Productivity Growth in the Small Firm Sector
in UK Manufacturing

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Abstract

This thesis analyses the performance of the small firm sector in UK manufacturing, focusing on productivity growth, technological change and innovation.

The natural starting point for the study is a consideration of the observed differences in firm sizes. Here, the thesis reviews the economic literature on the size and growth of firms focusing on 'Gibrat's Law'. The review concludes that while the law has reasonably validity for larger firms it breaks down among smaller enterprises and that the small firm in industrial sectors needs to be considered as both complementary to, as well as competitive with, its larger counterparts.

The analysis of the performance of the sector begins in chapter 3 with an analysis of the growth of output, employment and labour productivity by size class for the period 1973-2002 both for total manufacturing and for the textile, food, paper, chemicals, electrical and transport equipment industries. The results show that the share of employment of the sector has increased over time, but that this as occurred at the same time as a fall in labour productivity relative to large firms. These are examined in chapter 4. The findings suggest that the higher growth rate of labour productivity in the large firm sector is related to the relative growth of capital intensity rather than any differences in rates of technological change between sectors.

Chapter 5 adopts an alternative approach based upon the analysis of labour demand and the impact on employment of technological change. Econometric models of labour demand for total manufacturing suggest positive impacts on productivity for both measures. The model is supplemented by panel data, which shows more mixed results, possibly because the spillover effect is not well captured within industries.

Chapter 6 seeks confirmation of the results in chapter 5 and further evidence regarding the sources of technology for small firms.
Acknowledgements

I would like to take this opportunity to express my gratitude to some people who have helped me during my research.

I am indebted to my excellent supervisor, Mr. Paul Temple, who is my present from God in the UK. Mr. Temple always guided, encouraged, supported and offered help to me at every stage of this thesis. Parts of chapter 5 and 6 are joint work with Paul. The joint work in chapter 6 with him and Stephen Drinkwater was presented in the Annual Scottish Conference in Perth in 2006. Actually, without Paul, it would have been very difficult to complete this thesis.

I also would like to thank my co-supervisor, Dr. Stephen Drinkwater, for his valuable comments on my thesis.

The most important personal debts are to the spirit of my father, whom I wish could see this thesis; and to my mother, for her help, encouragement and sacrifice during my education.

This thesis would never have been completed without the great support from my wife, Marwa. She always supports and pushes me, and looks after our children, Salma, Habiba and Mostafa. I am sure that they will be happy when they see this thesis.
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Glossary

ABI: Annual Business Inquiry
ACoC: Annual Census of Construction
ACoP: Annual Census of Production
AFNOR: French Standards Institution
ANBERD: R&D database
BERR: Department for Business, Enterprise and Regulatory Reform
BSI: British Standards Institution
CIS3: Community Innovation Survey
COS: Central Office Statistics
DIN: Deutsche Institut fur Normung (German Standards Institute)
DTI: Department of Trade and Industry
GCS: Gross Capital Stock
MFP: Multi Factor Productivity
NCS: Net Capital Stock
NIC: National Insurance Contributions
OECD: Organisation for Economic Co-operation and Development
ONS: Office for National Statistics
PERINORM: Database of Standards
PIM: Perpetual Inventory Method
R&D: Research and Development Expenditure
SBC: Small Business Council
SBS: Small Business Service
SIC: Standard Industrial Classification
STAN: Structural Analysis of Industries
TFP: Total Factor Productivity
Chapter One
Introduction

1.1 Background

From today's perspective, it is self evident that small firms play an important role in the UK Economy. Both government policy – where industrial policy has favoured the small firm sector for at least the period since 1979 – and the popularity of the role of entrepreneur have seen to that. The 2005 annual report of the Small Business Council claims that:

"Small businesses make a vital contribution to the health of the UK economy and to improving the productivity of UK business. The government has a clear vision to make the UK the best place in the world to start and grow a business."

In the view of this small business-lobbying group, small firms as a whole are 'big business', contributing significantly to employment and turnover in almost every sector. Moreover, it is claimed that small firms have specific characteristics that allow them to serve not only as a source of competitive pressure for their larger counterparts but also to provide a complementary role – an aspect which may draw on their alleged greater flexibility (e.g. Clarke, 1972). Thus, when market conditions demand a change in the design of a product, or indeed a change of product itself, the large firm is often handicapped by highly planned and expensive production lines, where the small firm with a smaller commitment to fixed equipment can switch more easily from making one product to another. Small firms are considered generally very innovative; the fact that the smaller firms produce more patents than their use of inputs would suggest is sometimes taken as evidence of their prevalence in innovation (SBS\(^1\), 2002). Recent estimates indicate that 33% of small firms are actively engaged in research and development at any one time (SBC, 2005).

\(^1\) On 17 July 2007, Stephen Timms, Minister of State for Competitiveness, announced the renaming of the 'Small Business Service' as the 'Enterprise Directorate'. The new name reflects the Department for Business, Enterprise and Regulatory Reform (BERR) emphasis on enterprise and growth.
The aim of this thesis is to test some of these claims against the evidence. For example, what is the contribution of small firms to employment and to productivity growth? Does the small firm sector innovate in any significant way and if so how? To answer these and other related questions this thesis is restricted to small firms in the manufacturing sector, defined as those with fewer than 100 employees. Justification for the concentration on manufacturing may be explained as follows:

- First, while there are hundreds of thousands of tiny firms in construction, services and distribution, the field is too big and heterogeneous for a single thesis. It is also difficult to measure output in these sectors, especially in services. Detailed data on small firms in these sectors has only became available relatively recently at the national level.

- Second, while manufacturing has shrunk in its importance as an employer, it remains extremely important to Britain, as a recent DTI\(^2\) report argues\(^3\):

  "Manufacturing matters to Britain. It creates a fifth of our national output, employs 4 million people and produces the majority of our exports. It supports well-paid jobs in all regions. It can make a very substantial contribution to improvements in our economy’s productivity. The success of United Kingdom manufacturing is crucial to our country’s prosperity, now and in the future”.

Nor has manufacturing shrunk in its importance as a contributor to exports\(^4\).

- Third, manufacturing may still be justly regarded as at the hub of the innovative effort in the economy. A large proportion of the intra-mural business expenditure on Research and Development (R&D) takes place within manufacturing. The ratio of total manufacturing R&D to that for UK is 47% in 2002 (ANBERD, 2005). Innovation elsewhere in the economy frequently takes the form of the use of innovations produced in manufacturing.

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\(^2\) This name was changed on 28/6/2007 to Department for Business, Enterprise and Regulatory Reform (BERR).
\(^3\) DTI (2002).
\(^4\) In 2004, manufacturing exports made up nearly two thirds of all the UK’s exports. The UK exported £190,548 million, of which manufactured goods accounted for £24,514 million, and machinery and transport for £78,815 million. Exports of other manufactured goods were worth £23,175 million (ONS, 2004).
Finally, it needs to be acknowledged that manufacturing is generally rather easier to research and the lessons to be drawn from this field may be applicable elsewhere (Boswell, 1973). In spite of extensive discussion regarding small firms’ problems, there has been relatively little research directly comparing the performance of small firms with other larger firms. Instead, most studies have focused on comparing productivity among industries or regions.

The organisation of this chapter is as follows. The definition of the small firm sector is presented in the next section. Policies towards small firms are introduced in section 3. Section 4 presents the importance of the small firm sector in UK manufacturing. The aims and scope of the thesis are presented in Section 5, and the plan of the overall thesis will be presented in Section 6.

1.2 Definition of small firms

There are various definitions of small firms. The UK Bolton Committee in 1971 drew on a definition that recognized that small firms:

1- Have a relatively small market share and cannot affect the market;
2- Are typically owner-managed;
3- Are independent and do not form part of a larger company.

Section 248 of the Companies’ Acts of 1985 states that small firms have to satisfy at least two of the following three conditions. They must have: a turnover of no more than £2.8 million, a balance sheet total of no more than £1.4 million, and no more than 50 employees.

In the UK, for statistical purposes, the Department for Trade and Industry (DTI)\(^5\) usually uses the following definitions:

- Micro firms: those with 0 to 9 employees

\(^5\) It is the definition of the European Union.
• Small firms: those with 0 to 49 employees (includes micro)
• Medium firms: those with 50 to 249 employees
• Large firms: those with 250 employees and over.

According to the European Commission, firms are classified by their number of employees into the following groups (Storey, 1994):

• Micro firms: those with 0 to 9 employees
• Small firms: those with 10 to 99 employees
• Medium firms: those with 100 to 499 employees
• Large firms: those with 500 employees and over.

In general, I shall use the latter definition in chapter 3, 4 and 5 in this thesis. I shall combine the micro and small firms into a single category and refer to them together as “small firms”.

The analysis in chapter 3, 4 and 5 depends on the Annual Census of Production (ACoP) and Annual Business Inquiry (ABI) data; these data are available for most of variables only from 0 to 99 employees. In chapter 6 which uses the Community Innovation Survey (CIS3) data, I use the 0-49 definition of the small firm as the data are available for this class.

After studying the employment and technological change indicators in chapter 5 by using the ACoP and ABI data, further evidence regarding the sources of technology for small firms. The analysis in chapter 6 gives more details about innovation in the small firm sector by using 0-49 employees’ definition.

1.3 Policies for small firms

The UK government now increasingly realise that the small firm sector is vital to the UK economy. The 2002 annual report of the Small Business Council for example recognised that:
The government sees small business as playing a major economic and social role. It is, however, concerned to raise productivity of UK enterprises both large and small."

The government's policies for small firms include the following:6

1- Building the capability for small firm growth;
2- Improving access to finance for small firms;
3- Developing better regulations and policies;
4- Encouraging more enterprise in disadvantaged communities and under-represented groups;
5- Improving small firms' experience of government services;
6- Encouraging a more dynamic start-up market;
7- Building an enterprise culture.

The main objective of these policies is to encourage people to establish new small firms and improve the overall productivity of small firms (SBS, 2005). Measuring small firms' productivity therefore provides an important element in determining the success of government policy towards small firms. Given the importance of small firms from this variety of aspects, the question of productivity in the small firm sector is vital and will be addressed in this thesis. This will be done using two approaches. First, it provides measures of labour productivity growth in the small firm sector. These are decomposed into two main sources - one attributable to factor substitution (capital for labour) and one to the growth of Total Factor Productivity growth (TFP), i.e. broadly measured technological change. These initial estimates are then supplemented by a different approach which focuses on the determinants of the demand for labour in the small firm sector of UK manufacturing. These of course include technological change.

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6 See SBS (2005).
1.4 The importance of small firms in UK manufacturing

The thesis will use several indicators to determine the importance of the small firm sector in UK manufacturing, such as the share of total manufacturing enterprises and the share of total manufacturing employment. Before examining these indicators, it is necessary to first examine the role of the small firm sector in various OECD countries and compare the UK to other countries.

1.4.1 Small firms in selected OECD economies

In this section, we shall compare the UK small firm sector with those in other countries. Figure 1.1 shows the share of enterprises by employment size class in some OECD countries.

