainable from each input level. Hence it reflects the current state of technology in producing that output. Firms operate either on the frontier, in which case they are technically efficient, or beneath the frontier, in which case they are technically inefficient. Point A represents an inefficient firm whereas points B and C represent efficient firms. The firm at point A is technically inefficient because it is not producing as much output as potentially it could given the level of inputs it employs.

The distinction between technical efficiency and productivity is illustrated in Figure 4.2 where productivity at a particular data point is measured as a ray through the origin. The slope of this ray is *y/x* and hence provides a measure of productivity. If the firm operating at point A moves to the technically efficient point B, the slope of the ray will be greater, implying higher productivity at point B. However, by moving to point C, the ray from the origin is at a tangent to the production frontier and hence defines the point of maximum possible

[54] This section heavily draws on from Coelli *et al.*(1999)

productivity and represents the optimal scale. Thus a firm may be technically efficient but may still be able to improve its productivity. Another concept that is widely used in empirical studies is the technical change, which involves advances in technology and can be represented by an upward shift in the production frontier.

Early Developments in the Frontier Analysis:

Farrell (1957) was the first to measure productive efficiency empirically. Using data on US agriculture he defined cost efficiency and decomposed it into its technical and allocative parts using linear programming techniques rather than econometric methods. His work using linear programming eventually led to the development of data envelopment analysis (DEA) and this method is widely used in the literature as a non-parametric non-stochastic technique.

Farrell's work also led to the development of stochastic frontier analysis which involved estimating deterministic production frontiers, either by means of linear programming techniques or by modification to the least squares techniques. Initial studies on efficiency using deterministic production frontier models assumed the error term was not affected in any way by statistical noise and thus represented inefficiency.

Following Farrell (1957), Aigner and Chu (1968) considered the idea of a deterministic production frontier using a parametric frontier function of Cobb-Douglas form defined as:

$$\ln y_i = \chi_i \beta - u_i \qquad \text{i=1,2, …,N.} \qquad (4.1)$$

where y_i is the output for the i-th firm, χ_i is a vector of inputs, β is a vector of unknown parameters of the intercept and the slope terms and u_i is non-negative random variable associated with technical inefficiency. The measure of efficiency is given as the ratio of the observed output of the i-th firm to the potential output defined by the frontier function and is outlined as:

$$TE_i = \frac{y_i}{\exp(\chi_i \beta)} = \frac{\exp(\chi_i \beta - u_i)}{\exp(\chi_i \beta)} = \exp(-u_i) \qquad (4.2)$$

Following Aigner and Chu (1968) there have been other studies in the literature using the same approach by applying different estimation techniques. Early studies used the Corrected Ordinary Least Squares (COLS) method to estimate the production frontier, which involved the estimation of the model in two stages where parameter estimates are obtained in the first stage using Ordinary Least Squares (OLS) method. Since Ordinary Least Squares estimates of the model produced a consistent but biased estimate of the intercept term, in the second stage the intercept term is corrected by shifting it upwards until all residuals are non-positive and the largest residual is zero. (Lovell, 1993) These corrected residuals are then used to calculate technical efficiency for each producer. The main drawback of this method was the implication of both efficient and inefficient producers having the same structure of frontier technology.

In order to overcome this drawback of the COLS method, an alternative method known as Modified Ordinary Least Squares (MOLS) was proposed. It involved

the assumption that the error term followed a one-sided distribution and that the mean of the assumed distribution could be used to modify the estimated OLS intercept. The main disadvantage of this method was that it could produce technical efficiency levels greater than one.

Schmidt (1976) argued that if the error term associated with the technical inefficiency effects followed a one side distribution such as exponential or half normal, then linear programming estimates proposed by Aigner and Chu (1968) were maximum likelihood estimates of the deterministic frontier model, which led to the widely use of maximum likelihood estimation techniques in stochastic production frontier analysis.

Although these early studies tried to estimate technical inefficiency, their approach was deterministic in the sense that no allowance was made for the possible influence of measurement error and other statistical noise on the estimated production frontier. In other words all the deviations from the frontier were assumed to be the result of technical inefficiency.

Stochastic Frontier Models:

The stochastic production frontier model was suggested by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). Both studies proposed the use of composed error terms associated with frontiers, which included a traditional symmetric random noise component and a new one-sided inefficiency

component in order to overcome the problems associated with the deterministic approach.[55] Their models were defined as:

$$y_i = \chi_i\beta + (v_i - u_i) \qquad i=1, 2, \ldots, N \qquad (4.3)$$

In this model the random error, v_i, accounts for measurement error and other random factors and is independently and identically distributed with mean zero and constant variance, σ_v^2. The u_i that accounts for technical efficiency is independent of the v_i, and is assumed to be independently and identically distributed exponential or half-normal.[56]

The early empirical studies in the literature used cross-section data. Using a panel data approach, this model was broadened by Pitt and Lee (1981). This specification, involving the use of panel data allows the investigation of both technical change and technical efficiency change over time. Their model can be defined as:

$$y_{it} = \chi_{it}\beta + (v_{it} - u_{it}) \qquad i=1\ldots N,\ t=1\ldots T \qquad (4.4)$$

where y, χ, β, v and u are defined as in Equation 4.3 with the introduction of time period t in the model.

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[55] The only difference between the two models was the assumption of the distribution of the one-sided error term. Meeusen and van den Broeck assumed an exponential distribution to u, whereas Aigner et al used both half-normal and exponential distributions.

[56] There have also been different distributional forms suggested in the literature, such as the truncated normal (Stevenson (1980)) and the two-parameter gamma (Greene (1990)).

Early studies using this approach assumed that technical inefficiency effects are time-invariant, namely $u_{it}= u_i$. This approach, with the assumption of time-invariant technical inefficiency, did not fully utilise the advantages associated with using panel data where individual enterprise's efficiency levels can be estimated for several years.[57] Kumbhakar (1990) suggested a stochastic frontier model for panel data where the technical efficiency effects vary systematically with time in which the error term associated with the technical efficiency had a half-normal distribution, involving the estimation of two unknown parameters.

Battese and Coelli's (1992) study on the paddy farmers in India proposed a time-varying model for the technical efficiency effects in the stochastic frontier production for panel data as an alternative to the Kumbhakar (1990) model, where the u_is were assumed to be an exponential function of time which involved only one unknown parameter. They defined technical efficiency as the ratio of a farm's mean production to the corresponding mean production if the farm utilised its level of inputs efficiently. In this study the maximum-likelihood estimates of the parameters of the model and the predictors of technical efficiency were calculated using the computer program **Frontier**.[58]

The Battese and Coelli (1992) method can be outlined as follows:

$$y_{it}= \chi_{it}\beta+ (v_{it}-u_{it}) \qquad i=1\ldots N,\ t=1\ldots T \qquad (4.5)$$

[57] As Coelli, Rao and Battese (1998) point out, the pattern of technical efficiency effects can change over time.

[58] Details of the programme can be found in Coelli (1996)

where y_{it} is the log of production of the i-the enterprise in the t-th time period, χ_{it} is a vector of input quantities of the i-th firm in time t and β is a vector of unknown parameters. The error tem is composed of two parts. The first part v_{it} are random variables assumed to be identically and independently distributed (iid) N~ $(0, \sigma^2)$ and independent from u_{it}. The u_{it} are defined by Battese and Coelli (1992) as:

$$u_{it}= \exp(-\eta (t-T))u_i \qquad (4.6)$$

These are non-negative random variables, which are assumed to account for technical inefficiency in production and to be identically and independently distributed as truncations of zero of the N $(0, \sigma^2)$ distribution, where η is a parameter to be estimated, which determines whether inefficiencies are time varying or time invariant. This model replaces σ^2_v and σ^2_u with $\sigma^2=\sigma^2_v+\sigma^2_u$ and $\gamma=\sigma^2_u/(\sigma^2_v+\sigma^2_u)$. The parameter γ must have a value between 0 and 1 for use in an iterative maximisation process.

It was recognised in the literature that if efficiency varied across producers or over time, which was proposed in the time-variant inefficiency models, then it was possible to examine the determinants of efficiency variation. Early empirical studies that investigated the determinants of technical inefficiencies among enterprises used a two-stage approach where estimates of the stochastic frontier model were obtained in the first stage and then the estimated values of technical inefficiency were regressed on a vector of explanatory variables. This approach contradicted the assumption of identically distributed inefficiency effects and in

order to overcome this drawback Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991) specified stochastic frontier models where the inefficiency effects were defined in the model and all parameters were estimated in a single Maximum-Likelihood procedure. Battese and Coelli (1995) extended their model so that it included the estimation of the parameters of the factors believed to influence the technical efficiency levels of producers and applied this approach to panel data. This model assumed the technical inefficiency effects to be independently, but not identically, distributed non-negative random variables, obtained by the truncation of the $N \sim (\mu_{it}, \sigma^2)$ distribution where

$$\mu_{it} = Z_{it}\delta \qquad (4.7)$$

in which Z_{it}s are the explanatory variables assumed to have an effect on the technical efficiency levels of individual enterprises and δ is a vector of unknown parameters.

4.2.2 Early Applications

Until recently, most of the empirical applications in the literature measuring technical efficiency using stochastic frontier production function approach have been in agricultural economics and operational research (mainly dealing with state-owned enterprises, non-profit organisations and the banking sector). Examples from the agricultural economics literature include Sidhu (1974) on the efficiency of wheat production in India, Battese and Corra (1977) on the efficiency of paddy farmers in India, Färe *et al.* (1985a) on the efficiency of

Philippine agriculture, Battese and Coelli (1988), Kumbhakar *et al.* (1991) examining technical efficiency using data on US dairy farms, Battese and Coelli (1992) using data on Indian paddy farmers, Heshmati and Kumbhakar (1994) analysing technical efficiency of Swedish dairy farms and O'Neill et al. (2001) examining farm technical efficiency in Irish agriculture.

Examples of the application of technical efficiency analysis on state-owned enterprises include Atkinson and Halvorsen (1984) and Färe *et al.* (1985b) on the technical efficiency of electricity generation units in the US, Bhattacharyya *et al.* (1994) studying the technical efficiency of water utilities and Deprins *et al.* (1984) on the labour efficiency of post offices in the US. We also see the application of stochastic production frontier functions in the analysis of transportation sector with the studies of Deprins and Simar (1989) and Gathon and Perelman (1992) using data on railways.

4.2.3 Applications to Manufacturing Sector

There has been a surge in the studies examining technical efficiency of the manufacturing industries recently, with the increased availability of micro data on manufacturing sectors. Although one of the early studies in the literature appeared in 1980s by Pitt and Lee (1981) analysing the technical efficiency of Indonesian weaving industry using panel data, most studies examining efficiency in manufacturing industries using the stochastic production function approach have used cross-sectional data sets. Cheng and Tang (1987) using data on the Taiwanese electronics sector for 1980 and Hill and Kalirajan (1993) using data

for 1986 on Indonesian garment industry are two examples of studies measuring technical efficiency utilising the stochastic production frontier approach with cross-section data sets.

Harris (1991) used a frontier production function approach to estimate efficiency in Northern Ireland manufacturing sector for the year 1987-88 using cross-section data from a survey of 140 manufacturing companies. He found that the mean technical efficiency in Northern Ireland was approximately 80%. He also found that foreign-owned firms were more productive than the domestic firms and that increasing returns to scale were important.

Sheehan (1997) using sample data from the Annual Census of Production (ACOP) covering 404 companies examined technical efficiency in firms in Northern Ireland over the period 1973-85 utilising a stochastic production function approach. Sheehan found that average technical efficiency increased from 65 per cent in 1973 to 79 per cent in 1985. In addition to the technical efficiency estimates provided, this study also analysed the factors that account for the observed levels of efficiency using a two-stage estimation approach where the technical inefficiency is estimated in the first stage and these technical inefficiency estimates are used as dependent variables in the second-stage. Sheehan found that foreign ownership was an important factor in determining average efficiency levels in the manufacturing sector of Northern Ireland.

Harris (1999a) studied productive efficiency in five UK manufacturing industries, namely, Electronic Data Processing Equipment, Motor Vehicles, Aerospace, Brewing and Malting and Newspapers, for the period 1974-94 using data from the ACOP and employing a stochastic production frontier approach. He found that plants in Data Processing Equipment, Motor Vehicles and Aerospace were relatively around the higher end of the efficiency distribution whereas plants in Brewing and Newspaper sectors had much lower levels of efficiency compared to the frontier. He also found that scale effects and foreign ownership had a positive effect in determining technical efficiency. In a more extended study of efficiency in UK manufacturing sector, Harris (1999b) provides estimates for over 200 manufacturing sectors using the same approach. In addition to the five leading sectors of UK manufacturing he estimates average efficiency levels for all of the 2 digit sectors and selected 4-digit industries. Using estimates from Harris (1999b), Harris (2001) compares the differences in efficiency of manufacturing firms in Northern Ireland and other UK regions. He finds that Northern Ireland had generally the lowest level of average efficiency throughout the period 1974-94. The results were consistent both at the aggregate level and the industry level. Examination of different ownership groups showed that foreign plants operating in Northern Ireland had higher efficiency levels compared to their domestic counterparts. However plants in Northern Ireland overall performed relatively less well than plants in other UK regions across all ownership groups.