Figure 1.1 shows that the share of small firms represents more than 50% of all firms in all of the included countries. In the UK this ratio is greater than in the US and Germany, but is smaller than in Italy and France. Moreover, the small firm sector makes an important contribution to overall employment in OECD countries. Figure 1.2 shows the employment share in OECD countries by employment size class.
Figure 1.2 Employment share in the manufacturing sector in OECD countries in 2002 by employment size class

Source: OECD, 2002 and US Census Bureau, on line

Figure 1.2 shows that the small firm sector makes a big contribution to employment, although there is considerable variation across countries. In Germany, for example, more than 60% of all employment is in firms with over 250 employees. In Italy, these firms account for just 30% of total employment compared to around 55% in the UK. The contribution of the smallest firms (less than 50 employees) to total employment also varies considerably; in Italy and UK, they account for 40% and 27% of total employment, respectively. In US and Germany, they only account for 13% and 14% of total employment.

1.4.2 The changing contribution of small firms

Beyond the snap-shot comparison of the UK small firm sector with that of other countries, it is also clear that the role of the small firm sector in UK manufacturing has increased during the last two decades. Martin W. Griffith,7 for example, declared that:

“I am encouraged by the recent positive statistics for the small business sector. There are now a record number of small and medium sized enterprises, nearly 600,000 more than seven years ago, start-ups are outnumbering closures and

7 Chief Executive of the Small Business Service (See SBS, 2005).
SMEs productivity growth exceeded all firms’ productivity growth over the four years period 1999-2003.

Table 1.1 emphasizes the shift in UK manufacturing towards small firms by presenting enterprises shared by employment size class.

<table>
<thead>
<tr>
<th>Year</th>
<th>1-99</th>
<th>100-199</th>
<th>200-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>83.9</td>
<td>7.4</td>
<td>5.7</td>
<td>3.1</td>
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<tr>
<td>1963</td>
<td>85.6</td>
<td>5.8</td>
<td>5.7</td>
<td>2.9</td>
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<tr>
<td>1968</td>
<td>86.7</td>
<td>5.4</td>
<td>5.1</td>
<td>2.8</td>
</tr>
<tr>
<td>1973</td>
<td>87.6</td>
<td>5.3</td>
<td>4.3</td>
<td>2.8</td>
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<tr>
<td>1980</td>
<td>90.9</td>
<td>4.0</td>
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<td>1985</td>
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<td>1990</td>
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</tr>
<tr>
<td>1995</td>
<td>95.8</td>
<td>2.2</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>2002</td>
<td>96.3</td>
<td>1.8</td>
<td>1.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>


Table 1.1 shows how the share of enterprises has increased over time for the size class 1-99, paralleled by a decline in the share of large firms, with the very largest firms accounting for less than 1% of the total number of establishments. Whilst medium sized firms only account for just over 3% of establishments.
Figure 1.3 indicates the share of total manufacturing employment by firm size. It shows that the contribution of the small firm sector to employment has increased over time, and by 2002 it had exceeded that of the large firm sector. In contrast, the contribution of the large firm sector has decreased over time. On the other hand, the contributions of other size categories have been relatively stable over time. In this context, a rising share of employment may be the result of entrepreneurial dynamism and a competitive product or indeed its opposite – slow productivity growth. It is important therefore to provide measures of labour productivity in this sector in order to judge its performance.

1.5 Aims and scope of the thesis

Given both its importance and increasing role, a deeper understanding of the small firm sector seems a valuable exercise. The main aim of this thesis is to study productivity growth, technical change, and innovation in the small firm sector in UK manufacturing. To achieve this objective, I seek answers to a comprehensive set of questions as follows:

1. What are the determinants of the size distribution of firms in an industry?

2. Were there differences in output, employment and labour productivity growth among employment size classes in UK manufacturing during the period 1958-2002?

3. What is the relationship between labour productivity and TFP growth? Were TFP growth and capital- labour substitution growth in UK manufacturing different across the employment size classes during the period 1973-2002?

More details about the employment share are available in chapter 3
4. What is the relationship between the labour demand and technological indicators (R&D expenditure and technical standards) in the small firm sector in UK manufacturing during the period 1973-2002?

5. Is there any relationship between the innovation and firm size?

6. What are the sources of innovation information in the UK manufacturing by employment size classes by using CIS3 data?

1.6 Thesis plan

To answer these six questions, seven chapters are presented in this thesis. This introduction forms Chapter 1. The organization of rest of the thesis is as follows.

The first objective of this thesis is to find out why we observe differences in firm sizes. More particularly, why do small firms coexist alongside large firms within the same industry? To answer this question, Chapter 2 discusses a body of literature which begins with the work of Gibrat (1931), who put forward a 'law of proportionate effect' – broadly consistent with constant returns to scale at the firm level - contrasting that with the Marshallian position as represented by Viner (1932), in which the long run distribution of firm sizes is given as the determinate and unique outcome of technological factors. Additionally, a review of certain seminal economic models - that attempt to bring the Marshallian approach and Gibrat's law closer together - such as the Lucas model (1978) and the Jovanovic model (1982) and the related concepts of 'active' and 'passive' models of firm learning. The chapter concludes with a review of the economic literature on the role of the entrepreneur and the small firm sector as specific agents of change and in which the role is seen as being as much complementary as competitive with larger firms.

In Chapter 3, the performance of the small firm sector in UK manufacturing will be examined over the longer term by examining the post-war sequence of Annual Censuses of Production (ACoP) and, later, the Annual Business Inquiries (ABI) covering the years 1958 to 2002. The main objective of this chapter is to present
some stylised facts about differences in output, employment, and labour productivity among employment size classes, and additionally to establish the nature of output, employment and labour productivity differences between the industries in the small firm sector in UK manufacturing over the period 1973-2002. This chapter shall conduct this analysis in two stages: the first stage is based on current prices; the second on constant prices. Using current prices, the analysis shows the relative importance of the small firm sector in UK manufacturing without using deflators that may not be suitable for the small firm sector. The main conclusion from this chapter is that there is a difference in the growth rates of the labour productivity between the small firm sector and large firms.

One source of labour productivity growth is, of course, the capital-intensity of production. Thus, to what extent do the differences in labour productivity growth rates uncovered in Chapter 3 simply reflect changing levels in the amount of capital stock available to workers in the different size classes? In order for the third task of this thesis - to provide reliable measures of productivity growth – to be completed it is important to provide measures of productivity growth that consider variations in the effect of changing capital intensity. Chapter 4 begins accordingly with an estimation of the gross capital stock by employment size class. It discusses the Perpetual Inventory Method (PIM), which was used in this estimation. Estimates of gross capital stock for UK manufacturing and for six industries by employment size class are then provided for the period of 1973-2002. Estimation of TFP growth for UK manufacturing and for six industries by employment size class for the period of 1973-2002 shows that there is a difference between size classes in both TFP growth and in the contribution of growing capital-intensity as well.

For reasons considered and discussed in Chapter 4, I develop in chapter 5 an alternative method of measuring and examining the sources of technological change by using an analysis of labour demand, which has the advantage of being less prone to measurement error. The chapter develops econometric models of the relationship between employment and technological change using two types of estimation. The first approach is that for total manufacturing; the second approach is a panel data analysis for eight industries. These industries are food, beverages and tobacco; textile and textile products; leather; paper and publishing; chemicals; rubber and plastic; non-metallic mineral products; and the basic metals and fabrication industries. For
these eight sectors, it was possible to construct data on wages, net output, employment, R&D and standards. For an additional four industries, data is available for the period 1985-1997. These industries are office and computing products, electrical and optical equipment, motor vehicles and transport equipment industries. For each sector data was collected across 4 size classes (1-99, 100-199, 200-499 and 500+). To proxy for the role of technological change, the chapter considers various sources of new technology in the small firm sector.

Technological change also contributes greatly to the proportion of aggregate productivity growth at both the whole economy and at the manufacturing sector levels. At a micro level, econometric estimates of production functions have also indicated the importance of technological change, but have additionally stressed the importance of ‘technology spillovers,’ which, in many instances, precede advances in growth theory. Oxford Dictionary of Economics defines spillover as follows: "Spillover is a connection between different parts of the economy. Spillover may be pecuniary or non-pecuniary. A pecuniary spillover occurs, for example, when changes in one industry affect factor supplies to another. Pecuniary spillover produces their effects through markets. A non pecuniary spillover occurs when one industry inflicts external diseconomies on another." In general, Spillovers are effects of economic activity or process upon those who are not directly involved in it. An important outcome from the increased attention being given to technology spillovers has been the development of new data sources. One of the more important new advances has been the development and use of the Community Innovation Survey (CIS), which was founded on the Oslo Manual (OECD, 1992a). Broadly, the survey reflects a resources-based view of the innovating firm, recognising that innovation is an information-intensive activity. Accordingly, Chapter 6 focuses on the role played by information in the generation of innovation, and compares and contrasts the use of information between large and small firms.
Chapter Two

A literature review: the size and growth of firms

2.1 Introduction

A natural starting point for considering the performance of the small firm sector in UK manufacturing is the question of why we observe differences in firm sizes. More particularly why do small firms coexist alongside large firms within the same industry? A long literature examines just this issue. Of course much of the economic interest in the topic stems from the policy concern with the development of monopoly power. However as we shall see, the debate also concerns the nature of technological change and the role of small firms in the process by which new technology is created and diffused. By examining the discussion from the latter point of view, this chapter is intended to review the economic literature on the size and growth of firms, as well as to place them in historical context.

Two famous studies form the starting point for this chapter, both published in the same period, and which presented very different positions. Gibrat (1931) put forward a 'law of proportionate effect' – that the observed size distribution of firms may be viewed as the outcome of growth rates distributed according to chance factors. In the following year came Viner's classic re-statement of the Marshallian doctrine of costs and supply curves, in which the long run distribution of firm sizes (in an industry) is seen as the determinate and unique outcome of technological factors (Viner, 1932). While early contributions in either tradition remained a very long way apart, the ensuing literature from the 1950s onwards saw a developing interest in the economic foundations of the observed size distributions and a gradual convergence in the two approaches. Moreover, as I explore below, the literature increasingly saw technological change – rather than Viner's static conception of technology – as being at the heart of the issue.

The plan of the chapter is as follows. The next section considers Viner's statement of the Marshallian tradition regarding the observed size distribution of firms, followed
by an analysis of Gibrat’s law. The fourth section discusses the early empirical
literature exploring Gibrat’s Law. Section five then considers the economic models
that were proposed in response to the empirical literature and the gulf that existed
between the Marshallian tradition on the one hand and the law of proportionate effect
on the other. Section six then explores the re-examination of the law of proportionate
effect, concluding that it establishes a special role for the small firm sector which can
only be captured if it is viewed as an “agent of change” (Audretsch, 2002). Section
seven then develops this idea by considering the economic literature on
entrepreneurship. Section eight concludes.