Using three digit data from the UK Census of Production for the period 1984-92, Driffield and Munday (2001) examined the determinants of technical efficiency in UK manufacturing industry, focusing particularly on the role of foreign investment and spatial agglomeration of similar industry activities. They found that foreign ownership is a determinant of technical efficiency in UK manufacturing industry, although the effect varies according to industry characteristics. In sectors that are relatively more productive and regionally concentrated, the effect of foreign investment on the technical efficiency of domestic industry is found to be higher.

Mahadevan (2000) studied the technical efficiency of 28 three digit manufacturing industries in Singapore from 1975-94 using a Cobb-Douglas production function and stochastic production frontier approach. This study showed that on the average Singapore's manufacturing industries were operating at 73 per cent of their potential output level and showed that capital intensity and labour quality were important factors in determining the efficiency levels.

Marcos and Galvez (2000), in their study of the Spanish manufacturing industry, utilise the stochastic production frontier approach and examine technical efficiency levels using data on 855 Spanish firms in 15 manufacturing sectors over the period 1990-94. They found that Spanish firms were on the average 60 per cent efficient.

In their study of the technical efficiencies of firms in the Indonesian garment industry, Battese *et al.* (2001) use stochastic frontier models for firms in five different regions of Indonesia for the period 1990 to 1995 and find that there are substantial efficiency differences among the garment industry firms across the five regions. Lundvall and Battese (1998) using an unbalanced panel of 235 Kenyan manufacturing firms in the Food, Wood, Textile and Metal sectors and utilising stochastic production frontier approach, estimated technical efficiency levels in Kenyan manufacturing industry and investigated whether technical efficiency is related to firm size and age. They found that the mean technical efficiency increases with size in all sectors and that there was no direct effect of age on efficiency.

As we can see from the different examples of technical efficiency studies in the literature using the stochastic production frontier approach, there are various applications on manufacturing. Some of the studies used cross-section data while others utilised panel data approach with the availability of data. We can also see that different studies took various approaches in using the level of data where we see studies using firm-level data, 2 and 3-digit industry level data and regional data. [59]

4.3 Measuring Technical Efficiency in Irish Manufacturing Industry

In this section using, data from the Census of Industrial Production (CIP), we measure technical efficiency levels in Electrical and Optical Equipment sector

[59] We have to make a distinction between the studies using firm level data and presenting their results at 2 or 3-digit level and studies which use 2 or 3-digit level data in order to get the results.

(NACE 30-33) of Irish manufacturing industry for the 1991-1999 period, using a stochastic production function that allows each plant to have different levels of efficiency in different years for the period. We also investigate the factors that determine efficiency with the one-step approach where parameters of the variables that explain efficiency are included in the model with the estimates of the stochastic production function.

Electrical and Optical Equipment sector plays an important role in Irish manufacturing industry. In 1991 this sector accounted for about 16 per cent of total manufacturing employment in Ireland and this has increased to over 25 per cent by 1999. This industry consists of four individual two-digit NACE industries, which are Office Machinery and Computers (NACE 30), Electrical Machinery and Apparatus (NACE 31), Radio, Television and Communications Equipment (NACE 32) and Medical, Precision and Optical Instruments (NACE 33). Table 4.3.1 shows the levels of employment in these four sectors and their share in total manufacturing employment in the Irish manufacturing sector. In all four sub-sectors we see that employment has increased more than the average increase in total manufacturing employment over the 1991-1999 period, which resulted in an increase in the share of employment, accounted for by these sectors in total manufacturing employment.

An important feature of the Electrical and Optical Instruments industry in Ireland is the dominance of foreign firms in terms of both employment and net output. This feature is the result of the Irish industrial development policy, which recognized in the 1970s that this sector could provide an important role in the

development of Irish manufacturing industry and encouraged foreign firms in this sector to locate in Ireland. Although foreign companies locating in Ireland have been, to a great extent, responsible for developing this sector, there has been important development on the indigenous side of the sector. Foreign firms still account for over 80 per cent of employment in this industry, but we can see from Table 4.3.2 that employment levels in Irish firms in the four sub-sectors of the industry have increased dramatically during the 1991-99 period. The highest increase has been in the Medical, Precision and Optical Equipments industry with a 236 per cent rise. Overall, domestic firms increased their employment levels in the Electrical and Optical Equipments sector by 106 per cent compared to a 15 per cent increase in total manufacturing employment in Irish firms during the period.

An investigation of labour productivity levels in domestic firms in this sector shows that over the period 1991-99, labour productivity has increased by 48 per cent compared to an average rise of 37 per cent in the labour productivity levels of Irish manufacturing firms. Table 4.3.3 shows that three of the four sub-sectors in the industry have experienced much higher growth rates in their labour productivity levels compared to the average growth with the only exception of Office Machinery and Computers industry which showed an 8 per cent rise.[60] The highest increase in productivity of domestic firms in these sub-sectors has been in the Radio, Television and Communications and Medical, Precision and Optical industries with 74 per cent and 70 per cent, respectively.

[60] It has to be noted that Office Machinery and Computers sector had already higher productivity levels than the other three sub-sectors in 1991 as well as the total manufacturing industry average.

It has been argued in the literature that the high presence of foreign firms in these sectors as a result of industrial policy followed since the 1970s has had a positive effect on the development of indigenous firms.[61] Görg and Ruane (1998) investigate the development and the determinants of inter-firm linkages between electronics[62] firms in Ireland and domestic sub-suppliers using firm level data for 1982 to 1995 and find that foreign-owned electronic firms in Ireland source, on average, 24 per cent of their inputs in Ireland and that firms in the electronics industry in Ireland have increased their backward linkages over time.

We investigated the changes in labour productivity and employment levels in the Electrical and Optical Equipment industry in Chapter 2, which gave us an overall picture of developments that took place in the sector over the period 1991-99. However our analysis in this chapter did not include the factors that could affect these changes. In this chapter we investigate the changes in the technical efficiency levels of Irish firms in this industry, which also enables us to examine some of the factors affecting these changes.

In using stochastic frontier analysis when measuring technical efficiency one of the difficulties that arise is the problem of heterogeneity in the outputs of producers. In order to reduce this heterogeneity we carry out our analysis at

[61] Cogan and Onyemadum (1981) argue, based on a small case-study survey of a number of Irish-owned firms in the electronics sector, that foreign MNCs act as "incubators" for indigenous firms with previous employees of MNCs acting as the main initiators for a number of Irish-owned electronics firms.

[62] This study uses data from Forfás Irish Economy Expenditure Survey database. Forfás is the policy and advisory board for industrial development in Ireland. We note that the Forfás classification of the electronics sector used in that study is quite different than the CSO NACE classification used here.

selected individual 4-digit sub-sectors of the Electrical and Optical Equipment sector since stochastic frontier analysis assumes a technology frontier common to all firms in an industry and using data at a more aggregated industry level could violate this assumption. The selected industries are presented in Table 4.3.4.

4.3.1 Model Specification

There are basically two common functional forms of production function used in the literature in studying technical efficiency using stochastic production frontier functions, namely Cobb-Douglas and general Translog functional forms. Since the Cobb-Douglas specification is nested in the translog model we start with the translog specification in our analysis and define it in Equation 4.8 as:

$$\ln y_{it} = \beta_0 + \sum_j \beta_j \ln \chi_{jit} + \beta_T t + \beta_{TT} t^2 + \sum_j \beta_{Tj} t \ln \chi_{jit} + \sum_{j \le k} \sum \beta_{kj} \ln \chi_{jit} \ln \chi_{kit} + v_{it} - u_{it} \quad (4.8)$$

where the subscripts i and t indicate plant and time; y is the output; χ_j is a vector of inputs and subscripts j and k index inputs. The v-random errors are assumed to be independently and identically distributed and independent of the u–terms that are plant specific technical inefficiency in production. In this model year of observation (t) and its interaction with input variables are included in a way to specify both neutral and non-neutral technical change, respectively.

In this specification if β_{kj}, the second-order terms, are all equal to zero then the model reduces to the standard Cobb-Douglas form. In our analysis we start with

the general translog model and using generalised likelihood ratio tests, we can specify whether general translog or Cobb-Douglas specification should be used in the analysis.

The inclusion of time as a variable allows for the shifts of the frontier over time, which is interpreted as technical change. In this model, technical change is input k using (saving) if β_{Tj} is positive (negative). Technical change is neutral if all β_{Tj}s are equal to zero. Using generalised likelihood tests we can test the significance of the neutral and non-neutral technical change in the model.

In this study the FRONTIER 4.1 software program developed by Coelli (1994) is used. It enables us to undertake a one-step estimation of the stochastic frontier model as well as the parameters of the variables included to explain efficiency.

There are a number of additional model parameters estimated with the stochastic production frontier when using FRONTIER 4.1. Of interest are the γ, μ and η parameters. The γ parameter is the variance-ratio parameter, which is important in determining whether a stochastic production frontier is a superior measure to the traditional average production function. Specifically, the average production function has a gamma value of zero, meaning there is no technical inefficiency. On the other hand the full frontier model without the v_{it} term is assumed when the value of γ is one. The μ parameter determines the distribution the inefficiency effects have, either a half-normal distribution or a truncated normal distribution. The η parameter determines whether the inefficiencies are time varying or time invariant. A η parameter value that is significantly different from zero indicates

time varying inefficiencies. Various tests of hypotheses of the parameters in the frontier function can be performed using the generalised likelihood ratio-test statistic, defined by

$$\lambda = -2\,[\ell(H_0)-\ell(H_1)] \tag{4.9}$$

where $\ell(H_0)$ is the log-likelihood value of a restricted frontier model, as specified by a null hypothesis, H_0 ; and $\ell(H_1)$ is the log-likelihood value of the general frontier model under the alternative hypothesis, H_1. This test statistic has approximately a chi-square distribution (or a mixed chi-square) with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. If the inefficiency effects are absent from the equation, as specified by the null hypothesis H_0: $\gamma=0$, then the statistic λ is approximately distributed according to a mixed chi-square distribution.[63]

4.4 Empirical Results

Using data from the CIP for selected 4-digit Irish manufacturing industries in the Electrical and Optical Equipment sector for the period 1991-1999, frontier translog production functions are estimated for each of them, which is defined as:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{2} \beta_j \ln \chi_{jit} + \beta_T t + \beta_{TT} t^2 + \sum_{j=1}^{2} \beta_{Tj} t \ln \chi_{jit} + \sum_{j\le k}^{2} \sum_{k=1}^{2} \beta_{kj} \ln \chi_{jit} \ln \chi_{kit} + v_{it} - u_{it} \tag{4.10}$$

[63] In this case, critical values for the generalised likelihood-ratio test are obtained from Table 1 in Kodde and Palm (1986).

where the subscripts i and t represent the i-th plant and the t-th year of observation, respectively; y represents real net output in 1985 prices (deflated by Producer Price Indices); χ_1 represents total employment; χ_2 is the capital variable which is proxied by the amount fuel and power used in 1985 prices (deflated by energy component of Wholesale Price Index)[64], t and t^2 are time trends to take account of technical progress; v_{it} are random errors assumed to be identically and independently distributed and independent from the u_{it} which are non-negative unobservable random variables associated with the technical inefficiency of production.

Following Battese and Coelli (1995), technical inefficiency is defined by:

$$u_{it} = \delta_0 + \delta_1 z_{1it} + \delta_2 z_{2it} + \delta_3 z_{3it} + \omega_{it} \qquad (4.11)$$

where plant level technical inefficiency u_{it} is influenced by the labour quality (z1), investment intensity (z_2) and the export intensity (z_3) variables. Labour quality variable is proxied by the ratio of skilled workers to unskilled workers and expected to have a negative effect on the technical inefficiency levels of firms. Following the nomenclature of the CIP, we define technical and administrative workers as skilled, and industrial workers as unskilled. Investment intensity is measured by the ratio of net capital additions of the firm during the year to total employment and export intensity is measured by the percentage of output exported. We expect both these variables to have a negative impact on the

[64] Since capital stock figures are not available from the CIP we use this measure as a proxy, which is often utilised in the literature. See Sjoholm (1998) and Kearns (2000)

technical inefficiency levels of firms In this specification ω_{it} are unobservable independently distributed random variables obtained by truncation of the normal distribution with zero mean and unknown variance. The mean of u_{it} is assumed to vary both across plants and time.[65] An important explanatory variable, which could be included in the model in explaining technical inefficiency levels of firms in the Electrical and Optical Equipment sector, is the foreign ownership variable and as outlined in Chapter 2, direct comparison of productivity levels of foreign and domestic firms in Irish manufacturing industry can result in biased results due to overstated output figures by foreign firms. Also it is very difficult to assume that foreign firms operating in Irish manufacturing industry, which are subsidiaries of MNEs, share the same technology frontier as domestic firms. For this reason we did not include foreign ownership variable in the model where we try to explain the technical efficiency levels and the model is estimated only for Irish firms, where we try to explain technical efficiency levels. The other variable, which could have an important role in explaining the inefficiency levels of domestic firms in Electrical and Optical Equipment industry, is the presence or entry of foreign firms in this sector. Since our analysis is carried out at the individual 4-digit sectors and this variable experiences very little change over the 1991-99 period we were unable to include it in our analysis. This issue will be examined in Chapter 5 using a different approach.