2.2 The Marshallian Tradition

In the year that followed Gibrat discussion of the stochastic approach to firm size
Jacob Viner published his famous re-statement of the Marshallian analysis of the
relationships between costs curves and supply curves and – by implication – the
optimum and a corresponding distribution of firms’ sizes within any given industry
(Viner, 1932). The theory works under the assumption of product market competition,
i.e. price taking by individual firms.

For short run equilibrium, the marginal cost equals the average cost and at this point
the marginal cost curve must cut the average cost curve at the lowest point of the
latter. The equilibrium level in the short run will be when the marginal cost equals the
price. For long-run equilibrium not only must the marginal cost of output from
existent plant equal the price for each individual producer, but it must also equal the
average cost. Moreover, it is necessary not only that each producer shall be producing
his portion of the total output by what is for them, under existing conditions, the
optimum method, but that no other producer, whether already in the industry or not,
shall be in a position to provide an equivalent amount of output, in addition to what
they may already be contributing, at lower cost.

Viner’s theory argues that the internal economies of large-scale production are
primarily a long-run phenomenon, dependent on appropriate adjustment of scale of
plant to each successive increment to output. On the other hand, the theory suggests
that the increase of scale of plant would involve less efficient operation and
consequently higher unit costs (lower productivity). In short, the individual firm encounters (long run) decreasing returns to scale – the ‘U-shaped’ long run average costs curve familiar in textbooks.

Long run constant costs are theoretically conceivable under two kinds of circumstances. The first case is when each producer can vary his scale of production without affecting long run average cost. Viner (1932) argues however that the equilibrium under this type of constant cost conditions is only conceivable on the assumption of some departure from perfect competition. The second conceivable case of long run constant costs is represented by situations in which all of the concerns within the industry and an indefinite number of potential entrants to the industry can operate at long run minimum average costs, although each individual firm is subject to eventual decreasing returns to scale and hence increasing long-run average costs. Thus there is an optimum size to each firm, but firm specific elements mean that this does not have to be the same for all firms.

The concept of replication shows that if an integrated firm of larger size had higher unit costs, then it should be possible to split the firm into completely independent and separately managed units under single ownership, so that any such disadvantage is eliminated (Sutton, 1995). However, management factors and ‘control loss’ could lead to diseconomies of scale at the firm level (Williamson, 1967)\(^1\). Robinson (1934) and Coase (1937) argue that problems of coordination imposed a static limitation to firm size. On the other hand, Kaldor (1934) argues that problems of coordination vanished under truly static conditions, and hence only declining product demand curves or rising factor supply curves could be responsible for a static limitation to firm size.

One implication of the received Marshallian theory of particular interest concerns the entry and exit of firms. In a long-run equilibrium, ‘normal profits’ are competed away. Out of long run equilibrium, either profits or losses are being made which will induce either entry or exit. With other random factors also influencing ‘entry’ and ‘exit’, the emphasis is on net entry, and a cross sectional pattern of gross entry and

\(^1\) Section 2.5.1 (Lucas’ model) presents the relationship between the managerial talent and firm size.
exit across industries displaying a *negative* correlation. As we shall see, this is actually very different from what subsequent empirical analysis has revealed.

### 2.3 The stochastic approach to firm size: Gibrat and the law of proportionate effect.

In many respects diametrically opposed to the Marshallian approach outlined by Viner is the 'stochastic' approach to observed firm size, which begins with Gibrat's contribution. As Sutton (1997) has noted, Gibrat's work drew his inspiration from the earlier work of the astronomer Kapteyn who brought attention to the widespread phenomenon of skewed distribution patterns (Kapteyn and van Uven 1916) in biology. Indeed, subsequent work has emphasised the importance of skewed distribution patterns in other settings as well – e.g for sociological and economic phenomena (see (for example) Simon, 1955). Kapteyn took the view that such distributions could be viewed as a process - the outcome of a sequence of independent additive influences, in which each increment may be the result of a normally distributed function of the variable of interest. Gibrat believed that the 'simplest' function of size was the logarithm of size.

The simplest way of presenting Gibrat's law, following the work of Sutton who in turn follows Steindl (1965) runs as follows. Denote the size of the firm at time $t$ by $b_t$ and let the a random variable $\varepsilon_t$ denote the proportionate rate of growth between period $(t-1)$ and period $t$, so that

$$b_t - b_{t-1} = \varepsilon_t b_{t-1} \quad (2.1)$$

when

$$b_t = (1 + \varepsilon_t)b_{t-1} = b_0(1 + \varepsilon_1)(1 + \varepsilon_2)\ldots\ldots(1 + \varepsilon_t) \quad (2.2)$$

If we choose a short time period, then we can regard $\varepsilon_t$ as being small justifying the approximation $\log(1 + \varepsilon_t) \equiv \varepsilon_t$.

Taking logs, we thus obtain

$$\log b_t \equiv \log b_0 + \varepsilon_1 + \varepsilon_2 + \ldots \ldots + \varepsilon_t. \quad (2.3)$$
By assuming the increments $\varepsilon_t$ to be independent variables with mean $m$ and variance $\sigma^2$, we have that as $t \to \infty$, so the term $\log x_0$ will be small compared to $\log x_1$, that distribution of $\log x_1$ is approximated by a normal distribution with mean $m$, and variance $\sigma^2$.

\[ R(s) = \frac{1}{\sqrt{\pi}} \int_0^\infty e^{-s^2} ds \]  

(2.4)

If the distribution of $b$ is lognormal, the observations will lie on a straight line.

From Figure 2.1, it can be seen that the horizontal axis shows $\log(b - 1)$, where $b$ is a size class, measured by employment, and the vertical axis shows $s$, calculated from observed values of $R(s)$, the number of firms of size $s$ or greater, according to the formula:

Three elements of the Gibrat process as formulated above need to be stressed at this point. First, the process applies to a fixed population of firms. There are neither births nor deaths, an essential element (as we shall see) in any discussion of the role of the small firm sector. Second, the independence of each increment in the process implies that we should observe no serial correlation in growth rates. Finally, the variance of the growth rates should be invariant to firm size (i.e. no heteroscedasticity). Each of these elements has been subject to considerable empirical scrutiny as I discuss below.
2.4 Early Empirical Analysis of the Law of Proportionate Effect

The 'Keynesian revolution' and policy interest following the Second World War precluded much concern with the evolution of industrial structure for some time, although Kalecki (1945) pointed to the implausibility of the assumption regarding the variance of the distribution driving the Gibrat process. In the 1950s however, interest was revived by the pioneering work of Hart and Prais (1956) in the UK and that of Simon (1955) in the US.

Hart and Prais - looking at the quoted firms in the UK in the mining, manufacturing, and distribution sectors for selected years in the period 1885-1950 - argued that the lognormal distribution gave a good description of sizes of firms; more particularly they found that the distributions tend to have positive values of their parameters indicating that the curves are skewed to the right.

In the US, Simon (1955) showed how varying assumptions about the underlying stochastic process produced different - but nonetheless highly skewed distributions. Moreover, Simon and Bonini (1958) provided an early attempt to reconcile the Gibrat process with economic theory and were particularly concerned to relate the process to the underlying costs structures of industry. Here they drew on the influential study of Bain (1956) who suggested that for many industries, average costs decline rapidly with output and then above a certain critical size become approximately constant, and that for most industries this critical size is only a fairly small fraction of aggregate industry output.

Accordingly it is assumed that there is a minimum critical size, $S_m$, of firms in an industry, and those firms for firms above this size, unit costs are constant. It is for this class of firms for which the law of proportionate effect is appropriate. As the authors point out however, the log-normal distribution is only one possible steady-state distribution of the stochastic process they envisage which depends upon additional assumption(s). New firms are assumed to be born into the smallest size class at a (roughly) constant rate. In these circumstances the Yule distribution is the steady state
outcome of the process. Let $f(s)ds$ be the probability density of firms of size $s$ then the Yule distribution is given by:

$$f(s) = KB(s, \rho + 1)$$

(2.5)

where $B(s, \rho + 1)$ is the Beta function of $s$ and $(\rho + 1)$, $K$ is a normalizing constant, and $\rho$ is a parameter. If $s \to \infty$,

$$f(s) \to Ms^{-(\rho+1)}$$

(2.6)

where $M$ is constant. Equation 2.6 is the Pareto distribution. Hence the Pareto distribution approximates the Yule distribution in the upper tail\(^2\). This they argue provides a better predictor of the upper tail of the distribution of firm size than the log-normal distribution.

In a sequence of papers, Ijiri and Simon continued to explore economic reasons underpinning differences among the class of skewed distributions of firm size. In Ijiri and Simon (1964) the authors stress the importance of looking at the empirical relevance of the assumptions when examining the plausibility of stochastic models. They find that firm size distributions closely resemble the Yule distribution. In this process the expected growth rates of individual firms are assumed proportional to weights, where the weights are the time discounted sums of previous increments in size.

To study the concavity of the firm size distribution, Ijiri and Simon (1974) use empirical firm size data identify the explanations of this concavity. They argue that the ratio of the actual size to the theoretical size of a firm with a given rank may be called a "size variance" then, the downward concavity of the distribution shows an upward size variance for middle-rank firms relative to small or large-rank firms, where the size variance is measured from the Parato curve. One explanation is based on the autocorrelation of growth and the other based on mergers and acquisitions.

In terms of the present thesis however, the study by Mansfield (1962) is particularly relevant since it directly considers both the entry and exit of firms, both of which one of considerable importance for the small firm sector – not least, given the impact of Bain's classic 1956 study - of the role played by minimum efficient scale (see above).

\(^2\) The details of derivation of the Yule distribution can be found in Simon (1955).
While the original formulations of the Gibrat process did not explicitly consider entry and exit, Mansfield formulated three alternatives which made the role clearer. He then conducted a sequence of tests on these alternatives, by classifying firms by their initial size \( b' \), computing the frequency distribution of \( b'^{\Delta} / b' \), within each of these classes, and using of the chi-square distribution to determine whether the frequency distributions are the same in each class.

First, it can be hypothesized that the law holds for all firms, including those that exit, by supposing that those which exit have zero size at end of period – a proportionate growth rate of minus 1. Here, Mansfield notes that the preponderance of business failures or (more generally exits) is among the smallest size class in each of the industries he examined steel, petroleum and rubber tyres.

Second, an alternative to the above proposition is to suppose the law as holding for those firms which do not exit, i.e. it holds conditional upon survival. In 4 out of 10 tests based upon various sub-periods for the three industries, Mansfield found that this version of the hypothesis could be rejected.

Third, one could propose that the law holds for firms which are above minimum efficient scale, including or excluding firms that die. This is as Manfield notes essentially the variant proposed by Simon and Bonini (1958). In fact, Mansfield – using Bain’s estimates of minimum efficient scale - did not find much support for this version of the Gibrat hypothesis either. However, this was not in terms of the expected growth rate across different sizes of firm, but in terms of an inverse relationship between the variance of the growth rates and the size of firm – there is a larger variance of growth rates for smaller firms.