Before interpreting the results of stochastic production frontier function we carry out various specification tests in order to see the most suitable model for the

[65] The inclusion of the variables reflects the availability of data in the CIP surveys. In other studies variables are included to reflect competitive factors in the industry such as market share and profitability. (See Harris (1999a).

analysis and present the results of these tests in Table 4.4.1. Testing for the validity of the translog over Cobb-Douglas specification using a log likelihood ratio test, we cannot reject the null hypothesis that Cobb-Douglas frontier is an adequate representation.[66] Given the Cobb-Douglas specification of the frontier function, we then carried out likelihood ratio tests to see whether there was neutral or non-neutral technical change. The null hypothesis of no technical change was rejected in all of the industries whereas neutral vs. non-neutral technical change hypothesis was only rejected in the Medical and Surgical Equipment and Television and Radio Receivers sectors.

The third null hypothesis that there are no technical inefficiency effects in the model, that is $\gamma=0$, was rejected by the data for all sub-sectors. This result shows that average production function specification in which all firms are assumed to be technically efficient is not an adequate representation for all sub-sectors of the Electrical and Optical Equipments industry in Irish manufacturing sector. The last hypothesis involved the nature and distribution of inefficiency effects in the frontier model. The null hypothesis that the inefficiency effects have half-normal distribution, $\mu=0$ could not be rejected in all industries.

Maximum likelihood estimates of the parameters of the stochastic frontier model using an unbalanced panel data for each industry are presented in Table 4.4.2.[67]

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[66] This result is not surprising given the multicollinearity problems associated with the translog production function specifications. (See Harris 1999a). The second order and cross parameter estimates of the translog production function were all statistically insignificant for all sectors reflecting the fact that multicollinearity is present in this specification.

[67] The top and bottom 1 percentiles of firms are excluded from the analysis in order to remove the effect of outliers in the analysis

The results show that the elasticity of output with respect to labour dominates over capital. The size of the elasticity of output with respect to capital varies from 0.11 in the Computers and Other Information Processing Equipment sector to 0.25 in the Television and Radio Receivers industry. This coefficient is positive and statistically significant in all sectors. Labour elasticity of output is positive and statistically significant in all sectors and the size of the coefficient is in the range of 0.66 in Television and Radio Receivers industry to 0.95 in Electricity Distribution and Control Apparatus.

We can see from the results that there is evidence that the stochastic frontier model is an appropriate specification since γ is closer to 1 and highly significant in all sectors. Hence the inefficiency effects are important, as indicated in Table 4.4.1 also, with the rejection of the null hypothesis that $\gamma=\delta=0$. As to the signs attached to the inefficiency model we see that the investment intensity variable has a negative and significant effect in all sectors reflecting the fact that inefficiency levels and investment intensity are negatively related. Export intensity variable has a positive effect but insignificant effect in all but one sector, namely Radio and Television Receivers industry where it has a negative and significant sign which shows that in this sector technical inefficiency decreases with the higher export intensity in the individual firms.[68] The sign of the skill intensity variable, which is used a proxy for labour quality, has a significant and negative effect only in the Radio and Television Receivers and

[68] These insignificant results on export intensity variable could be explained by the industrial policy followed in this sector since 1970s, which encouraged foreign firms to establish linkages with their domestic counterparts especially in the electronics industry which means that firms in this sector could be supplying the foreign firms in this sector in Ireland rather than trying to export their products.

Medical and Surgical Equipment industry showing that high quality labour is important in these two sectors in reducing inefficiency levels.

In terms of technical change we see that there is neutral technical progress in all of the sectors and we see some evidence of non-neutral technical change in the sub-sectors of Radio, Television and Communications and Medical and Surgical Equipment industries. This non-neutral technical change is labour using in the Medical and Surgical Equipment and Television and Radio Receivers sectors whereas it is capital using in the Electronic Valves and Other Electronic Components industry.

We also estimated the technical inefficiency levels in the six sub-sectors of the Electronic and Optical Equipment industry using Equation 4.8, where the results are presented in Table 4.4.3. The estimated technical efficiency effects decreased over the period 1991-99 only for Electronic Valves and Other Electronic Components and Television and Radio Receivers industries. On the other hand in all of the other industries we see that the technical inefficiency effects are estimated to increase over time. We see that efficiency has considerably increased in two of the sectors over the period. These sectors are the Electronic Valves and Other Electronic Components which had average efficiency levels of 0.48 in 1991 that increased to 0.63 in 1999 and the Television and Radio Receivers industry whose efficiency levels have increased from 0.69 in 1991 to 0.75 in 1999. On the other hand we see that technical efficiency levels of Electric Motors and Generators and Medical and Surgical Equipment industries have

declined over the period. This result could be due to the fact that these two sectors have experienced higher technical change than the other sectors in the industry, which could have pushed the production frontier in these sectors further for some firms in the industry making them relatively more inefficient in 1999 than their levels in 1991.

4.5 Summary and Conclusion

This chapter has explored the technical efficiency levels in the Electrical and Optical Equipment industry in Irish manufacturing sector and the factors that could affect these levels utilising a stochastic production frontier approach over the period 1991-99 using firm-level panel data.

The model used is that outlined by Battese and Coelli (1995) which determines the causes of inefficiency simultaneously, rather than employing a two-step approach whereby efficiency estimates are obtained in the first step and are then regressed on a set of determinants. Our analysis showed that technical efficiency levels have increased in two sectors, namely Electronic Valves and Other Electronic Components and Radio and Television Receivers whereas Electric Motors and Generators and Medical and Surgical Equipment industries have experienced a decline in the average technical efficiency levels over the period 1991-99.

We found that investment intensity plays an important role in explaining technical inefficiency levels in all sub-sectors of the Electrical and Optical Equipment industry. Our results show that investment intensity reduces technical inefficiency levels of firms in all of the sub sectors. We found no significant relationship between export intensity and the technical inefficiency levels of individual firms in all but one sector, namely Television and Radio Receivers industry. As outlined above as well, this result could be due to the linkages policy that has been pursued in this sector in order to encourage the development of supplier relationship between foreign and domestic firms with the aim of developing the indigenous companies, which could have resulted in low export intensity levels in individual firms. We also showed that labour quality plays an important role in determining efficiency levels in some sectors.

Overall these results show that investment intensity and labour quality play an important role in reducing technical inefficiency levels of the indigenous firms in the Electrical and Optical Equipments industry in Irish manufacturing sector.

Another important variable, which could have an effect in determining technical efficiency levels, is the foreign presence variable, which could not be included in our analysis due to the analysis being carried out separately for each 4-digit industry where the foreign presence variable shows little variation during the period. Chapter 5 shall deal with this issue using a standard production function approach.

4.A Tables

Table 4.3.1: Employment Levels in Electrical and Optical Equipments Industry and Its Share in Total Manufacturing Employment

	Employment Levels				Employment Share			
	1991	1995	1999	1991-1999 (% Change)	1991	1995	1999	1991-1999 (% Change)
Electrical Machinery	10278	12395	14564	42	5.2	5.6	5.8	12.1
Medical, Precision and Optical	9299	11818	16618	79	4.7	5.4	6.7	41.3
Office Machinery and Computers	8019	14420	19923	148	4.1	6.5	8.0	96.5
Radio, Television and Communications	4887	7230	13357	173	2.5	3.3	5.4	116.1
Electrical and Optical Equipments	32483	45863	64462	98	16.5	20.8	25.9	56.9
Total Manufacturing	196878	220578	248971	26	100.0	100.0	100.0	26

Table 4.3.2: Employment Levels of Irish firms in Electrical and Optical Equipments Industry and Their Share in the Sector

	Employment Levels				Employment Share			
	1991	1995	1999	1991-1999 (% Change)	1991	1995	1999	1991-1999 (% Change)
Electrical Machinery	2467	3364	4426	79	24.0	27.1	30.4	26.6
Medical, Precision and Optical	745	1274	2504	236	8.0	10.8	15.1	88.1
Office Machinery and Computers	1252	2042	2321	85	15.6	14.2	11.6	-25.4
Radio, Television and Communications	759	1073	1502	98	15.5	14.8	11.2	-27.6
Electrical and Optical Equipments	5223	7753	10753	106	16.1	16.9	16.7	3.7

Table 4.3.3 Labour Productivity Levels of Irish Firm in Electrical and Optical Instruments Industry, 1991-1999

	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991-1999
Electrical Machinery	17.5	17.8	16.4	18.9	19.9	20.3	20.7	22.3	25.6	46%
Medical, Precision and Optical	25.5	32.4	36.5	32.7	31.3	37.6	45.3	42.9	43.4	70%
Office Machinery and Computers	28.8	29.6	26.9	28.3	22.6	31	26	28	31.1	8%
Radio, Television and Communications	19.8	16.7	21.2	19.8	19.2	25	25.4	33	34.4	74%
Electrical and Optical Equipments	21.7	22.0	22.5	23.7	22.4	26.8	27.0	29.3	32.1	48%
Manufacturing Average	24.6	24.9	25.9	26.7	26	27.8	29.2	30.3	33.5	37%

Table 4.3.4 Sub-Sectors of Electrical and Optical Equipment Industry and Corresponding NACE Codes

Electrical and Optical Equipment Industry (30-33)			
Office Machinery and Computers (30)	Electrical Machinery and Apparatus (31)	Radio, Television and Communication Equipment (32)	Medical, Precision and Optical Equipment (33)
Computers and Other Information Processing Equipment (3002)	Electric Motors and Generators (3110) Electricity Distribution and Control Apparatus (3120)	Electronic Valves and Tubes and Other Electronic Components (3210) Television and Radio Receivers (3230)	Medical and Surgical Equipment (3310)

Notes: Numbers in brackets are corresponding 2-digit and 4-digit NACE classification codes

Table 4.4.1: Generalised Likelihood-Ratio Tests of Hypotheses for Parameters of the Stochastic Production Functions

Null Hypothesis, H_0:	3002	3110	3120	3210	3230	3310	Critical Value[1]
$\beta_{ij}=0$ i,j=1,2[2]	4.20	5.68	7.92	2.94	3.60	3.58	9.48
$B_3=0$[3]	4.51*	6.42*	13.76*	10.24*	14.25*	8.44*	3.84
$\beta_{j3}=0$ j=1,2[4]	2.15	3.45	1.28	4.12	7.90*	13.81*	5.99
$\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$[5]	24.72*	37.92*	41.17*	33.10*	21.28*	22.38*	10.37
$\mu=0$[6]	1.12	2.57	3.16	2.41	1.68	1.24	3.84
$\eta=0$[7]	5.47*	6.23*	5.47*	15.47*	6.98*	6.54*	3.84

Notes: 1) Values of the generalised likelihood-ratio statistic (λ) are given in the table.
Values, which exceed the critical value in the table, are significant at the 5% level and are marked by an asterisk (*)
2) Cobb-Douglas specification, Critical Value $\chi^2_{0.05,6}$
3) No technical Change $\chi^2_{0.05,1}$
4) Neutral vs. Non-Neutral Technical Change $\chi^2_{0.05,2}$
5) No inefficiency effects $\chi^2_{0.05,5}$. The critical value for the test involving $\gamma=0$ are obtained from Table 1 of Kodde and Palm (1986) where the degrees of freedom are q+1 and q is the number of parameters which are specified to be zero. (See Coelli et al. 1998)
6) Inefficiency effects are assumed to be half-normal $\chi^2_{0.05,1}$
7) Inefficiency effects are time invariant $\chi^2_{0.05,1}$

Table 4.4.2: Maximum-Likelihood Estimates for Parameters of the Stochastic Frontier Inefficiency Models