In addition to these formulations, another possibility noted by Mansfield is that the law could be applicable if the relevant growth rates were those which would have been observed if no firms had left the industry. Rather than exiting and achieving a growth rate of -1, these firms would probably have achieved low growth rates. Since exit is much more likely among small firms, the resultant sample censorship effect (not observing small firms with low growth rates) could account for Mansfield’s
finding that surviving small firms grew faster, since the slow growing smaller firms disappeared from the sample. Mansfield concludes, "Research should be carried out to develop and study more sophisticated models of the growth process." Some examples of the emerging theoretical work are discussed in the next section. The question of the sample censoring effect noted by Mansfield became central to the empirical analysis which began in the 1980s and which is discussed below.

Central to the present thesis is the topic of innovation and technological change. Here Mansfield specifically discusses (p.1035) the role of innovation in determining growth patterns among firms. Using his sample of firms developed for Mansfield (1962) compared growth rates of innovating firms with non-innovating firms among a specific size class in both the steel and petroleum industries finding that innovators grew faster than comparable non-innovators in both industries in each of several time periods. Moreover, the difference in growth rates was inversely related to size, small innovating firms receiving a greater impact on their post-innovation growth.

Outside the work of Mansfield, the main focus in this early phase of the empirical literature was on the implications of the Gibrat process for industrial concentration. The potentially negative relationship between firm size and the variance of the Gibrat process came in for particular attention, since this could account for considerable stability in the size rankings of the largest firms (Sutton, 1997; Ijiri and Simon, 1974). From the point of view of this thesis however, the important discovery was the fact that the entry of new firms was primarily in the smallest size class (McGowan, 1965; Ijiri and Simon 1971), and that they were more likely to exit (Mansfield 1962). This is reminiscent of Schumpeter and the concept of creative destruction - the relationship between entry, exit and the introduction of new technology (Schumpeter 1942). However, it is hard to trace any reference to Schumpeter at this stage, and even Mansfield's 1962 study contains no explicit reference. Rather, the attempt was made to 'explain' the Gibrat process and its variations with reference to economic models, i.e. models grounded in optimising behaviour. Before considering a 'second wave' of empirical research I now consider various relevant models which assist understanding of the role of the small firm sector.
In addition to standard profit maximising models, it is useful to draw attention here to other literatures which bring in other considerations. Foremost perhaps in its significance for the small firm sector are 'life cycle' effects. These have been studied at both the product and industry level as well as, at the level of the individual firm. In fact it was Marshall himself who raised the possibility that the traditional entrepreneurial firm might be subject to such a cycle.

2.5 Economic Models

The apparent inconsistency between the Marshallian approach and the emerging empirical literature organised around Gibrat's Law and the work of Bain on the cost structure of industry provides plenty of scope for economic models which can attempt to bring the two approaches closer together. As examples, I first consider the 1978 contribution of Lucas before moving on to the more dynamic model associated with Jovanovic (1982). This is followed by a discussion of the distinction between 'active' and 'passive' models of firm learning.

2.5.1 The Lucas Model

Well aware of the contradictory nature of the extant literature, Lucas (1978) uses a neoclassical model to study the size distribution of firms. The basic idea behind the model is that managerial talent acts as a multiplicative factor complementary to the standard two-factor production function. The model draws upon Manne's suggestions, in which a market for corporate control ensures that resources are optimally managed. Accordingly, Lucas assumes that at the outset that this allocation of assets

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3 Manne (1965) argues that the size of firm is a solution to the problem of allocating productive factors over managers of different ability so as to maximize output. He introduces several mechanisms for taking over the control of corporation. The three basic techniques are the proxy fight, direct purchase of shares, and mergers. Manne concludes that the costs, practical difficulties and legal consequences of these approaches vary widely. Moreover, he suggests that the selection of one or another or some combination of these techniques frequently represents a difficult strategic decision.
and employees over managers is perfectly carried out, before working out some of the implications of this hypothesis.\footnote{More details about Lucas’ model are available in appendix 2.1}

In fact Lucas uses a neoclassical model to study the size distribution of firms. He assumes that the “talent for managing” is unevenly distributed among agents, with firm output increasing in this talent (Kumar et al, 1999). Lucas (1978) developed a model which takes into account the distribution across individuals of managerial talent and that in turn determines distribution across firms (Aquilina et al, 2005). A firm is identified with a manager, the labour and capital under the manager’s control. The main ideas of this model are the decision an agent faces between becoming a manager or an employee, and the decision a manager faces on the optimal choice of the levels of employment and capital in his firm. In equilibrium, only the most talented become managers, and the unique size (number of employees) of the marginal manager’s firm minimizes average cost. Lucas (1978) assumes that those individuals who lie at the top end of the spectrum, i.e. the most talented managers, run firms and become entrepreneurs; the others prefer to be employees and work for them (Aquilina et al, 2005).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{lucas_model}
\caption{Lucas’ model}
\end{figure}

Source: Lucas (1978)
As shown in Appendix 2.1, Lucas' model determines the marginal manager's employment level \( l(z,w,u) \). This level of employment should satisfy the marginal - cost equals the price condition that is determined from equation A2.1.7 and the average cost equals the price condition for the marginal manager that is shown in equation (A2.1.9). These curves\(^5\) determine a unique employment level \( l(z,w,u) \) for the marginal manager: the level, which minimizes average cost.

If the elasticity of substitution between capital and labour in the production function is less than one, as an economy gets richer (i.e per capita capital increases) average firm size increases with per capita capital (You, 1995). This is due to the fact that an increase in per capita capital raises the wedge between the wage rate and the return to managerial activities, pushing individuals out of entrepreneurship and into paid work and therefore increasing average firm size. On the other hand, if the elasticity of substitution is larger than one then an increase in per capita capital decreases average firm size (Aquilina et al, 2005). Lucas finds a regression of firm size on per capita GNP based on US time series data reveals a positive relationship between the two variables.

2.5.2 The Jovanovic Model of Entry and 'Passive Learning'

In contrast to the Lucas model, which is rooted firmly in the neo-classical tradition, Jovanovic (1982) introduces a model of firm growth which specifically cites the contribution of Mansfield (1968), seeking to explain why smaller firms grow faster, but are more likely to fail. The model was and remains highly influential for the empirical literature which followed in the later 1980s. The model proposed is one of 'noisy selection'. Potential entrants know about average levels of productivity in an industry but are uncertain about their own post entry productivity level. In this section we introduce Jovanovic's model, which studies the selection and evolution of industry. The following figure shows an outline of this model.

\(^5\) Lucas' model depends on Viner's theory p.
From Figure 2.3 it can be seen that the relationship between the time and the output depends on the values of $C$ and $E$. $E$ is the expected present value of the firm’s fixed factor (its “managerial ability” or “advantageous location”) if it is employed in a different activity. The value of $E$ is the same for all firms in the industry regardless of how successful they are in the industry. This means that if the firm learns that it is efficient in this industry, this does not increase its estimated efficiency anywhere else (Jovanovic, 1982). $C$ is the value that is determined at time $t$, of staying in the industry for one period and then behaving optimally. The value of $C$ depends on prices of inputs. The boundary defines an “exit” region in which $C \leq E$ and a “continuation” region in which $C > E$.

Jovanovic’s model, in its simplest form, predicts that the annual growth rate of a firm will be a function of the accuracy of the manager’s predictions regarding their ability, as well as the price of the product (Rizov and Mathijs, 2001). Jovanovic made an early contribution to the literature on firm entry and learning processes, in his passive learning by doing model (You, 1995). This model is one of ‘noisy selection’ where entrants are uncertain about their own post entry productivity level, but they know about average levels of productivity in an industry but this model predicts that firm size and concentration are positively related to rates of return and that the correlation...
over time of rates of return is higher for large firms and in concentrated industries (Robinson et al, 2006). Jovanovic’s model has implications for the relationships between the growth rates and firm size and age. As a successful firm ages, its manager’s estimate of their efficiency becomes increasingly accurate. Therefore, on average old firms grow more slowly than younger ones (Rizov and Mathijs, 2001).

2.5.3 Active versus Passive Concepts of Firm Learning

The Jovanovic (1982) model is based on what is known as ‘passive’ learning — while the firm is uncertain about the true nature of its productivity, there is no adaptation post entry. This model helps explain the high hazard rates facing the (typically small) entrant. There is no scope however for post entry learning and adaptive behaviour by incumbents.

In the active learning model (Ericsson and Pakes, 1995), a firm explores its economic environment actively and invests to earn profits under competitive pressure from both within and outside an industry. A firm’s potential and actual profitability changes over time in response to the stochastic outcomes of the firm’s own investment, and those of other actors in the same market. The firm grows if successful but will exit if unsuccessful. In a follow-up study, Pakes and Ericsson (1998) tried to compare these two learning models (Jovanovic, 1982; Ericsson and Pakes, 1995) to see which of them is more appropriate for alternative data sets. Based on the evolution of size distribution of the surviving firms from the year 1979 cohort of Wisconsin firms in manufacturing and retailing over eight years. Pakes and Ericsson (1998) concluded that manufacturing firms were consistent with the active learning model while retailing firms were consistent with the passive learning model.

The models discussed above are only of course relevant for the analysis of the role of the small firm sector in a modern economy. However, further importance here is the development by economists of the role of the entrepreneur. This discussion is postponed to section 2.7.
The learning models of the firm discussed above proved very influential in the empirical literature which developed from the late 1980s. We consider the influence of these studies further in section 2.6

2.6 The ‘Second Wave’ of Empirical Research

As seen above, the early empirical literature on the size and growth of firms was only broadly consistent with static constant costs and Gibrat’s Law. In particular an absence of data on small firms left many unanswered questions. Beginning perhaps with the study by Evans (1987) these puzzles produced what might be termed a second wave of empirical research based upon large scale, census based data. The study by Evans like that of Hall (1987), is important because it explicitly considers the problems with Gibrat’s law identified in the early literature.

Evans’ study is based on census data for all firms in a sample of 100 4-digit US manufacturing industries (drawn from a population of 450). Importantly, in view of the early literature, the study controls for both size related heteroscedasticity and sample selection effects. The 100 industries comprise 22.2 percent of all 450 manufacturing industries. They contribute 24.2 percent of value added and account for 25.9 percent of employment. The ratio of capital to sales was 0.33 for the sample and 0.35 for all manufacturing industries.

Evans was able to reject Gibrat’s Law in 80% of industries; however, but he concluded that the severity of the failure does decrease with firm size. In addition to tests of the size growth relationship Evans also found evidence of firm ‘life-cycle’ effects since he found that there was an inverse relationship between growth and the age of the firm, indicative of the life-cycle effects discussed above.

Various studies have examined the size-growth relationship for the UK. (e.g. Kumar, 1985; Dunne and Hughes, 1994; Hart and Oulton, 1996). All of these studies find that smaller firms grow faster. The following table summarizes these studies and other studies in the UK, US and other countries.
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<td>US</td>
<td>Growth rate regression</td>
<td>Gibrat’s law fails although the severity of the failure decreases with firm size.</td>
</tr>
<tr>
<td>Hall, 1987</td>
<td>1778 manufacturing firms</td>
<td>US</td>
<td>Growth rate regression</td>
<td>Small firms grow faster</td>
</tr>
<tr>
<td>Boulakis, 1990</td>
<td>633 manufacturing industry from 1966 to 1986</td>
<td>Greece</td>
<td>Growth rate regression</td>
<td>Gibrat's law is rejected</td>
</tr>
<tr>
<td>Dunne and Hughes, 1994</td>
<td>2149 incumbent firms</td>
<td>UK</td>
<td>Logarithmic specification</td>
<td>Small firms grow faster</td>
</tr>
<tr>
<td>Hart and Oulton, 1996</td>
<td>87109 incumbent firms from 1989 to 1993</td>
<td>UK</td>
<td>Logarithmic specification</td>
<td>Small firms grow faster</td>
</tr>
<tr>
<td>Hart and Oulton, 1998</td>
<td>29000 independent firms divided into 12 size classes 1989-1993</td>
<td>UK</td>
<td>Logarithmic specification</td>
<td>Small firms grow more quickly than larger firms with more than 8 employees.</td>
</tr>
<tr>
<td>Hardwick and Adams, 2002</td>
<td>176 life insurance industry from 1987-1996</td>
<td>UK</td>
<td>Logarithmic specification</td>
<td>Gibrat's law is accepted for the entire period. Small firms grow faster.</td>
</tr>
<tr>
<td>Lotti et al, 2003</td>
<td>1889 new manufacturing firms from 1987 to 1993</td>
<td>Italy</td>
<td>Logarithmic specification</td>
<td>Gibrat's law fails to hold in the years immediately following start up.</td>
</tr>
</tbody>
</table>

Kumar (1985) used data on 1747 UK quoted firms in manufacturing and services over the period 1960-1976 to measure size in terms of net assets, physical assets, equity assets, employment and sales. Kumar controlled for persistence in growth and found
weak evidence of serial correlation. He tested a logarithmic specification of Gibrat's law and found coefficients significantly less than unity.

Dunne and Hughes (1994) made another important contribution to the investigation of Gibrat's law. They tested the law of proportionate effect over the periods 1975-1980 and 1980-1985 using 2149 quoted and unquoted UK firms belonging to 19 different manufacturing industries. They controlled for sample selection by using Evans' method. They found that small firms tend to grow faster than larger ones.

Hart and Oulton (1996) used data on 87109 UK incumbent firms over the period 1989-1993 and tested a logarithmic specification of Mansfield (1962) measuring size in terms of employment, sales and net assets. In all cases, they found an overall estimated coefficient of less than one. Moreover, they found that small firms grow more quickly than large ones. Unlike the previous studies, Hart and Oulton (1996) did not control for sample selection.

Another explanation for exit of new firms (entry) was provided by Audretsch (1995). He shows how new firms entered the industry not only increased output but also replicated of the large incumbent firms. This suggested that small firms, at least in some situations, were not about being smaller clones of the larger incumbents but rather about serving as agents of change of innovative activity (Audretsch, 2002).

Much of the theoretical literature on entry and exit depend on the Schumpeterian idea of “creative destruction” (Robinson et al, 2006). The idea of creative destruction means that firms that did not innovate before: it is called “widening” (Breschi et al, 2000). This idea means that entry of new firms due to introducing new products or new technologies that replaces old ones (Robinson et al 2006). Gorecki (1975) argues that the determinants of entry can be divided into two categories:

1- The conventionally considered barriers to entry such as capital requirements, economies of scale and product differentiation.

2- Entry including factors such as the rate of industry growth and the rate of profit.
Dunne et al (1988) argue that there are three models of entry:

1- The creation of a new firm.
2- A change in the product mix produced by each firm.
3- Buying a firm from an existing producer in the same industry.

Caves (1998) and Geroski (1995) presents some stylised facts about entry:

1- Entry is common. There are large numbers of firms that enter every year.
2- Most of the total variation in entry across industries and over time is within the industry variation rather than between industry variation.
3- Entry and exit rates are highly positively correlated.
4- Entry and exit both have growth size relations. Entry occurs into smaller size classes and the likelihood of unit's exit declines with its size.
5- The survival rate of most entrants is low.
6- Mean growth rates of surviving firms are dependent on their sizes but tend to decline with size.
7- Entry rates vary over time, coming in waves that often peak early in the life of many markets.

2.7 The Entrepreneur and the Small Firm as Agents of Change

The review of the literature on the size and growth of the firm conducted above leads to the conclusion that the small firm sector is rather different, and that, while smaller firms may to some extent be competing with their larger counterparts, their role is also to some extent complementary. In addition, because both entry and exit are so important in this sector, the implications of 'churn' for the performance of the sector as a whole cannot be ignored. To consider these ideas further, it is useful to introduce the concept of the entrepreneur and its relationship in the creation and generation of new technology, and how this may relate to the process of entry and exit.

According to Baumol, "the entrepreneur is at the same time one of the most intriguing and one of the most elusive characters in the cast that constitutes the subject of
economic analysis” (Baumol, 1968, p. 64). In fact as the following table reproduced from Deakins and Freel (2003) makes clear, while the concept of the entrepreneur dates back at least to the Irish banker Cantillon who wrote in Paris (1680-1734), there is no general agreement as to the entrepreneurial function.

<table>
<thead>
<tr>
<th>Writer</th>
<th>Key role of the entrepreneur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Say</td>
<td>Organizer of factors of production</td>
</tr>
<tr>
<td>Cantillon</td>
<td>Organizer of factors of production</td>
</tr>
<tr>
<td>Kirzner</td>
<td>Ability to spot opportunity</td>
</tr>
<tr>
<td>Schumpeter</td>
<td>Innovator</td>
</tr>
<tr>
<td>Knight</td>
<td>Risk-taker</td>
</tr>
<tr>
<td>Casson</td>
<td>Organizer of resources</td>
</tr>
<tr>
<td>Shackle</td>
<td>Creativity</td>
</tr>
</tbody>
</table>

Source: Deakins and Freel, 2003

From table 2.2, it can be seen that the role of entrepreneur differs across economists and over time. Say, Cantillon and Casson agree that entrepreneur is the organizer of production factors. On the other hand, Schumpeter, Knight and Shackle argue that the entrepreneur is not only organizer of production function but also can do as an innovator, risk-taker or creativity. There are however, two aspects of the entrepreneurial function which is common to most – if not all - writers on the subject: that it is a ‘dynamic’ function that operates in conditions of ‘uncertainty’: the entrepreneur creates change in response. Thus Cantillon for example operated in a world in which their income was unpredictable – organizing and purchasing factors of production at known prices, in order to create sales at uncertain prices (Spiegel, 1999)

Early writers however made no particular distinction between the managerial and entrepreneurial functions. The former function – discussed above – may be regarded as “taking charge of the activities and decisions encompassed in our traditional models” (Baumol 1968, p. 65). Entrepreneurs on the other hand have the “job to locate new ideas and to put them into effect” (ibid, p. 65). Typically therefore, the entrepreneur has been “read out of traditional models. There is no room for enterprise or initiative” (ibid, p.67). Leibenstein (1968) makes a similar point – the entrepreneur is essentially a “gap-filler”, perceiving opportunities when either input
output markets are incomplete. He therefore draws a sharp distinction between activities captured by a traditional ‘production function’, which relates marketed inputs to marketed outputs, and those which require an entrepreneurial function. His discussion of those inputs not well marketed suggests that these vary systematically with economic development. He lists the functions that the gaps needed to be filled as:

- Search, discovery and evaluate economic opportunities;
- Responsibility for management;
- Risk bearer;
- Responsibility for the motivational system of the firm;
- Marshalling and possible provision of financial resources;
- Translation of new information into new markets, techniques, and goods;
- Providing leadership for the work group.

The degree to which markets for these inputs may be expected to vary systematically according to the level of development and a variety of factors across both sectors and industries of the various functions. They can also vary as economies develop, with access to skilled labour and developed capital markets the gaps increasingly occur notes. However, the increasing emphasis in advanced economies is around the search, discovery and evaluation of economic opportunities organised around innovation – functions which come closest to Schumpeter’s conception of the innovative entrepreneur. As Temple (1998) however notes, the success of the Schumpeterian entrepreneur depends upon the principle of comparative advantage, the fewer the gaps they have to fill, the better able they will be to specialise in what they do best. As he goes on to show, much of the literature which has developed exploring the impact of geography upon innovation are based around allowing the entrepreneur to concentrate upon innovation. These include shared knowledge bases and “visions” concerning future technological trajectories, as well as various institutions and “norms of business behaviour”, which help prevent opportunism and allow the market economy to flourish (Temple, 1998). For a recent review of the impact of geography on innovation, see Asheim and Gertler (2005).
According to Schumpeter, entrepreneurs are economic agents whose functions are the carrying out of new combinations, the creative destruction of equilibrium, thereby preparing the ground for a superior state of equilibrium (Swoboda, 1983).

Schumpeter’s entrepreneur can be described by the following five qualities (Swoboda, 1983; Deakins and Freel, 2003):

1- The entrepreneur can be but need not to be the owner of the firm. Schumpeter distinguishes between four types of entrepreneurs: the sole, proprietor the industrial leader who still owns the majority of shares, the employed manager, and the founder.

2- The entrepreneur is an economic leader. His task is not to invent or to create new possibilities; he has to carry them out.

3- The entrepreneur as such is never a risk bearer; he only bears risk if he is also a capital owner. He is driven rather by the will to conquer.

4- The objective of the entrepreneur is not the maximization of the present value of his income.

5- Entrepreneurial activity is not a factor of production.

An important facet of the latter is the importance of motivation which cannot be simply summed up by profit maximisation. A well-known study of the small firm in the UK by Storey (1994) has for example stressed the importance of motivational factors – and their heterogeneity – as influences on the growth of small firms.
From Table 2.3 it can be noticed that there are 15 elements within the entrepreneur/resources component. These elements refer to the characteristics of the person who provides the managerial resources to the small firm the entrepreneur and his access to resources can be determined before the firm is established. There are another 6 elements referring to the decisions made by the entrepreneur when he starts his firm. Moreover, there are 14 elements that have been studied by researchers strategies which influence small firm growth. The main conclusion of Storey’s study is to demonstrate that the three components—the entrepreneur, the firm and strategy—all need to combine appropriately in order that the firm achieves rapid growth.

There are clearly links between this conception of the entrepreneur which is concerned with process and so-called “Austrian” approaches to economic analysis. For example, in his review of the Austrian approach, Kirzner refers to the “dynamic character of active markets” (p. 64) and of entrepreneurship as discovery (Kirzner 1997).