		3002	3110	3120	3210	3230	3310
Intercept	β_0	10.03*	8.7*	10.55*	9.8*	8.26*	13.8*
		(0.45)	(0.22)	(0.21)	(0.70)	(0.95)	(0.49)
Capital	β_1	0.11*	0.15*	0.03	0.12**	0.25*	0.14*
		(0.48)	(0.04)	(0.02)	(0.07)	(0.12)	(0.05)
Labour	β_2	0.77*	0.78*	0.95*	0.83*	0.66*	0.87*
		(0.58)	(0.05)	(0.03)	(0.21)	(0.21)	(0.09)
Time	β_3	0.03*	0.06*	0.03*	0.08*	0.12**	0.05*
		(0.01)	(0.01)	(0.01)	(0.01)	(0.07)	(0.01)
Capital*Time	β_4	-	-	-	0.009**	-0.004	-0.006*
					(0.005)	(0.02)	(0.002)
Labour*Time	β_5	-	-	-	-0.002	0.011*	0.003*
					(0.02)	(0.002)	(0.001)
Other ML Parameters							
Sigma-squared	σ^2	1.44*	1.34**	1.24*	0.79*	0.93*	0.88**
		(0.51)	(0.71)	(0.64)	(0.28)	(0.15)	(0.33)
Gamma	γ	0.77*	0.92*	0.90*	0.89*	0.92*	0.91*
		(0.08)	(0.31)	(0.05)	(0.04)	(0.09)	(0.05)
Log-Likelihood		-244.14	-49.81	-134.42	-46.17	-107.64	-63.01
LR One-sided error		24.72	37.92	41.17	33.10	21.28	22.38
Inefficiency Effects							
Constant	δ_0	0.74	-8.3	1.73	-5.8*	2.87	-10.4*
		(1.40)	(43.16)	(0.98)	(0.22)	(1.96)	(2.3)
Skill	δ_1	-0.70	0.40	0.76	-0.07*	-0.48**	-0.12*
		(0.56)	(2.06)	(0.43)	(0.24)	(0.07)	(0.04)
Investment Intensity	δ_2	-0.17**	-0.68*	-0.78*	-0.58*	-0.07*	-0.13*
		(0.11)	(0.18)	(0.36)	(0.18)	(0.02)	(0.04)
Exports	δ_3	0.29	0.15	0.49	0.06	-0.33*	0.08
		(0.32)	(1.34)	(0.38)	(0.10)	(0.15)	(0.06)

Table 4.4.3 Technical Efficiency Levels

	3002	3110	3120	3210	3230	3310
1991	0.64	0.75	0.73	0.48	0.69	0.72
1992	0.67	0.71	0.74	0.51	0.73	0.75
1993	0.66	0.68	0.74	0.43	0.76	0.72
1994	0.67	0.66	0.70	0.46	0.70	0.74
1995	0.61	0.67	0.68	0.48	0.68	0.69
1996	0.64	0.63	0.68	0.48	0.88	0.64
1997	0.62	0.67	0.68	0.46	0.86	0.62
1998	0.61	0.67	0.72	0.54	0.75	0.60
1999	0.63	0.64	0.71	0.63	0.75	0.59

4.B Figures

Figure 4.1 Production Frontiers and Technical Efficiency

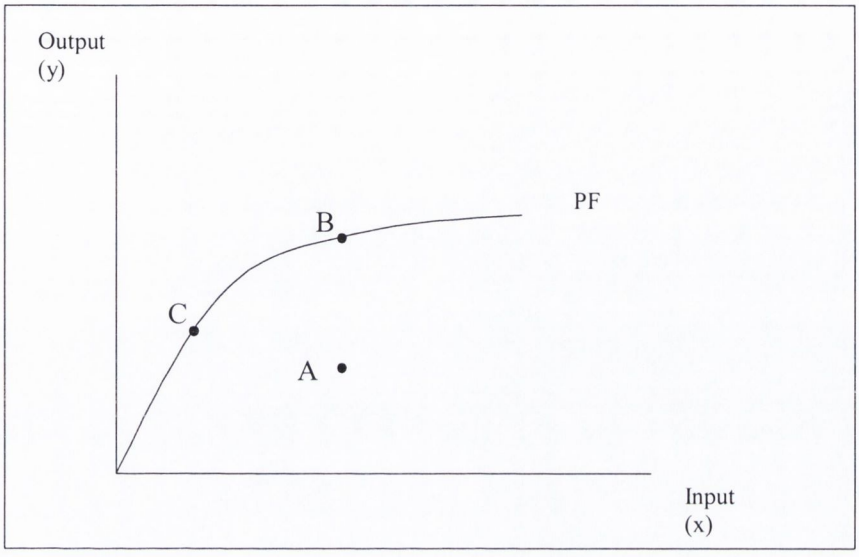
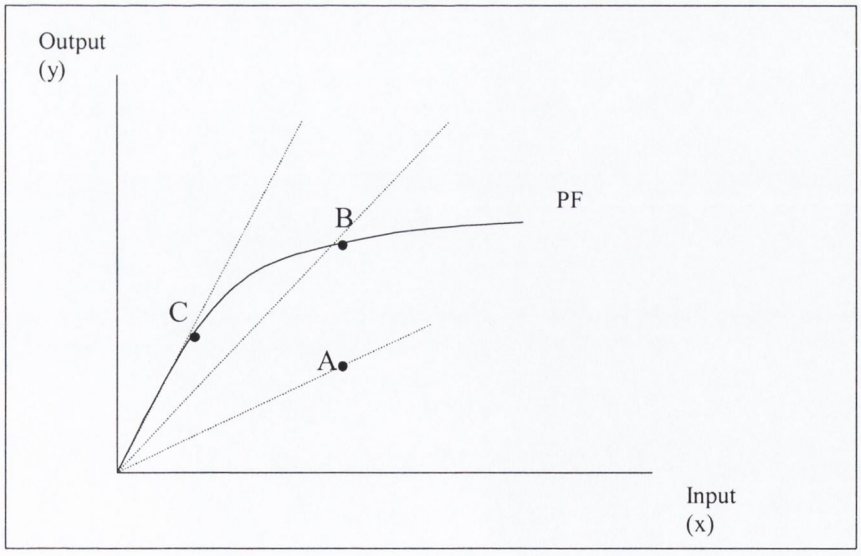


Figure 4.2 Productivity and Technical Efficiency



CHAPTER 5 FOREIGN DIRECT INVESTMENT AND PRODUCTIVITY SPILLOVERS IN IRISH MANUFACTURING INDUSTRY: EVIDENCE FROM PLANT LEVEL PANEL DATA[69]

5.1 Introduction

Labour productivity levels domestic firms in Irish manufacturing industry have improved significantly in the 1990s as outlined in Chapter 2. We also showed that technical efficiency levels in some of the sub-sectors of the Electrical and Optical Equipment industry, which plays an important role in the Irish manufacturing industry, have increased. This chapter investigates whether FDI in Irish manufacturing sector has played a role in the increases in labour productivity of domestic firms over the 1990s in the Irish manufacturing sector.

Over the past two decades direct investment across national borders by international firms – primarily multinational corporations (MNCs) has grown significantly in the world economy, especially into developed countries. This development is evident in the fact that in the past decade global output and sales of foreign affiliates have grown faster than either world gross domestic product or world exports. In 1999, the ratio of foreign affiliates' sales to global GDP was almost 50 per cent, with the sales value being over twice as high as the value of world exports of goods and services.[70] Increasingly such foreign direct investment (FDI) is seen as an important channel for

[69] The data in this study refers to 1991-1998 period.
[70] See World Investment Report, 2001

obtaining access to resources for development and the emerging positive attitudes to FDI are reflected in policy changes that increasingly facilitate direct investment.[71]

The analysis of the effects of FDI on host countries in the literature implicitly distinguishes between its *direct* and *indirect* effects. *Direct effects* are reflected in capital formation, employment and trade associated with the FDI project.[72] Although the direct effects of foreign investment may be more important for certain countries, it is increasingly accepted that FDI is likely to have important indirect *effects* on host economies by giving local companies (LCs) access through contact with the FDI companies to the technology and management practices of the home country. Indeed, Blomstrom and Kokko (1998) argue that the most important reason behind many countries' efforts to attract more foreign investment today is a desire to acquire modern technology. They and others suggest that the investments of MNCs generate important externalities that enhance the productivity of indigenous firms in the economy. These externalities, which are typically referred to as "positive productivity spillovers", are seen as helping to improve the comparative advantage of the economy over time.[73] It is also argued in the literature that foreign presence can reduce productivity of domestic firms, i.e., generate "negative productivity spillovers" especially if the foreign firms are producing for the local market. For example, Aitken and Harrison (1999) show that foreign entry, by disturbing the existing market equilibrium in the host country, could force domestic firms to

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[71] According to the World Investment Report (2001), many countries in different regions of the world have increasingly adopted FDI-specific regulatory frameworks to support their investment-related objectives over the past four decades. Out of the 150 regulatory changes relating to FDI made during 2000 by 69 countries, 98 per cent were in the direction of creating more favourable conditions for FDI.

[72] For example, many developing countries have sought FDI in the manufacturing sector in order to acquire crucial capital to develop the local manufacturing industry sector.

[73] In addition to productivity spillovers, Blomstrom and Kokko (1998) also examine "market access spillovers", which focus on the effect of the export operations of foreign firms on domestic firms.

produce less output; this in turn could push them up their average cost curves[74] and hence lower the productivity of these firms. If this decline in the productivity of domestic firms is large enough, net domestic productivity can decline despite the technology transfer from foreign firms.

In terms of FDI, Ireland is one of the most globalised economies in the world, having pursued a strategy of promoting green-field investment in the manufacturing sector by foreign companies for over forty years. The focus and incentive structure of the policies adopted to promote such FDI has meant that these companies established plants to produce for export, primarily to other countries within Europe. This aspect of industrial policy has contributed significantly to Ireland's exceptionally high growth rates during the last decade, and has facilitated considerable restructuring in the manufacturing sector of the Irish economy.[75] The scale of such FDI is evident in data from Central Statistics Office (CSO), which show that in 1998, foreign firms accounted for 82 per cent of net output and 47 per cent of employment in the Irish manufacturing sector. In 1998 these foreign firms exported approximately 92 per cent of their output, which in turn accounted for 87 per cent of all manufacturing exports from Ireland.[76]

From a domestic policy perspective, the *direct effects* of FDI, and particularly employment creation have been the main focus of attention in Ireland for most of the past forty years.[77] Since the mid-1990s the focus has begun to shift to the indirect impact of FDI on the manufacturing sector, especially as unemployment rates have

[74] This would be the case if average cost curves were downward sloping due to substantial fixed costs.
[75] For an overview, see Barry (1999).
[76] One has to be careful when interpreting net output and export figures for foreign firms in Irish manufacturing industry due to transfer pricing activities of foreign firms.
[77] See Ruane and Görg (1997).

declined; consequently the direct benefits of additional employment in the MNC sector are seen as having reduced value. This emphasis is evident in the policy of building linkages between MNCs and local companies (LCs), as well as in the policy of building manufacturing agglomerations in targeted sectors, especially in electronics and healthcare products.[78] The linkage programmes were directly concerned with building up supply chains between MNCs and LCs, which were both intra-sectoral and inter-sectoral.[79] There is much anecdotal evidence of product imitation having taken place, in some cases facilitated by the movement of skilled labour into the LC sector.[80] If such impacts are important, they should be reflected in the different productivity levels in LCs, depending on the degree to which they are exposed to MNCs.

The objective of this chapter is to examine empirically whether there is any evidence that FDI has had a positive impact on productivity performance in Irish-owned companies in the manufacturing sector, i.e., whether there is evidence of positive productivity spillovers from MNCs to individual LCs. In the context of the experience of other countries, one might expect that the net impact of FDI spillovers in Ireland would be positive for several reasons: Ireland's long history of promoting FDI and of seeking to encourage it to build (positive) connections with LCs; the export orientation of MNCs, which means that there is little likelihood of competitive pressures on LCs (positive) while at the same time little risk of crowding out (negative) in local product markets; over much of the past 20 years there has been

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78 Görg and Ruane (2001) analysed backward linkages in the Irish electronics industry for the period 1982 to 1995. They found that foreign firms in downstream sectors had relatively higher linkages and that these tended to increase relatively over time.

[79] See Ruane, 2001

[80] The scale of R&D activities has been much greater in the MNC than in the LC sector. Furthermore many of the successful LC entrepreneurs had previous experience in MNCs in same sectors.

high unemployment, making crowding out in the labour market less likely (not negative); the common language and shared culture with the dominant source of FDI into Ireland, namely, the USA, means that there is easy mobility of labour between MNCs and LCs and fewer impediments to imitation than might be found elsewhere (positive).

The remainder of the chapter is organised as follows. Section 5.2 discusses some of the growing literature on productivity spillovers from FDI. In Section 5.3 we look specifically at the existing evidence on Ireland and describe the data set that we use to estimate spillover effects. In Section 5.4 we use the standard model in the literature to estimate such productivity spillovers and present the results obtained. We also look at the sensitivity of results to assumptions made about the sectoral aggregates across which spillovers are expected to occur. In Section 5.5 we consider the impact of using an alternative approach to determining the method of measuring the source of potential FDI spillovers. We present some concluding remarks in Section 5.6.