It is of course well known that Schumpeter argued that the role of the entrepreneur had changed in his lifetime, reacting to the growth of the large scale business corporation (Schumpeter, 1942; Langlois, 2003). Here he presented the idea of “the
obsolescence of the entrepreneurial function”, which means that the role of entrepreneur has changed in the capitalism and there is nothing left for entrepreneurs to do. According to the Schumpeterian hypothesis about the key role of large firms in advancing technology, many have found that the likelihood of a firm conducting R&D expenditure increases with firm size and approaches unity among large firms (Cohen, 1995).

The view of the mature Schumpeter has led to a considerable exploration of the relationships between firm size, market structure and innovation. The literature does not conclude that large firms have a monopoly or that ‘ex-post’ market power makes for more innovation. It can be seen from section 6.4 in this thesis that some studies have found a positive relationship between firm size and technological change (Scherer, 1965, 1984; Pavitt et al, 1987). On the other hand, there are some studies have identified no relationship or even a negative one (Cohen et al, 1987). Audretsch and Acs (1991) argue that there are two main reasons for these inconsistent findings. The first is that different measures have been used to quantify technical change (e.g. Patents and R&D). The second reason is that every study examining the relationship between firm size and technical change has had to use a truncated distribution of firm sizes. The important role that Schumpeter (1912) saw small firms playing is related to one of initiating ‘creative destruction’, through introduction of totally new products (Storey, 1994).

Schumpeter’s early emphasis on the entrepreneur made a clear association between technological opportunities, entrepreneurship and entry. To what extent can such a link be found? For the UK, two studies of the manufacturing industry by Geroski merit attention. Geroski (1989a) documented positive correlation between entry and the innovation rate in 3-digit UK manufacturing industries for the period 1976-1979. Geroski (1989b) examined the effect of entry and innovative activity on total factor productivity growth. Using a sample of 79 UK industries for the period 1976-1979, he concluded that the effects of foreign-based entry were much more innovation.
2.8 Conclusions: The Role of the Small Firm and the Case for a ‘Top-Down Approach’

This chapter has investigated the literature relating to the size and growth of firms. It has started with Viner’s theory which suggests that the increase of scale of plant would involve less efficient operation and consequently higher unit costs (lower productivity). This chapter also presented Lucas’ model, which studied the size distribution of firms. Lucas’ model equates a firm with a manager and posits decreasing effectiveness of management as the scale of production is increases. In this model the replication of the managerial input is ruled out. This model is more applicable to small firms as it equates a firm with a manager. Empirical studies exploring Gibrat’s Law generally show that small firms grow faster. Evans (1987) was able to reject Gibrat’s Law in 80% of industries; however, he concluded that the severity of the failure does decrease with firm size.

The review of the literature on the size and growth of the firm conducted above leads to the conclusion that the small firm sector is rather different, and that, while smaller firms may to some extent be competing with their larger counterparts, their role is also to some extent complementary. The important role that Schumpeter (1912) saw small firms playing is related to one of initiating ‘creative destruction’, through introduction of totally new products. The view of the mature Schumpeter has led to considerable exploration of the relationships between firm size, market structure and innovation. This Schumpeterian hypothesis will be studied in chapter 6 by using data for UK manufacturing firms. The analysis will be based on the Community Innovation Survey (CIS3) data.

After discussing the importance of the small firm sector in the literature in this chapter, it is essential to turn to an empirical analysis of the small firm sector in UK manufacturing. The forthcoming chapter will study the performance of the small firm sector in UK manufacturing by using historical data to analyses output, employment and labour productivity in UK manufacturing by size class and for manufacturing certain industries within the small firm sector.
Appendix 2.1
Lucas' model

Lucas' model of closed economy with a given quantity of capital \( K \) and a workforce of the size \( L \), which is homogeneous with respect to the productivity of each unit. These factors of production may be combined to produce \( q \) homogeneous units of output. This model considers separately the production technology and the managerial (or entrepreneurial) technology. Let \( f(l,k) \) be the output produced with \( l \) units of labour and \( k \) of capital, under normal management. Let this technology exhibit constant returns, so that we may write \( f(l,k) = l\phi(r) \), where \( r = k/l \), and \( \Phi : R^+ \to R^+ \) is a twice differentiable function, increasing and strictly concave.

The managerial technology involves two elements: variable skill or talent, and an element of diminishing returns to scale. First each agent is endowed with a managerial talent level \( x \), drawn from a fixed distribution \( \Gamma : R^+ \to (0,1) \). If the agent \( x \) manages resources \( l \) and \( k \), his firm produces \( xg(f(l,k)) \) units of output, where \( g : R^+ \to R^+ \) is a twice differentiable function, increasing and strictly concave, satisfying \( g(0) = 0 \). That is to say each firm consists of a single manager, \( l \) homogeneous employees, and \( k \) homogenous units of capital.

Lucas' model assumes that the entire distribution \( \Gamma \) of talent is always fully represented. Then an allocation of resources is described by two functions \( l(x) \) and \( k(x) \), giving the labour and capital managed by agent \( x \). For equilibrium allocations, it will be only the most talented who manage, so that there will exist a cut-off level \( z > 0 \) such that if \( x < z \), one is an employee, and, if \( x \geq z \), one is a manager. By an allocation, then, Lucas' model uses a number \( z \) and a pair of functions \( l(x), k(x) : R^+ \to R^+ \) such that \( l(x) = k(x) = 0 \) for \( x < z \) and \( l(x), k(x) > 0 \) for \( x \geq z \).

An allocation is feasible if it does not utilize more than available population \( L \) and capital \( K \). That is,
\[ 1 - \Gamma(z) + \int_{z}^{\infty} l(x) d\Gamma(x) \leq 1 \quad (A2.1.1) \]

The fraction engaged in managing plus the fraction engaged as employees sum to no more than one) and

\[ \int_{z}^{\infty} k(x) d\Gamma(x) \leq \frac{K}{L} = R. \quad (A2.1.2) \]

subject to (A2.1.1) and (A2.1.2).

In the Lagrangian associated with this variational problem, let \( w \) and \( u \) be the multipliers associated respectively with the constraints (A2.1.1) and (A2.1.2). Then the efficient allocation will also be the competitive equilibrium, with \( w \) and \( u \) being the equilibrium wage rate and rental price of capital. The income or rent to managers \( x > z \) will be the residual

\[ xg[f(l(x), k(x))] - wl(x) - uk(x). \quad (A2.1.3) \]

the first-order conditions for this maximum problem include:

\[ xg'[f]f_i(l(x), k(x)) = w, x \geq z. \quad (A2.1.4) \]

and

\[ xg'[f]f_k(l(x), k(x)) = u, x \geq z. \quad (A2.1.5) \]

so that the marginal products of both factors are equated across firms. Recalling that \( f(l, k) = l\phi(r) \), where \( r = k/l \), (A2.1.4) and (A2.1.5) imply

\[ \frac{\phi(r) - r\phi'(r)}{\phi'(r)} = \frac{w}{u}. \quad (A2.1.6) \]

Thus, given the ratio of factor prices, all firms have a common capital-labour ratio \( r(w/u) \) given implicitly by (A2.1.6). The function \( r(.) \) is strictly increasing. Given \( r \)

From (2.1.6), the equilibrium scale \( l(x) \) of firm \( x \) will be

\[ xg'[l(x)\phi(r)] \phi' = u, \quad (A2.1.7) \]

which gives employment as an implicit function

\[ l(x, w, u): x \geq z. \]

This function is increasing in \( x \) and \( u \) and decreasing in \( w \).

The first-order condition for the cut-off value \( z \) is
\[ zg[f(l(z), k(z))] = w[l + l(z)] + \alpha k(z). \]  \hspace{1cm} (A2.1.8)

For the marginal manager \( z \), as for all, \( k(z) = rl(z) \) with \( r \) given by (A2.1.6), so that (A2.1.8) may be written:

\[ zg[l(z)\phi(r)] = w + (w + ur)l(z) \]  \hspace{1cm} (A2.1.9)

The right-hand side of (A2.1.8) or (A2.1.9) is total cost and the left side is output. The marginal manager’s employment level must also satisfy the marginal cost equals price condition (A2.1.7), evaluated at \( x = z \). Then, given \( r \), (A2.1.7) and (A2.1.9) are two equations in \( z \) and \( l(z) \). Figure (2.2) in the main text displays these relationships in the \((l, z)\) plane.
Chapter Three

Historical data analysis: output, employment and labour productivity in UK manufacturing by size class

3.1 Introduction

Having discussed the ways in which economists have tackled the size distributions of firms within an industry in the previous chapter, I now present an analysis of the performance of the small firm sector in UK manufacturing over the longer term. This analysis is made possible by the publication of the post-war sequence of the Annual Censuses of Production (ACoP) and later the Annual Business Inquiry (ABI). This covers the period from 1958 to 2002. The main objective of this chapter is to present differences in output, employment, and labour productivity among employment size classes. I am also particularly concerned to establish the nature of output, employment and labour productivity differences among the industries in the small firm sector in UK manufacturing over the period 1973-2002.

This chapter introduces the analysis in two stages. The first stage depends on current prices and the second on constant prices. The importance of using current prices in the analysis is to show the relative importance of the small firm sector in UK manufacturing without using deflators that may be unsuitable for the small firm sector. The organization of this chapter is as follows: section two introduces the data sources, section three presents definitions of output and employment and section four shows output, employment and labour productivity using nominal values. Section five presents analysis of the data using output measured at constant prices after applying the deflators. The conclusion will be presented in section six.
3.2 Data sources

The data used was collected from the ACoP for the period of 1958-1997. The Census has always been the most important source of business data covering the manufacturing industries (Smith and Penneck, 2007). From the earliest ACoP until that for 1986, the reporting unit to the Census was the establishment. This was defined as the smallest unit which could provide the full range of data required for an economic Census. In 1987, for a number of administrative and statistical reasons, a new system of company-based reporting (the reporting unit) was introduced. Under the new system the reporting unit to the Census is generally the company (ACoP, 1990).

Not all establishments with employment below a certain size are sent a Census form (Oulton, 1997). From 1972 to 1994, the minimum number of employees was 20. Furthermore, until 1995, stratified random sampling was used with varying sampling fractions by size bands; the same fraction was used for all industries (ONS, 1996). Establishments employing 20-99 people have been sampled, with the sampling fractions varying from year to year (Oulton, 1997).

In 1995 the ACoP sample was redesigned. Under the new design, the sample was selected using stratified random sampling. Two stratification variables, employment size band and industry, were used as in the past. For production, industry stratification is at the four-digit SIC1992 for units with an employment greater than nine and by employment size bands: 10-19; 20-49; 50-99; 100-199 and 200+. The 1 in 1 band varies for each industry: nearly half of the industries for the 1995 inquiry have a 1 in 1 cut-off of 200+ employment; around 25% for both size bands 10-19 and 20-49 (ONS, 1996).