5.2 International Evidence on Productivity Spillovers

The general approach in the literature to examining the productivity spillovers from foreign to local firms has been to relate the productivity of domestic firms to some measure of foreign presence, while controlling for industry and firm characteristics. One of the earliest empirical studies on productivity spillovers from FDI to host countries is Caves (1974). Applying econometric techniques to Australian industry level data on 22 industries at 2-digit level for 1962 and 1966, he finds that the

coefficient for the foreign firms' presence is positive and significant. This leads him to conclude that relatively high foreign subsidiary shares in Australian manufacturing sectors are associated with higher productivity levels in competing domestic firms. Globerman (1979), applying a similar approach to data on the Canadian manufacturing sector, concludes that differences in labour productivity levels are associated with spillover efficiency benefits associated with foreign direct investment.

There have been several studies focusing on developing countries, including Blomstrom and Persson (1983) who examine the relationship between foreign investment and spillover efficiency in the Mexican manufacturing industry using 4-digit industry level data for 1970. The empirical evidence from their study confirms the findings of the developed country studies, namely, that there are efficiency spillovers from foreign-owned to domestically-owned plants.

One drawback of these early studies was their use of cross section data sets at the sectoral level, which made it impossible to control for firm characteristics in different industries. More recently, Haddad and Harrison (1993), using firm level data find that while sectors with a large foreign presence have less deviation from maximum productivity levels, there is no evidence of significant positive effect of foreign investment on the productivity growth of domestic firms in Moroccan manufacturing industries. Aitken and Harrison (1999) study the productivity spillovers from MNCs to local firms in the Venezuelan manufacturing sector using a firm-level panel data set. They find that increases in foreign equity participation are correlated with increases in productivity for recipient plants with less than 50 employees. However,

by contrast with earlier studies, their overall results show that increases in the foreign presence negatively affect the productivity of domestically-owned firms in the same sector.

Flores *et al.* (2000) examine the impact of foreign direct investment on the productivity of domestic firms in Portugal. They find a positive relationship between domestic firms' productivity and foreign presence only when proper account is taken of the technology differences between the foreign and domestic producers and these spillovers are within the modern sectors. They use data at 2-digit sectoral level, as this was the only basis on which the authors had access to the data used.

A recent paper in the literature by Könings (2000) investigates empirically the effects of foreign direct investment on the productivity performance of domestic firms in three emerging economies of Central and Eastern Europe, namely, Bulgaria, Romania and Poland. Konings finds that there are negative spillovers to domestic firms in Bulgaria and Poland, while there are no spillovers to domestic firms in Poland.

In the past two years there have been several UK studies, using newly available data on the UK manufacturing sector. Liu *et al.* (2000), using 48 3-digit UK industries for the period 1991-96, find that the presence of multinational firms has a significant positive impact on the productivity in the local UK manufacturing firms. Using 2-digit industry level panel data for 1983-92, Hubert and Pain (2001) investigate the impact of direct investment by foreign firms on the technical progress and labour productivity in the UK and find that foreign firms have a significant positive effect on the level of technical efficiency in domestic firms. Driffield (2001) investigates

the extent to which inward investment generates a gain in domestic productivity in UK manufacturing industry using 3 digit industry level data. He finds no significant evidence of spillovers from FDI.[81] Girma *et al.* (2001) investigate whether the presence of foreign firms in a sector raises the productivity of domestic firms using a firm-level panel data set in the UK manufacturing industry for the period 1991-96. They find no evidence of productivity spillovers on average. However their results show evidence of spillovers where firms are in industries with high levels of import competition or skills.

Overall, the empirical evidence on productivity spillovers is mixed, with some studies finding positive spillovers effects, while others find negative effects or no spillovers at all. However, a careful analysis of the pattern of results, as set out in Görg and Greenaway (2001), shows that in the case of panel data, the preponderance of results indicate negative rather than positive spillovers, while the results from sectoral studies and especially cross sectional studies suggest positive spillovers. In the context of theory, the results of the panel level data are a better test of the productivity spillover phenomenon. Thus these results overall suggest that negative rather than positive spillovers might be expected.

Before turning to look at the Irish data, it is helpful to note that the theory, such as it is, is quite vague on how one might measure foreign presence, as the source of spillovers. The majority of studies either use the share of employment or net output accounted for by foreign firms to measure foreign presence. This begs the question of whether the share really captures the likely source of the impact. For example,

[81] Driffield (2001) examines output, R&D and investment spillovers from FDI.

does the scale matter? Is the impact of foreign presence similar for all levels of FDI in a sector? When we think in terms of sectors, over what sectoral domain do we expect spillovers to occur? Early studies have tended to use relatively high levels of sectoral aggregation, namely 2 or 3-digit NACE sectors, while more recent studies have looked at lower levels of sectoral aggregation when seeking to link LC productivity to foreign presence. It is also suggested implicitly that all of these spillovers are horizontal, with inter-sectoral spillovers being assumed to arise from vertical linkages. This is an issue that we address below using Irish data.

5.3 Productivity Spillovers in Ireland[82]

Thus far there have been just two studies available that have examined the impact of FDI on the productivity of Irish companies.[83] Ruane and Uğur (2000) examined, using 2-digit and 4-digit sector level data form the Central Statistics Office, the effects of FDI on the productivity levels of LCs in the Irish manufacturing industry. They estimated a labour productivity equation for the period 1991-1997 for domestically-owned manufacturing plants in the Irish manufacturing sector, controlling for capital intensity and labour quality of these plants. Their results, based on sectoral aggregations across over 3,700 Irish companies and 750 foreign-owned companies showed no evidence of significant productivity spillovers from FDI.

[82] In general we follow the nomenclature used above to discuss spillovers, viz, from foreign to domestic is described as being from MNCs to LCs.
[83] We are aware of a further study by Barry et al (2001), but have not yet had sight of it.

In the same year, Kearns (2000) examined productivity spillovers from FDI in Ireland conducting a firm-level analysis. In his study Kearns uses data from a large sample of companies collected by Forfás, the Irish industrial policy agency, and published as the Forfás Irish Economy Expenditures Survey (FIEES). The sample is not balanced and under-represents the numbers of Irish companies operating in that period. It is likely that the more successful, i.e., higher-productivity companies, are more represented in the sample of over 1,300 indigenous plants covered in the analysis, which covers the period 1984-1998. Estimating labour productivity equations for these, he finds that indigenous plants have higher productivity levels in those sectors where there is a higher share of foreign employment, which suggests that there are positive productivity spillovers from MNCs to LCs. [84]

The results of another study of the impact of FDI on Irish manufacturing by Görg and Strobl (2000) should also be noted. They examine the effect of the presence of MNCs on plant survival using plant-level data for the Irish manufacturing industry for the period 1973 to 1996, using the employment survey conducted annually by Forfás.[85] Their results show that the presence of MNCs has a life-enhancing effect on LCs in high-tech industries but not on those in low-tech sectors.[86]

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[84] Kearns extends his analysis by using the same approach on different sub-samples of the data set defined according to productivity gap and R&D activity of domestic firms. He finds no evidence that productivity gap has any effect on the productivity spillovers from foreign to domestic firms. He also finds that there were relatively greater productivity spillovers to domestic R&D active plants.

[85] They postulate that an increase in productivity through technology spillovers will reduce a host country firm's average cost of production and hence increase the plant's probability of survival, all other things being equal.

[86] The classification of sectors into high tech and low tech is based on an OECD classification used by Kearns and Ruane (2000).

The data used in this paper are from the Irish Census of Industrial Production (CIP).[87] This census is carried out annually by the Central Statistics Office of Ireland and covers all industrial local units with 3 or more persons engaged.[88] As such it is the only fully representative survey of plants in Ireland. In the CIP the classification by nationality of ownership is determined by the nationality of the owners of 50 per cent or more of the share capital. There are no details recorded on the extent of foreign ownership within a given company and thus it is not possible to determine the impact of different shares of foreign ownership, as done in several panel level data studies for other countries. FDI policy in Ireland does not require minimum domestic equity participation as is the case in many developing countries, and most FDI is in the form of green-field investment with 100% foreign ownership.

The analysis is for the period 1991-98, and covers an average of 4,600 companies, of which more than 3,800 are Irish-owned.[89] Table 5.3.1 presents a summary of some of the main variables: number of firms, total net output and total employment together with the percentage accounted for by foreign firms. There was a net increase in total employment of 23% during the period. Foreign firms increased their share of total employment from 44% in 1991 to 47% in 1998 - an increase of 7% in the share of total employment accounted for by them. Although the increase in share of manufacturing employment in MNCs was moderate, the absolute employment accounted by foreign firms rose by 35% during the same period. As the number of foreign firms decreased by 5%, the average size of MNCs in the Irish manufacturing

[87] Because of the small number of companies in Ireland and in line with a strong emphasis on confidentiality in the Irish statistical office, the data can only be accessed under "safe-setting" conditions at the Central Statistics Office.
[88] For further details see Chapter 1.
[89] The data series, distinguishing company ownership goes back before 1991, but the data available to us only covers the period since 1991, when the new NACE classification was introduced

sector increased over the 1990s. Labour productivity levels of the domestic part of the industry have risen by 21% during the period in real terms. We note in passing that the quality of the data is particularly high – they cover companies virtually from birth as company registration records for Ireland are well maintained.[90]

5.4 Empirical Model and Methodology

We follow the approach commonly used in this literature, which hypothesises that the labour productivity of local firms can be estimated by the function

$$(Q/L)_{ijt} = f\{(K/L)_{ijt}, (L_s/L_u)_{ijt}, (FO)_{jt}\} \qquad (5.1)$$

where labour productivity of firm i in sector j in year t $(Q/L)_{ijt}$ is measured by the ratio of net output (Q) to total employment (L) in Irish owned plants. Plant level labour productivity is influenced by the current physical capital intensity of the plant $(K/L)_{ijt}$. Since the capital stocks of plants are not recorded for the Census of Industrial Production (CIP) we use a proxy for capital, namely, fuel and power consumption by the plant. Thus our capital intensity variable is measured by the ratio of fuel and power consumption to total employment.[91] We measure the labour quality variable $(L_s/L_u)_{ijt}$ as the ratio of skilled workers (L_s) to unskilled workers (L_u). Following the nomenclature of the CIP, we define technical and administrative workers as skilled, and industrial workers as unskilled. In line with existing studies,

[90] One effect of having a proactive industrial policy is that there is a very early recording of all new industrial establishments.

[91] In some studies with the unavailability of capital stock data, investment or consumption of energy is used as a proxy for capital assets. See Sjoholm (1998) and Kearns (2000).

the foreign presence variable $(FO)_{jt}$ is measured by the share of employment accounted by all foreign-owned plants in the sector in which the plant operates.

We expect a positive relationship between the dependent variable and both capital intensity and labour quality. The main interest of our study lies in the coefficient on the foreign presence variable: if there are positive productivity spillovers from MNCs to LCs, this variable should have a significant and positive effect on the labour productivity levels of Irish LCs.

Before proceeding with the results of our analysis we address a few econometric concerns. One of the concerns is the omission of unobserved variables in our specification. There may be firm and time specific factors unknown to us but known to the firm that may affect the correlation between firm productivity and foreign presence variable. In order to avoid this, we estimate Equation 5.1 in logs with plant level data, using both Fixed Effects (FE) and Random Effects (RE) models. These allow us to account for the unobservable heterogeneity and to control for unobserved time invariant factors that might affect productivity. (The descriptive statistics are shown in Table 5.4.1 in levels rather than logs). In addition to this we also provide estimates using first differencing to test the robustness of our results. Another concern in this specification could be with the foreign presence variable. As pointed out by Aitken and Harrison (1999) " *if foreign investment gravitates towards more productive industries, then the observed correlation between the presence of foreign and the productivity of domestically owned firms would overstate the positive impact of foreign investment*" In order to account for this, we use sector dummies in our

Random Effects and first differenced specifications as well as time dummies to control for general macroeconomic conditions.

As noted in Section 5.2, early studies in this literature have tended to use relatively high levels of sectoral aggregation in measuring the potential spillover effects of foreign presence, namely 2 or 3-digit NACE sectors. More recent studies have looked at lower levels of sectoral aggregation when trying to link LC productivity to foreign presence. The choice of sectoral aggregation is typically not discussed, despite the fact that it is crucial to interpreting the spillovers. The lower levels of aggregation effectively restrict the range over which productivity spillovers can occur. In order to examine the sensitivity of our results to different levels of sectoral aggregation of the foreign presence variable, we estimate Equation 5.1 using foreign presence variable aggregated at 2, 3 and 4-digit sector levels.

Table 5.4.2 presents the results from estimation of Equation 5.1 for all LCs in Irish manufacturing industry using both FE and RE approaches. Both approaches show that capital intensity and labour quality have a positive and significant effect on the productivity levels of LCs. The foreign presence variable has a positive but insignificant effect in both models at 2 and 4-digit sectoral aggregation. The coefficient of foreign presence variable is negative for 3-digit estimation using the FE model and positive for the RE model, but both results are statistically insignificant. Overall, the results from Table 5.4.2 indicate that there are no significant productivity spillovers from FDI in the Irish manufacturing sector and these results are invariant to the scale of sectoral aggregations for the foreign presence variable. As such, the Irish results obtained are in line with the majority of

results reported in Görg and Greenaway (2001), which show either negative or no significant spillovers from FDI at plant level across a range of countries.