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1 The ACoP began in 1907 and continued at roughly five-yearly intervals until it became annual in 1970. ACoP information for this year onwards is available in the Annual Summary Volume up to and including 1997.
2 For more details, see Table 1(p. 48) in Oulton (1997).
3 For example in 1990 1 in 4 samples were drawn for establishments employing 20-49 and 1 in 2 samples for those employing 50-99.
Oulton (1997) argues that because of sampling and the exemption of smaller establishments, the number of selected establishments is only a fraction of the number of businesses. Moreover, Harris (2002) finds that the sample is biased towards larger establishments over the very smallest units. Thus, given the sampling of small firms and the selection for the financial information, this means that the financial information for small companies in the ACoP and ABI may vary considerably from year to year. This should be kept in mind when considering the results in this chapter.

Since 1998, these data have been available online from the ONS as part of the ABI, although the ABI covers all industries and not just those in production (manufacturing and energy). Businesses in the Channel Islands and the Isle of Man are excluded. The most important changes to the methods employed in the ABI were (Smith and Penneck, 2007):

- A change in the apportionment between regions.
- A change from sampling independently each year to having a 50 percent overlap between samples to reduce the response burden.
- Introducing of a new outlier adjustment procedure.

The ABI form has two parts, one dealing with employment data (ABI/1) and the other with accounting data (ABI/2). The sample size of ABI/1 in 1998 was 78,500. The ABI/2 sample size is slightly lower at about 75,500. The sample design is a stratified random one with three stratification dimensions. Strata are defined in terms of (Jones, 2000):

- Six employment size bands (1-9, 10-19, 20-49, 50-99, 100-249 and 250+).
- Region (England and Wales combined/ Scotland/ Northern Ireland).
- SIC industry (4-digit for England and Wales, 2/3/4 digit for Scotland).

From 1973 to 1979, Censuses were conducted on the 1968 Standard Industrial Classification (SIC). The Censuses for the years between 1980 and 1992 were

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4 In 1993, there were 16,797 selected establishments, compared with around 149,000 businesses in scope of the ACoP, so the fraction of the sample is 11.3% of the total population and has declined over time.

5 The ABI was set up in 1998 and is the combination of the Annual Census of Production & Construction (ACoP/ACoC) and the Distribution and Services Inquiries.
conducted based on the SIC 1980. From 1993 to 2002, Censuses were conducted on the SIC 19926. For the early Census years, I use data for 1958, 1963 and 1968. On the other hand, from 1973 and thereafter I use annual data. Appendix 3.1 presents the details of all of these classifications.

3.3 Definitions

According to the ACoP, employment, wages, gross output and net output can be defined as follows:

1- Employment

This is the average number of administrative, technical employees and operatives on the payroll and the number of working proprietors (self-employed) employed during the year of return. Employment data are available in ACoP and ABI for the total (full and part time) per head, whilst it is available for full and part time only in 1996 and 1997. The analysis in this chapter, chapter 4 and 5 depends on total (full and part time) employment per head.

2- Wages and salaries

This represents the amount paid during the year to administrative and technical employees and operatives. All overtime payments, bonuses, commissions, holiday pay and redundancy payments less any amounts reimbursed for this purpose from government sources are included. No deduction is made for income tax or employees’ national insurance contributions, etc. Payments to working proprietors, payments in kind, travelling expenses, lodging allowances and employers’ national insurance contributions are excluded.

3- Gross output

This represents the amount of value of total sales and work done plus the change during the year, stocks of work in progress and goods on hand for sale.

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6 For the years between 1998 and 2002, Censuses were conducted on the SIC 1997, which is very similar to the SIC 1992, but some 2-digit industries are aggregated together.
4- Net output

This is calculated by deducting from the gross output the cost of purchases of materials for use in production, fuel, and purchases of goods for factoring and the cost of industrial services received. Purchases are adjusted for changes during the year of stocks of materials, stores, and fuel.

3.4 Employment and nominal values of output, wages and labour productivity

This section presents data on employment, gross output and net output in nominal values and consists of two parts. The first section shows these values for UK manufacturing by employment size class between 1958 and 2002. The second section reports these values for the small firm sector for the 2-digit level between 1973 and 2002.

3.4.1 Employment and nominal values of output, wages and labour productivity in total UK manufacturing

This subsection aims to present shares of employment, purchases/gross output ratios, relative wages, and relative labour productivity in total UK manufacturing by employment size class for the period 1958-2002. Calculation of the shares shows the importance of every size class to total UK manufacturing. Moreover, these shares are calculated from nominal values, which may be more accurate for the small firm sector.

3.4.1.1 Employment shares in UK manufacturing

The following figures show employment in the whole UK manufacturing sector and by employment size class. Note that I have chosen specific years to show some of the changes that happened between these years if the data are not reported on an annual basis. I use 1958 and 2002 because there are the first and last years in the period of the analysis. However, I use 1968 as the last year in the five-yearly intervals and 1973 as the first year in the annual intervals (which is the first year available in my dataset). In between these years, I also use data from 1979 as this year saw a decline in
productivity and 1990 as this year had very high level of productivity growth. Thus, the years 1973, 1979 and 1990 represent important points in the economic cycle.

From Figure 3.1a it can be observed that employment in UK manufacturing increased from 1958 to 1973 and steadily decreased thereafter; however, the overall picture hides important differences by size band. In particular, Figure 3.1b shows that employment slightly increased over the whole period in the 1-99 size class, although there has not been much change since 1973. On the other hand, employment decreased substantially over time for the largest firms (those with at least 500
workers), while employment has been more stable for the other size classes, although still generally on the decline. The fall in employment for large firms has been particularly dramatic, decreasing from over 6 million workers in 1968 to just over a 1 million in 2002. In this year manufacturing employment in small firms also exceeded that in very large firms.

Table 3.1 Average annual growth rates of employment in UK manufacturing, 1958-2002

<table>
<thead>
<tr>
<th>Period</th>
<th>Total</th>
<th>1-99</th>
<th>100-199</th>
<th>200-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958-68</td>
<td>1.40</td>
<td>-1.87</td>
<td>-3.71</td>
<td>-3.80</td>
<td>3.23</td>
</tr>
<tr>
<td>1973-79</td>
<td>-1.57</td>
<td>0.25</td>
<td>-1.13</td>
<td>-1.77</td>
<td>-2.22</td>
</tr>
<tr>
<td>1979-90</td>
<td>-3.02</td>
<td>0.00</td>
<td>-1.64</td>
<td>-1.00</td>
<td>-5.61</td>
</tr>
<tr>
<td>1990-2002</td>
<td>-2.90</td>
<td>-0.56</td>
<td>-2.83</td>
<td>-4.47</td>
<td>-4.18</td>
</tr>
<tr>
<td>1958-2002</td>
<td>-1.74</td>
<td>0.24</td>
<td>-0.98</td>
<td>-1.03</td>
<td>-3.12</td>
</tr>
<tr>
<td>1973-2002</td>
<td>-2.67</td>
<td>-0.18</td>
<td>-2.03</td>
<td>-2.61</td>
<td>-4.32</td>
</tr>
</tbody>
</table>


In order to examine changes over time in more detail, Table 3.1 reports average employment growth rates by size band. From the table it can be seen that average employment growth rates were negative in all of the periods except for most size bands for 1968-73. However, average employment growth rates were also positive in 1973-79 and zero between 1979 and 1990 for small firms. The largest decline occurred for the largest size class between 1968 and 1973 when employment fell by 8.3% per annum. On the other hand, the largest increase occurred for the size band 200-499 between the same years (1968 and 1973). In general, Table 3.1 implies that there has been a marked change in the size distribution of firms in manufacturing. This shows the continuation of the trend noted by Oulton (1987), who argues that the number of extremely large firms (1000 employees or more) and the proportion of the manufacturing force employed by them has declined significantly.

Figure 3.2 further emphasizes the shift in UK manufacturing towards small firms by presenting employment shares in UK manufacturing by employment size class.
From Figure 3.2 it can again be seen that the shares of employment has increased over time for the 1-99 size class, paralleled by a large decline in the share of the largest establishments (more than 500 employees), while the shares have been relatively stable for the other size classes. This decrease in the share of the largest firms is related to globalisation and closures. In particular, the share of employment accounted for by the small firm sector increased from 16% in 1958 to 38% in 2002, whilst this share decreased from 64% in 1958 to 34% in 2002 for the very large firm sector. Thus the small firm sector in UK manufacturing is now more important in employment terms than very large firms.

3.4.1.2 Relative wages and salaries in UK manufacturing

However, employment is only one aspect so I will now go on to look at other indicators, starting with wages. Relative wages are measured by dividing wages per head in each size class by wages per head in manufacturing as a whole. Figure 3.3 shows relative wages and salaries in the UK manufacturing sector by employment size class.
From Figure 3.3 it can be seen that relative wages and salaries have increased over time for firms in the largest size class despite the declining levels of employment, whilst relative wages have been fairly constant for the other size classes. Oulton (1987) argues that there is a strong positive relationship between firm size and the average wage. For example, relative wages and salaries for the small firm sector decreased from 84% in 1973 to 80% in 2002, compared with an increase from 109% in 1973 to 122% in 2002 for the large firm sector.

3.4.1.3 Purchases / gross output ratios in UK manufacturing

In order to get some indication of the importance of inputs for UK manufacturing, figure 3.4a shows the ratios of purchases to gross output in total UK manufacturing.
From Figure 3.4a it can be observed that the ratio of purchases to gross output are quite constant over time, although this ratio has decreased from well over 60% in the 1970s to 55% in the early 2000s. Figure 3.4b reports these ratios for each of the size classes. In general, these ratios are relatively stable over time by size class. However, there has been a reduction in the ratio of purchases to gross output for the small firm sector, falling from 56% in 1973 to 46% in 2002. For the largest firms it has remained around 60% in each of the time periods. It can be noticed that the large firms depend on the other size classes to get their inputs as the ratio of purchases to gross output are 60% for large firm sector, whilst it is 46% for the small firm sector.
3.4.1.4 Relative labour productivity in UK manufacturing

Labour productivity is the most widely used measure of productivity in the manufacturing sector (Ahmed and Wilder, 2001). Labour productivity measures average products of labour and measures the productivity of the labour unit. There are many studies that have researched labour productivity in small and large firms in the manufacturing sector (see for example Miller, 1980 and Idson and Oi, 1999 in the US and Waite, 1973; Oulton, 1987 in the UK). In this section I measure labour productivity by calculating the relative net output per head at current prices for every size class. This method uses the following equation:

\[ RNOP_i = \frac{NOP_i}{\sum NO / \sum EMP} \]  

(3.1)

where \( RNOP_i \) is the relative net output per head for size class \( i \), \( NOP_i \) is net output per head for the class \( i \) and \( \sum NO \) and \( \sum EMP \) represent the total of net output and total of employment for every year, respectively. Figure 3.5 shows relative labour productivity in total UK manufacturing by employment size class.

![Figure 3.5 Relative labour productivity * in UK manufacturing by employment size class, 1958-2002](image)


* Relative labour productivity = net output per head in every size class/ net output per head in the manufacturing sector

From Figure 3.5 it can be seen that the relative labour productivity of the very large firm sector has increased over time, and has exceeded that of the small and medium sized sectors throughout the period with the differences generally widening, especially
since the mid 1990s. Relative labour productivity in the small firm sector has decreased over time although it has recovered somewhat since the late 1990s. On the other hand, the relative labour productivity of the medium firm sector has been relatively stable over time.