In line with other studies in the literature, we also check to establish if the results are sensitive to whether the relationship between the dependent and independent variables is estimated in terms of growth rates. So we modify Equation 5.1 as

$$\Delta (Q/L)_{ijt} = f \{\Delta (K/L)_{ijt}, \Delta (L_s/L_u)_{ijt}, \Delta FO)_{jt}\} \quad (5.2)$$

Equation 5 is a first difference equation and relates the change in labour productivity of domestic firms to changes in capital intensity and skill level within the firm and to changes in the foreign presence measure in each corresponding sector. Labour productivity, skill level and foreign presence are defined as above. As plants provide data on investment for the CIP, we can measure the change in capital intensity in the standard way, namely as the ratio of net investment to the change in total employment. The estimation technique used is simply Ordinary Least Squares (OLS) on the first differenced equation. First differencing enables us to control for firm-specific factors and also we can use sector dummies directly to control for sector-specific effects. We also specify in the estimation that the observations are independent between groups, but not necessarily within groups. In other words, we specify the model so that it takes the fact that we have multiple observations from the same firms into account and the standard errors are clustered for all observations in the same industry and year.

As in Table 5.4.2 we check to see whether results are sensitive to the degree of sectoral aggregation of the foreign presence variable. Results from Table 5.4.3 show that when variables are expressed in terms of growth rather than levels there are no significant positive productivity spillovers from foreign firms when foreign presence variable is measured as a share. We also see that these results are not sensitive to the sectoral aggregation of the foreign presence variable used.

5.5 Productivity Spillovers in Ireland- An Alternative Approach

The approach used in Section 5.4 follows that in most studies in the literature. In particular it measures foreign presence as the share of employment accounted for by foreign companies in the corresponding sector. This ignores the fact that there may be a critical mass in terms of the actual scale of FDI, which could affect productivity spillovers. In effect it does not take account of the possibility that the absolute levels of employment, rather than shares, accounted for by MNCs could be important. In the Irish case this is particularly relevant because during the period of our study, employment in both foreign and domestic segments of the manufacturing sector have grown substantially, while the shares have changed only marginally. (See Table 5.4.1)

In a recent study, Castellani and Zanfei (2002) argue that using the share of employment accounted for by foreign firms as the foreign presence variable assumes that changes in the same proportion of foreign and aggregate activity have no effect on the productivity of local firms and can cause a downward bias in the results. They

find positive spillovers from FDI when they use this new specification, using data on the Italian manufacturing firms. They propose that foreign presence should be measured by the absolute level of employment in foreign firms rather than by the share. Noting that the use of total employment levels alone in the regressions would cause a bias through a sector-size effect, Castellani and Zanfei (2001) suggest that employment in domestically-owned firms (DO) be included as a control variable, where (DO) is measured by the total employment of domestic firms in the corresponding sector.

Table 5.5.1 presents the results when foreign presence is measured as the actual level of employment in MNCs rather than shares, using FE and RE models. In order to check for the sensitivity of sectoral aggregation in foreign presence variable, we again present results for 2,3 and 4-digit levels of aggregation. Capital intensity and labour quality have positive and significant effects on the labour productivity levels of domestic firms, a pattern similar to that of Table 5.4.2. In contrast to our results in Table 5.4.2, the foreign presence variable has a positive and significant effect on the domestic firms' productivity levels in this specification, suggesting the presence of positive productivity spillovers from FDI in the Irish manufacturing industry.

We also see from the regression results that spillovers from FDI are sensitive to the sectoral aggregation of the foreign presence variable. At 2-digit sectoral and 4-digit sectoral aggregation, the foreign presence variable shows a significant and positive relationship with LC productivity levels, although the results are not significant when 3-digit sectoral aggregation is used.

Table 5.5.2 presents the estimation results for Equation 5.2 where all variables are expressed in first differences and the foreign presence variable is measured as the employment level accounted for by foreign firms in the corresponding sectors. These results show that foreign presence variable has a positive and significant effect only at the 4-digit sectoral aggregation level, which suggests that results are sensitive to the degree of sectoral aggregation specified.

5.6 Summary and Conclusions

Uniquely within Europe, Ireland has promoted FDI in its manufacturing sector for over 40 years. As noted in the introduction, this has resulted in MNCs in the sector playing a major role in terms of net output, employment and exports.

In terms of likely spillovers from FDI companies to LCs, there are several arguments, which would suggest that, if these are significant in any country, they should be evident in Ireland. The arguments favourable to net positive spillovers include: a policy regime which has increasingly fostered connections between MNCs and LCs; a shared language and culture with the major home country for FDI in Ireland (USA), both of which favour product imitation and labour movement; and the absence of direct competition from MNCs in the home market. Our analysis, using panel data on all companies in the Irish manufacturing sector and covering the period 1991-98, finds no evidence of such spillovers when the standard measure of foreign presence adopted in most of the literature is used, viz., MNC employment as a percentage of total employment. In effect, LC labour productivity is no higher in sectors with a larger foreign share of employment. However, when we follow Castellani and Zanfei (2001) by using an alternative measure, namely, employment

in foreign companies in the relevant sector, a different picture emerges – at both the 2- and 4-digit NACE sector levels, the coefficient of employment is positive and significant. The difference in the results suggests that we need to look in more detail at what it is we believe actually leads to the spillover, and whether the absolute rather than the relative size of the MNC sector is important. In the Irish case the 1990s saw a rapid increase in the presence of multinationals (32% change in employment), but since the LC sector was also growing quickly, there is relatively small variation in the FDI share of employment. This may explain in part the difference in the results obtained here from those obtained by Kearns (2000), who, using the employment share measure to capture foreign presence, finds evidence of spillovers in the Irish case. The difference may be due to the fact that his analysis is based on data that are more limited in terms of plant coverage, but it may also be due to the fact that the data cover a longer time period, during which there was more variation in the share of FDI employment. (The change in the share of employment accounted by foreign firms between 1984 and 1998 was nearly 26%, whereas this change is only 7% for the period 1991-1998)

One further issue that arises from this chapter is what the appropriate sectoral measure for FDI presence should be for this type of analysis. For data reasons, much of the early analysis of spillovers at plant level has used 2- or 3-digit level – mirroring the analyses undertaken at sectoral levels before plant level data became available. In this paper we used 2-, 3- and 4-digit and found, in the case where FDI presence is measured in levels, that the results are sensitive to the choice of level of aggregation. But this begs the question of what the level should be. The lower the level of aggregation, the more likely the spillovers are to be horizontal – but if we

lower the level too much, we miss out on the possible spillovers which can occur as a result of FDI in neighbouring sectors. Furthermore, while some authors suggest that all such spillovers are horizontal rather than vertical, this is not plausible even at 4-digit[92]. It points to the need to explore in more detail the conduits for such spillovers, and to give direct attention to differences in the capacity of LCs to exploit spillover potentials and the likelihood that MNCs will generate these.[93] These issues and other possible future work in this are discussed in more detail in Chapter 6 in the conclusion.

[92] There is a tendency to use linkages when intra-firm relationships are vertical, and to limit the term "spillovers" to horizontal relationships.
[93] See Kearns and Ruane (1999)

5.A Tables

Table 5.3.1- Changes in Irish Manufacturing Sector 1991-1998

	Total Plants	Foreign Plant Share (%)	Total Net Output *(£000)	Foreign Output Share (%)	Total Employment	Foreign Employment Share (%)	Domestic Labour Productivity* (£000)
1991	4,546	16.3	8,889,788	68.4	196,878	44.1	25.56
1992	4,542	15.9	9,488,818	69.5	198,954	44.0	25.97
1993	4,544	15.2	10,139,901	70.8	200,003	44.4	26.60
1994	4,603	15.8	11,398,702	73.7	205,421	46.6	27.34
1995	4,602	15.7	13,553,398	76.9	220,578	47.1	26.79
1996	4,599	15.8	15,037,708	77.1	226,634	46.9	28.69
1997	4,739	15.5	17,690,030	79.1	240,454	47.4	29.35
1998	4,702	15.4	21,921,440	81.9	242,772	47.5	31.07
1991-98 % Δ	3.43	-5.52	146.59	19.73	23.31	7.70	21.57

Source: CSO: Census of Industrial Production, 1991-98
*In 1985 prices

Table 5.4.1- Descriptive Statistics for regression Variables

	Mean	Std. Deviation
Net Output	3633108	3.19e+07
Labour Productivity	28534.93	37870.57
Total Engaged	30.45	66.89
Skill	0.488	1.057
Foremshare4*	28.41	30.57
Foremshare3*	32.43	28.33
Foremshare2*	38.16	20.96
Forem4	732.86	1549.99
Forem3	1592.30	1958.95
Forem2	5848.83	4138.99

*Unweighted averages

Table 5.4.2- Sensitivity of Productivity Spillovers to Sectoral Aggregation
(Foreign presence measured as Employment Shares)

	2-digit		3-digit		4-digit	
	FE (1)	RE (2)	FE (3)	RE (4)	FE (5)	RE (6)
$\widetilde{K}$/L	0.013***	0.011***	0.013***	0.011***	0.013***	0.011***
	(2.76)	(2.54)	(2.77)	(2.56)	(2.77)	(2.56)
L_s/L_u	0.077***	0.086***	0.077***	0.086***	0.077***	0.086***
	(11.96)	(15.83)	(12.14)	(15.58)	(12.14)	(15.58)
FO	0.027	0.023	-0.001	0.001	0.004	0.003
	(1.29)	(1.35)	(-0.05)	(0.19)	(0.65)	(0.59)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sector Dummies	-	Yes	-	Yes	-	Yes
No. Of observations	26286	26286	26286	26286	26286	26286
Prob>F	0.000		0.000		0.000	
Prob>Chi2		0.000		0.000		0.000

Notes: 1) t-ratios for Fixed Effects and z-values for Random Effects are in brackets
2) ***=Significant at 1%, **=significant at 5%, *=significant at 10%

Table 5.4.3- Sensitivity of Productivity Spillovers to Sectoral Aggregation (Growth)
(Foreign presence measured as shares)

	2-digit		3-digit		4-digit	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ (K/L)	0.019***	0.022***	0.019***	0.022***	0.019***	0.023***
	(6.56)	(7.40)	(6.55)	(7.40)	(6.56)	(7.42)
Δ (L_s/L_u)	0.072***	0.071***	0.072***	0.071***	0.072***	0.071***
	(7.93)	(7.37)	(7.93)	(7.36)	(7.94)	(7.37)
Δ FO	-0.002	-0.007	0.002	0.003	0.008	0.008
	(-0.13)	(-0.32)	(0.25)	(0.37)	(1.42)	(1.29)
Year Dummies	-	Yes	-	Yes	-	Yes
Sector Dummies	-	Yes	-	Yes	-	Yes
No. Of observations	15455	15455	15455	15455	15455	15455
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000

Notes: 1) t-ratios are in brackets
2) ***significant at 1%, **=significant at 5%, *=significant at 10%

Table 5.5.1- Sensitivity of Productivity Spillovers to Sectoral Aggregation
(Foreign Presence measured as levels of employment accounted by foreign firms)

	2-digit		3-digit		4-digit	
	FE (1)	RE (2)	FE (3)	RE (4)	FE (5)	RE (6)
$\widetilde{K}$/L	0.013***	0.011***	0.012***	0.011***	0.013***	0.013***
	(2.77)	(2.85)	(2.70)	(2.80)	(2.77)	(2.83)
L_s/L_u	0.077***	0.086***	0.077***	0.087***	0.077***	0.086***
	(12.18)	(15.60)	(12.20)	(15.62)	(12.19)	(15.59)
FO	0.016*	0.009*	0.004	0.004	0.005*	0.004*
	(1.67)	(1.66)	(0.76)	(0.57)	(1.68)	(1.74)
DO	0.073***	0.043	0.053***	0.027	0.023	0.004
	(2.30)	(1.42)	(2.94)	(1.61)	(1.49)	(0.33)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sector Dummies	-	Yes	-	Yes	-	Yes
No. Of observations	26286	26286	26286	26286	26286	26286
Prob>F	0.000	-	0.000	-	0.000	-
Prob>Chi^2	-	0.000	-	0.000	-	0.000

Notes: 1) t-ratios for FE and z-values for RE are in brackets
2) ***=Significant at 1%, **=significant at 5%, *=significant at 10%

Table 5.5.2- Sensitivity of Productivity Spillovers to Sectoral Aggregation (Growth)
(Foreign presence measured as levels)

	2-digit		3-digit		4-digit	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ (K/L)	0.019***	0.022***	0.019***	0.022***	0.019***	0.023***
	(7.23)	(7.61)	(7.29)	(7.64)	(7.29)	(7.66)
Δ (L_s/L_u)	0.072***	0.071***	0.072***	0.071***	0.072***	0.071***
	(10.06)	(9.85)	(10.04)	(9.83)	(10.05)	(9.83)
Δ FO	0.001	-0.003	0.004	0.004	0.0075*	0.0076*
	(0.06)	(-0.16)	(0.64)	(0.63)	(1.67)	(1.68)
Δ DO	0.045	0.044	0.012	0.004	-0.009	-0.015
	(1.56)	(1.36)	(0.71)	(0.24)	(-0.67)	(-0.94)
Year Dummies	-	Yes	-	Yes	-	Yes
Sector Dummies	-	Yes	-	Yes	-	Yes
No. Of observations	15455	15455	15455	15455	15455	15455
Prob>F	0.000	0.000	0.000		0.000	0.000

Notes: 1) t-ratios are in brackets
2) ***=Significant at 1%, **=significant at 5%, *=significant at 10%

CHAPTER 6 CONCLUSION

6.1 Overview

The Irish economy has experienced substantial growth rates over the last decade and Irish manufacturing industry has played a major role in this growth. Despite the substantial growth in labour productivity levels over the period there has been no detailed analysis of productivity in Irish manufacturing industry. This thesis aimed at analysing the patterns of labour productivity change that took place over the 1991-99 period.

In Chapter 2 we examined the patterns and growth of labour productivity and employment in Irish manufacturing industry over the 1990s for both domestic and foreign firms separately using 2-digit industry level data. Over the period overall labour productivity growth was 158 per cent. An examination of this growth by nationality of ownership showed that labour productivity growth has been much higher in foreign firms than it has been in their domestic counterparts, 185 per cent compared with 37 per cent, showing evidence of increased divergence of labour productivity in the Irish manufacturing sector between foreign and domestic firms. A comparison of the productivity ratios of domestic firms to foreign ones over the 1991-99 period shows that in 1991 labour productivity in Irish companies was one third that of foreign companies, and that by 1999, this ratio had been halved to one sixth. The decline in the overall relative productivity of Irish firms is found in all size categories with the

exception of the 50-99 size, where Irish average productivity increased faster than foreign productivity though it still remains at only a third of the level of foreign productivity.

Investigation of productivity differences between foreign and domestic firms across sectors using the OECD 4-group classification indicated that the relative decline in productivity levels in Irish firms is concentrated in two sectors – the medium-high tech and the low-tech sectors. By contrast, productivity levels in Irish firms in the Medium-Low Tech sector have grown more quickly than that in foreign firms, reaching over 80 percent of their levels in 1999. The performance in the High-Tech sector is not as striking but Irish firms have at least lost no productivity ground in the High-Tech sector over the period. The fall in the Medium-High and Low-Tech sectors is primarily due to the rapid productivity growth of foreign firms in the Chemicals sector, which is in the medium-high-tech group, and in the Food, Beverages & Tobacco and Printing & Publishing sectors, which are in the Low-Tech sectors. In order to take account of these sectors, which are known to have exceptionally high value added in multinational firms in Irish manufacturing industry, we went on to re-analyse the labour productivity ratios between foreign and domestic firms in the 4-group OECD sectors and with these sectors removed from the data. The impact of removing these sectors was to raise the productivity ratios significantly in all but the Medium-Low tech sector, which is unchanged by the emendation. In the case of the High-Tech sector, the amended ratio stays constant over the period, while in the Medium-High it increased and in the Low-Tech sector fell by a lesser amount.

Our analysis in Chapter 2 also showed that Irish firms are still predominantly involved in the low and medium-tech industries of OECD classification. Although we see that employment in high-tech sectors has increased by 92 per cent over the period, Irish firms only account for 4.2 per cent of overall employment in these sectors. This indicates the relatively late move of Irish entrepreneurs into the sectors being promoted by government for over twenty years.

From a policy perspective it is noteworthy that high tech does not necessarily equate to high labour productivity – labour productivity measures value added per unit labour and this can be high because of marketing/patents, etc without any significant technology being embedded in the product or indeed any high physical productivity of labour. Hence, it is not surprising that there is relatively little difference in labour productivity between the medium-high and medium-low tech sectors in Irish manufacturing. However, policy must be clear on its focus – high productivity and not high-tech per se is what counts for growth and the data here suggest that the most serious issue for Ireland is to shift activities out of the low-tech sectors where currently 57% of workers in indigenous manufacturing are employed.

Our analysis of the sectoral productivity ranking for productivity levels between Irish and foreign owned firms in 1999 indicated a close parallel between productivity levels for foreign and Irish firms. The situation is quite different for

growth rates in productivity between 1991 and 1999 indicating that the sectors that are experiencing greater productivity growth are not the same for foreign as for Irish firms. Thus there is little evidence of greater convergence in productivity levels across sectors during the 1990s.[94]

In Chapter 3 we examined the factors that affect the growth of labour productivity in Irish manufacturing sector using a decomposition analysis. The results for all manufacturing firms indicate that productivity increases within the continuing firms and the entry of firms which displayed productivity more than the industry average, have contributed significantly to the labour productivity growth in Irish manufacturing over the period 1991-1999. These results are in line with the findings from other studies where we see the dominance of within and entry effects on the overall productivity growth.[95] In addition to the usual approach utilised in the literature we provided labour productivity decomposition results for both foreign and indigenous firms, as well as four different nationality groups. Results for foreign and domestic firms showed that overall within firm productivity improvements were the main drivers of labour productivity growth for both groups. An examination of the differences in productivity growth and the factors that contribute to this growth for intra-EU and extra-EU firms showed that productivity growth has been highest in the US firms, followed by Other Non-EU, Other EU and UK firms. We can see that within firm and net entry

[94] The Pearson rank correlation coefficient for productivity levels between foreign and domestic firms across sectors in 1999 is 0.80, whereas the same coefficient is only 0.28 for the productivity growth between 1991-1999.

[95] Comparison of the results of different studies is very difficult in decomposition analysis due to the variance of the methods, data sources and time periods used in the analyses.

effects are substantial across different nationalities although the sizes of these effects particularly within-effect, are quite different.

Results for four OECD sectors show that within-effect contributes most to overall labour productivity growth in all but one sector, namely high-tech sector in which net entry, that is mainly driven by entry effect, and cross term contribute most. This shows that in high-tech sector, the entry of above average firms and employment expansion in the high productivity firms has been the main drivers of the productivity growth.[96] Foreign firms dominate the overall average in all but one sector, medium-low tech sector where we also see that the domestic firms' productivity increase has been greater than foreign firms'.

Our analysis in Chapter 3 also showed that for both foreign and domestic firms most of the labour productivity growth through the 1991-99 period occurred in the second half, i.e., after 1995. Overall labour productivity growth was 40 per cent in the first half of the 1991-99 period and this increased to 84 per cent in the second half. In the case of Irish firms labour productivity grew only by 8 per cent between 1991-95 whereas we see a 27 per cent increase in the 1995-99 period.[97] This result is interesting because employment growth has been quite substantial for both domestic and foreign firms in the 1995-99 period compared to virtually no change in the 1991-95 period, which reflects the fact that both foreign and domestic firms on the average were able to increase their productivity levels as well as their employment levels in the 1995-99 period. Our decomposition

[96] This result is in line with the findings of a recent OECD (2002) study.
[97] Results for foreign firms also show a similar pattern where labour productivity grew by 46 per cent in the 1991-95 period, but the this growth increased to 95 per cent in 1995-99 period.

analysis showed that in the 1991-95 period the within component is the most significant contributor to labour productivity growth for both domestic and foreign firms Results from the second period reflect more closely results for the full period where within and entry terms account for most of the growth in the overall labour productivity growth.[98]

In Chapter 4 we investigated the technical efficiency levels in the Electrical and Optical Equipment sector and the factors that could affect these levels utilising a stochastic production frontier approach over the period 1991-99 based on firm-level panel data.

Using the model outlined by Battese and Coelli (1995) which determines the causes of inefficiency simultaneously, rather than employing a two-step approach whereby efficiency estimates are obtained in the first step and are then regressed on a set of determinants, we found that investment intensity plays an important role in explaining technical inefficiency levels in all sub-sectors of the Electrical and Optical Equipment industry. We found no significant relationship between export intensity and the technical inefficiency levels of individual firms in all but one sub-sector, namely, Television and Radio Receivers industry. As outlined above, this result could be due to linkages policy that has been pursued in this sector in order to encourage the development of supplier relationship between foreign and domestic firms with the aim of developing the indigenous companies, which could have resulted in low export intensity levels in the firms

[98] The entry terms high contribution in the second half of the 1990s could be due to the high number of firm formation on the domestic part of the industry but this does not necessarily mean that these new firms will contribute positively, on average, to overall productivity growth.

in these sectors. We also showed that labour quality plays an important role in determining efficiency levels in some sectors.

Our analysis showed that technical efficiency levels have increased in two sectors, namely Electronic Valves & Other Electronic Components and Radio & Television Receivers whereas Electric Motors & Generators and Medical & Surgical Equipment industries have experienced a decline in the average technical efficiency levels over the period 1991-99.

We investigated the effect of foreign firms' entry or presence in the Irish manufacturing sector on both the levels and growth of labour productivity in domestic firms in Chapter 5. Our analysis, using panel data on all companies in the Irish manufacturing sector and covering the period 1991-98, finds no evidence of positive productivity spillovers from foreign to domestic firms when the standard measure of foreign presence adopted in most of the literature is used, namely, MNC employment as a percentage of total employment.

However, when we follow Castellani and Zanfei (2001) by using an alternative measure, which is employment in foreign companies rather than employment shares in the relevant sector, a different picture emerges – at both the 2- and 4-digit NACE sector levels, the coefficient of foreign presence measure is positive and significant which shows that there are positive productivity spillovers from FDI in Irish manufacturing industry over the period 1991-99.

One further issue that arose from Chapter 5 is what the appropriate sectoral measure for FDI presence should be for this type of analysis. For data reasons, much of the early analysis of spillovers at plant level has used 2- or 3-digit level – mirroring the analyses undertaken at sectoral levels before plant level data became available. In this thesis we used 2-, 3- and 4-digit and found, in the case where FDI presence is measured in levels, that the results are sensitive to the choice of level of aggregation, but this brings the question of what the level should be. The lower the level of aggregation, the more likely the spillovers are to be horizontal – but if we lower the level too much, we miss out on the possible spillovers which can occur as a result of FDI in neighbouring sectors. Furthermore, while some authors suggest that all such spillovers are horizontal rather than vertical, this is not plausible even at 4-digit.

6.2 Concluding Comments and Future Work

This thesis has contributed to the research into productivity issues in Irish manufacturing industry using labour productivity analysis. As outlined above, labour productivity is only a partial measure of performance. An analysis using Total Factor Productivity (TFP) measure that is a more comprehensive tool than labour productivity analysis is necessary. Our analysis was limited to the labour productivity due to data constraints that did not allow us to construct capital stock series for individual firms, which is necessary for any investigation for TFP analysis. Also to our knowledge capital stock figures do not exist for even individual 2-digit industries in Irish manufacturing industry. So a starting point

would be to construct capital stock figures for individual industries at a disaggregated level, which depends on the availability of a longer time period in order to be able to apply methods in constructing these series.

Our analysis of productivity spillovers from foreign firms to domestic firms has focused on the measurement issues and sensitivity of results related to the foreign presence variable that is used in the regression analysis. This points to the need to explore in more detail the channels for such spillovers, and to give direct attention to differences in the capacity of LCs to exploit spillover potentials and the likelihood that MNCs will generate these.

Further research is needed to investigate the channels through which these spillovers can occur, such as horizontal and vertical spillovers. This will require using Input-Output tables in the Irish manufacturing sector, which again requires a longer time series of plant level data. Another future work possibility could be to investigate productivity spillovers at a regional level as well as an examination of potential spillovers between foreign firms.

BIBLIOGRAPHY

Aigner, D. J., C. A. K. Lovell, and P. Schmidt (1977) "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics* 6 (1), 21-37.

Aigner, D. J. and S. F. Chu (1968) " On Estimating the Industry Production Function" *American Economic Review* 58:4 (September), 826-39.

Aitken, Brian J. and Harrison A. (1999) "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela" *The American Economic Review*, Vol. 89, no.3, pp. 605-618.

Atkinson, S. E. and R. Halvorsen (1984) " The Relative Efficiency of Public and Private Firms in a Regulated Environment: The Case of U.S. Electric Utilities, *Journal of Public Economics* 29, 281-94

Baily, Martin E., Charles Hulten and David Campbell (1992) " Productivity Dynamics in Manufacturing Plants", *Brookings Papers on Microeconomic Activity*, pp. 187-249.

Barry, Frank (1999) (ed.). *Understanding Ireland's Economic Growth* (London: Macmillan)

Barry, Frank, Holger Görg and Eric Strobl (2001) "Foreign Direct Investment and Wages in Domestic Firms: Productivity Spillovers vs. Labour Market Crowding Out" *Mimeo*, University College Dublin and University of Nottingham.

Bartelsman, E. J., S. Scarpetta and F. Schivardi (2002) " Comparative Analysis of Firm Demographics and Survival: Micro-level Evidence for the OECD Countries", *OECD Economics Department Working Papers*, forthcoming, Paris.

Battese, G. E. and G. S. Corra (1977) " Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia" *Australian Journal of Agricultural Economics* 21:3, 169-179.

Battese, G. E. and T.J. Coelli (1988) " Prediction of Firm-Level Technical Efficiencies with a Generalised Frontier Production Function and Panel Data" *Journal of Econometrics* 38, 387-99.

Battese, G. E. and T. J. Coelli (1992) " Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis,* 3, 153-169

Battese, G. E. and T.J. Coelli (1995) " A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data" *Empirical Economics* 20, 325-32.

Battese, G. E. , D. S. Prasado Rao and Dedi Walujadi (2001) " Technical Efficiency and Productivity Potential of Firms Using a Stochastic MetaProduction Frontier" *Efficiency Series Paper* 8/2001, Universidad de Oviedo, Permanent Seminar on Efficiency and Productivity.

Bhattacharyya, A., E. Parker and K. Raffiee (1994) " An Examination of the Effect of Ownership on the Relative Efficiency of Public and Private Water Utilities" *Land Economics* 70:2 (May), 197-209.

Blomstrom, M. and Persson H. (1983) " Foreign Investment and Spillover Efficiency in an Underdeveloped Economy: Evidence from the Mexican Manufacturing Industry" *World Development*, Vol. 11, pp. 493-501

Blomstrom, M. and Ari Kokko (1998). " Multinational Corporations and Spillovers." *Journal of Economic Surveys* Vol. 12 No. 3, 247-277

Castellani, Davide and Zanfei, Antonello (2001) " Technology Gaps, Inward Investments and Productivity of European Firms" *Mimeo*, ISE-Universita di Urbino

Castellani, Davide and Zanfei, Antonello (2002) "Multinational Companies and Productivity Spillovers: Is there a Specification Error" *Mimeo*, ISE-Universita di Urbino

Caves, R. (1974) "Multinational Firms, Competition and Productivity in Host-Country Markets" *Economica*, Vol. 41 (162), pp. 176-93

Chen, T. and D. Tang (1987) " Comparing Technical Efficiency Between Import-Substituting and Export-Oriented Foreign Firms in a Developing Country" *Journal of Development Economics* 26, 277-289.

Coelli, T. J. "A Guide to Frontier Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation" *Centre for Efficiency and Productivity Analysis Working Papers*, No: 7/96, University of New England, Australia

Coelli, T. J., D. S. Prasada Rao, and G. E. Battese (1998) *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Deprins, D. and L. Simar (1989) "Estimating Technical Inefficiencies with Corrections for Environmental Conditions with an Application to Railway Companies" *Annals of Public and Cooperative Economics* 60:1 (January/March), 81-102.

Deprins, D., L. Simar and H. Tulkens (1984) " Measuring Labour Efficiency in Post Offices" in M. Marchand, P. Pestiau and H. Tulkens (eds.), *The Performance of Public Enterprises: Concepts and Measurements*, Amsterdam: North-Holland.

Disney, Richard, Jonathan Haskel and Ylva Heden (2000) " Restructuring and Productivity Growth in UK Manufacturing" *CEPR Discussion Paper Series*, No.2463

Driffield, N. (2001) 'The Impact on Domestic Productivity of Inward Investment in the UK', *The Manchester School,* 69, 103-119.

Driffield, Nigel and Max Munday (2001) " Foreign Manufacturing, Regional Agglomeration and Technical Efficiency in UK Industries: A Stochastic Production Frontier Approach" Regional Studies 35 (5), 391-399

Fare, R., R. Grabowski and S. Grosskopf (1985a) " Technical Efficiency of Philippine Agriculture" *Applied Economics*, 17, 205-214.

Fare, R., S. Grosskopf and J. Logan (1985b) " The Relative Performance of Publicly-Owned and Privately-Owned Electric Utilities" *Journal of Public Economics*, 26, 89-106.

Farrell, M. J. (1957) "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society*, Series A, General, 120 (3), 253-81

Flores, G. Renato Jr., Maria Paula Fontoura and Rogerio Guerra Santos (2000) " Foreign Direct Investment Spillovers: What can we learn from Portuguese data?" *Mimeo,* ISEG, Universidade Tecnica de Lisboa, Lisbon

Foster, Lucia, John Haltiwanger and C. J. Krizan (1998) " Aggregate Productivity Growth: Lessons from Microeconomic Evidence", *NBER Working Paper*, No. 6803

Gathon, H.-J., and S. Perelman (1992) " Measuring Technical Efficiency in European Railways: A Panel Data Approach" Journal of Productivity Analysis 3 (1/2) (June), 135-51.

Globerman, S. "Foreign Direct Investment and Spillover Efficiency Benefits in Canadian Manufacturing Industries" *Canadian Journal of Economics*, Vol. 12 (1) pp. 42-56.

Görg, Holger and Greenaway, David (2001) "Foreign Direct Investment and Intra-Industry Spillovers", paper delivered at the *UNECE/EBRD Meeting on Financing For Development: Enhancing the Benefits of FDI and Improving the Flow of Corporate Finance in the Transition Economies*, Geneva, December 2001

Görg, Holger and Ruane, Frances, 2001 "Multinational Companies and Linkages: Panel-data Evidence for the Irish electronics sector". *International Journal of the Economics of Business*, Vol. 18, pp 1-18, 2001.

Görg, Holger and Eric Strobl (2000) " Multinational Companies, Technology Spillovers and Firm Survival: Evidence from Irish Manufacturing" *Research Paper 2000/12, Leverhulme Centre for Research on Globalisation and Economic Policy.*

Greene, W. H. (1990) " A Gamma-Distributed Stochastic Frontier Model" *Journal of Econometrics* 46:1/2 (October/November), 141-64.

Griliches, Zvi and Haim Regev (1995) "Firm Productivity in Israeli Industry: 1979-1988", *Journal of Econometrics*, 65, pp. 175-203.

Guiomard, Cathal (1995) *The Irish Disease and How to Cure It* (Dublin: Oak Tree Press)

Haddad, M. and Harrison A. (1993) "Are There Positive Spillovers from Direct Foreign Investment? Evidence from Panel Data for Morocco" *Journal of Development Economics*, Vol. 42, pp. 51-74.

Haltiwanger, John (1997) " Measuring and Analysing Aggregate Fluctuations: The Importance of Building from Micro-economic Evidence", *St. Louis Federal Reserve Bank Economic Review*. January/February.

Harris, R. I. D. (1991) " Efficiency in Northern Ireland Manufacturing" *Scottish Journal of Political Economy* 38, 386-97

Harris, R. I. D (1999a) " Productive Efficiency in UK Manufacturing 1974-1994: Estimates for Five Leading Sectors" *Mimeo*, University of Portsmouth

Harris, R. I. D (1999b) " Efficiency in UK Manufacturing 1974-1994" *Mimeo*, University of Portsmouth.

Harris, R. I. D (2001) " Comparing Regional Technical Efficiency in UK Manufacturing Plants: The Case of Northern Ireland 1974-1995" *Regional Studies* 35 (6), 519-534.

Haskel, Jonathan and Ralf Martin (2002)" The UK Manufacturing Productivity Spread", *Centre for Research into Business Activity Discussion Paper.*

Heshmati, A. and S. C. Kumbhakar (1994) " Farm Heterogeneity and Technical Efficiency: Some Results from Swedish Dairy Farms" *Journal of Productivity Analysis* 5:1 (April), 45-61.

Hill, H. and K. P. Kalirajan (1993) " Small Enterprise and Firm-Level Technical Efficiency in the Indonesian Garment Industry" *Applied Economics* 25, 1137-1144.

Hubert, Florence and Nigel Pain (2001) " Inward Investment and Technical Progress in the United Kingdom Manufacturing Sector" *Scottish Journal of Political Economy*, Vol. 48, No. 2, pp. 134-147.

Kearns, Allan (2000) " Essays on the Consequences of Research and Development for Manufacturing Firms in Ireland"

Kodde, D. A. and F. C. Palm (1986) "Wald Criteria for Jointly Testing Equality and Inequality Restrictions" *Econometrica*, 54, 1243-1248.

Konings, Joseph (2000) "The Effects of Direct Foreign Investment on Domestic Firms: Evidence from Firm Level Panel Data in Emerging Economies" *CEPR Discussion Paper No: 2586*

Koopmans, T. C. (1951) "An Analysis of Production as an Efficient Combination of Activities" in T. C. Koopmans, ed., *Activity Analysis of Production and Allocation, Cowles Commission for Research in Economics*, Monograph No.13. New York: Wiley

Kumbhakar, S. C. (1990) "Production Frontiers with Panel Data and Time Varying Technical Inefficiency" *Journal of Econometrics*, 46, 201-212

Kumbhakar, S. C., S. Ghosh and J. T. McGuckin (1991) " A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in US Dairy Farms" *Journal of Business and Economic Statistics* 9:3 (July), 279-86.

Kumbhakar, S. C. and C. A. K. Lovell (2000) *Stochastic Frontier Analysis* (New York: Cambridge University Press)

Liu, Xiaming; Pamela Silver, Chengqi Wang and Yingqi Wei (2000) " Productivity Spillovers from Foreign Direct Investment: Evidence from UK Industry Level Panel Data" *Journal of International Business Studies,* Vol.31, pp. 407-425

Lundvall K. and G. E. Battese (1998) " Firm Size, Age and Efficiency: Evidence from Kenyan Manufacturing Firms" *Centre for Efficiency and Productivity Analysis Working Paper* No: 7/98, University of New England, Australia

Mahadeven, Renuka (2000) " How Technically Efficient are Singapore's Manufacturing Industries" *Applied Economics* 32, 2007-20014

Marcos, Ana Martin and C. S. Galvez (2000) " Technical Efficiency of Spanish Manufacturing Firms: A Panel Data Approach" *Applied Economics* 32, 1249-1258.

Meeusen, W. and J. van den Broeck (1977) " Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error" *International Economic Review*, 18 (2), 435-44

OECD (2001) "Productivity and Firm Dynamics: Evidence from Micro data", *OECD Economic Outlook*, No.69, OECD, Paris

O'Muircheartaigh, Fionan (2000) " Industry in Ireland in the 1990s: Comparative Performance of Irish-Owned and Overseas-Owned Companies." *ESRI Seminar Paper*

O;Neill, Suzanne (2001) " Essays on Productivity in Irish Agriculture" *Unpublished Ph. D thesis, Department of Economics, University of Dublin, Trinity College.*

O'Neill, Suzanne, A. Matthews and A. Leavy (2001) " Farm Technical efficiency and Extension" *Trinity Economic Paper Series* No: 12, Trinity College Dublin.

Pitt, M. and L. Lee (1981) " The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry" *Journal of Development Economics*, 9, 43-64

Reifschneider, D. and R. Stevenson (1991) " Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency" *International Economic Review* 32:3 (August), 715-23.

Ruane, Frances (2001) "Reflections on Linkage Policy in Irish Manufacturing – Policy chasing a moving target?" paper delivered at the *UNECE/EBRD Meeting on Financing For Development: Enhancing the benefits of FDI and Improving the Flow of Corporate Finance in the Transition Economies*, Geneva, December 2001

Ruane, Frances and Uğur, Ali (2000) " Foreign Direct Investment and Productivity Spillovers in Ireland – Some Preliminary Results" Paper delivered at the *Annual Conference of the Irish Economic Association in Waterford*, 31st March- 2nd April 2000.

Ruane, Frances and Görg, Holger (1997) "The Impact of Foreign Direct Investment on Sectoral Adjustment in the Irish Economy" *National Institute Economic Review*. No.160. pp. 76-86

Scarpetta, S., A. Bassanini, D. Pilat and P. Schreyer (2000) "Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Level" *OECD Economics Department Working Papers*, No. 248

Schmidt, P. (1976) "On the Statistical Estimation of Parametric Frontier Production Functions" *Review of Economics and Statistics* 58:2 (May), 238-39.

Sidhu, S. S. (1974) "Relative Efficiency in Wheat Production in the Indian Punjab" *American Economic Review* 64:4 (September), 742-51.

Sheehan, Maura (1997) " The Evolution of Technical Efficiency in the Northern Ireland Manufacturing Sector, 1973-85" Scottish Journal of Political Economy 44 (1), 59-81.

Sjoholm, Fredrik (1998) " Productivity Growth in Indonesia: The Role of Regional Characteristics and Direct Foreign Investment" *Working Paper in Economics and Finance NO. 216, Stockholm School of Economics.*

Stevenson, R. E. (1980) " Likelihood Functions for Generalised Stochastic Frontier Estimation" *Journal of Econometrics* 13:1 (May), 57-66.

United Nations Conference on Trade and Development (2001) *World Investment Report 2001: Promoting Linkages*, United Nations, New York and Geneva