3.4.1.5 Competitiveness in UK manufacturing

Competitiveness can be measured by using relative unit labour costs. Unit labour costs are calculated by dividing wages per head by labour productivity. Relative unit labour costs are calculated by dividing unit labour costs for every size class by unit labour costs for the manufacturing sector. This ratio will enable us to compare the relative cost of employment for every size class.

Figure 3.6 Competitiveness* in UK manufacturing by employment size class, 1973-2002

*Competitiveness is measured by calculating relative unit labour costs. Relative unit labour cost = (wages per head / net output per head in every size class) / (wages per head/ net output per head in the total manufacturing)

Figure 3.6 shows that the relative unit labour costs of the small firm sector increased from 1973 to 1990 and decreased after that. Unit labour costs in the large firm sector decreased from 1973 to 1990 and increased after that. The decrease of relative unit labour costs in the small firm sector in 1990s related to the decrease in relative wages being greater than the decrease in relative productivity. In contrast, following the productivity gains in the large firm sector in 1980s (through labour shedding) relative wages have outgrown relative productivity in this sector.
3.4.2 Employment and nominal values of wages and output in the small firm sector in UK manufacturing by consistently defined industries

This section aims to present details of employment, gross output, wages and relative labour productivity in the small firm sector in UK manufacturing at the 2 digit level for the period covering 1973-2002. The consistently defined industries are the textile, food, paper, chemicals, electrical and transport equipment industries. Please see table A3.5 for details of how these industries have been defined over time. These industries represented about 60% of total employment and 66% of total gross output in UK manufacturing in 2002 (ABI, 2002). I calculate the variable share as follows:

\[ X_{Sy} = \frac{X_y}{X_j} \]

where \( X_{Sy} \) is the variable share in industry \( j \) for size class \( i \), \( X_y \) is the variable value in industry \( j \) for size class \( i \), and \( X_j \) is the variable value in industry \( j \). The use of shares helps us to compare the performance of the small firm sector in each industry.

3.4.2.1 Employment shares of the small firm sector

Figure 3.7a reports employment in the small firm sector as a whole for UK manufacturing over the period 1958-2002.
From Figure 3.7a, it can be seen that employment decreased from almost 1.2 million in 1958 to less than 1 million in 1968 before increasing to 1.4 million in 1973. After 1973 it remained relatively constant until 1993 but then increased quite sharply until 1996. Since 1996 manufacturing employment in the small firm sector has decreased steadily. Thus this figure provides more detail on what is happening in the small firm sector compared to Figure 3.1b. For example, there has been a reduction in around 400,000 jobs in small manufacturing firms from its peak in 1996 to 2002, mirroring the decline in manufacturing more generally in recent years.
Figure 3.7b shows that employment decreased between 1973 and 2002 in all industries except in the paper and electrical industries. Employment within small firms in the paper industry increased from 153,000 in 1973 to 190,000 in 2002 and from 54,000 in 1973 to 135,000 in 2002 in the electrical industry. The largest employment fall was seen in textiles, where employment fell from around 250,000 in 1973 to under 100,000 in 2002. In contrast, employment in chemicals, food and transport equipment industries have remained relatively constant.

Table 3.2 reports the average growth rates of employment in the small firm sector in UK manufacturing.

<table>
<thead>
<tr>
<th>Period</th>
<th>Textiles</th>
<th>Food</th>
<th>Paper</th>
<th>Chemicals</th>
<th>Electrical</th>
<th>Transport equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-79</td>
<td>-1.76</td>
<td>-0.10</td>
<td>0.23</td>
<td>1.07</td>
<td>2.36</td>
<td>1.52</td>
</tr>
<tr>
<td>1979-90</td>
<td>-2.59</td>
<td>0.34</td>
<td>1.69</td>
<td>-0.71</td>
<td>5.11</td>
<td>-1.55</td>
</tr>
<tr>
<td>1990-2002</td>
<td>-4.47</td>
<td>-1.59</td>
<td>0.15</td>
<td>0.50</td>
<td>1.91</td>
<td>0.18</td>
</tr>
<tr>
<td>1973-2002</td>
<td>-3.20</td>
<td>-0.55</td>
<td>0.75</td>
<td>0.16</td>
<td>3.21</td>
<td>-0.20</td>
</tr>
</tbody>
</table>


From Table 3.2, it can be observed that the paper and electrical industries had positive growth rates of employment during each period. In contrast, employment growth rates were negative in each period for textiles and negative in the first and third periods for the food industry.

The employment share of the small firm sector differs considerably between the industries. Figure 3.8 shows the key differences. The share of employment in the small firm sector is calculated by dividing the total employment in the small firm sector by total employment, which is done for every industry.
From Figure 3.8, it can be seen that the employment share of small firms in the textile industry increased from 20% in 1973 to 51% in 2002. The employment share of small firms in the electrical industry increased from 5% in 1973 to 30% in 2002; whilst small firms in the chemicals industry remained relatively constant. According to these employment shares, the role of the small firm sector in the food, transport equipment, and paper industries has also increased quite substantially over time.

3.4.2.2 Relative wages and salaries in the small firm sector

The next task is to establish whether relative wages and salaries differ across the industries within the small firm sector. Relative wages are calculated by dividing wages per head in the small firm sector by wages per head in the industry as a whole. Figure 3.9 shows these differences.
From Figure 3.9 it can be seen that the relative wages and salaries of the textile industry increased from 86% in 1973 to 96% in 1990 and had decreased to 87% in 2002. Whilst the ratios increased in paper industry from 101% in 1973 to 121% in 1990 before falling back slightly by 2002. The increase in this ratio in the paper industry is related to the increase in both of employment share (see Figure 3.8) and wage share (for example, the wage share increased from 19% in 1973 to 38% in 1990). On the other hand, the relative wages in chemicals industry decreased from 84% in 1973 to 71% in 2002 and also fell in the electrical and transport equipment industries, but stayed fairly constant in food.

**3.4.2.3 Purchases/gross output ratios in the small firm sector**

The extent to which purchases/ gross output ratios differ across the industries within the small firm sector is shown in Figure 3.10.
From figure 3.10 it can be seen that the purchases/gross output variation within the textile industry decreased from 60% in 1973 to 44% in 2002; while it has been highest in the food sector in each period, but it did fall from almost 80% in 1979 to around 65% in 2002. In contrast, the ratios are quite stable in the other industries.

3.4.2.4 Relative labour productivity in the small firm sector

In this section I measure the labour productivity by calculating the relative net output per head at current prices for every industry. This method uses the following equation:

\[ RNOP_{ij} = \frac{NOP_{ij}}{NOP}, \quad (3.2) \]

where \( RNOP_{ij} \) is the relative net output per head in the size class \( i \) in the industry \( j \), \( NOP_{ij} \) is net output per head in the size class \( i \) in the industry \( j \), and \( NOP \) represents the net output for total manufacturing. Figure 3.11 shows the relative labour productivity in the 6 industries.
Figure 3.11 shows that the relative labour productivity in the chemicals industry has exceeded that of the other industries, although the differences have fallen over time. In contrast, relative productivity has risen in textiles (where employment has fallen dramatically) and transport equipment in recent years. In contrast, relative labour productivity has fallen in food but remained more stable in the paper and electrical industries. To analyse these changes in more detail I will now decompose relative labour productivity into two parts as follows:

\[
\frac{NOP_j}{NOP} = \frac{NOP_{j,*}}{NOP_j} \times \frac{NOP_j}{NOP},
\]  

(3.3)

where \( NOP_j \) is net output per head in the industry \( j \). If we take logs we can decompose the percentage difference into the size effect (the difference between each size class) and the second term represents the percentage difference between the whole industry and total manufacturing as a whole. The results of applying this equation to the data are presented in Figures 3.12a, b, and c.
Figure 3.12a Total effect* of labour productivity differentials in UK manufacturing, 1973-2002


*Total effect = log (net output per head in the small firm sector in specific industry) - log (net output per head in the total manufacturing)

Consistent with Figure 3.11, Figure 3.12a shows that the total effect is generally negative in all industries except for the chemicals industry, although the positive advantage has declined in this industry over time. The food industry had a positive total effect until 1982, but it had a negative effect after that. The textile industry has the highest negative total effect but this has diminished substantially in recent years.

To complete the analysis, Figure 3.12b shows the industry effect.

Figure 3.12b Industry effect* of labour productivity differentials in UK manufacturing, 1973-2002


*Industry effect = log (net output per head in specific industry) - log (net output per head in the total manufacturing)
While the industry effect (percentage difference between the whole industry and manufacturing as a whole) has a positive effect in paper industry, it has declined over time. The chemicals industry has a positive industry effect, which is consistent with the high levels of productivity in the industry as a whole. In contrast, the textile industry has the highest negative industry effect. The food industry has a positive industry effect until 2000, but it has declined over time and became negative in 2002.

Figure 3.12c Size effect* of labour productivity differentials in UK manufacturing, 1973-2002

*Size effect = the log of ( net output per head in the small firm sector in specific industry/ net output per head in the industry)

Figure 3.12c shows that the size effect (percentage difference between each size class) has a negative effect in all industries. This indicates that the lower productivity for the small firm sector is displayed across all industries. However, there are some variations in the extent of the disadvantage across industries. The paper industry had the highest negative size effect in 1973 and it has generally decreased over time, whilst in 2002 the chemicals industry has the highest negative size effect. The increasing size effect in this later industry is particularly noticeable, while there also trends to be a large negative size effect in the food industry.

3.4.2.5 Competitiveness in the small firm sector

Competitiveness can again be measured by using relative unit labour costs. Unit labour costs are calculated by dividing the wages per head by labour productivity per head. Relative unit labour costs are calculated by dividing the unit labour costs in the small firm sector in each industry by the unit labour costs for the industry. These
ratios will help us to compare the relative cost of employment for every industry in the small firm-manufacturing sector.

Figure 3.13 Competitiveness* in the small firm sector in UK manufacturing, 1973-2002

![Graph showing competitiveness in different industries over time.]


*Competitiveness is measured by calculating relative unit labour costs.

Relative unit labour cost = \( \frac{\text{wages per head}}{\text{net output per head in the small firm sector in specific industry}} \) / \( \frac{\text{wages per head}}{\text{net output per head in the industry}} \)

Figure 3.13 shows that relative unit labour costs in the textile industry decreased from 100% in 1973 to 88% in 2002, while relative unit labour costs in the paper industry increased from 91% in 1973 to 110% in 2002. This implies that productivity gains in this industry were not enough to offset the wage increases. On the other hand, relative unit labour costs in chemicals increased from 102% in 1973 to 120% in 1990, but still remained relatively uncompetitive in 2002 since it had only decreased to 105%.

3.5 Further analysis of net output

In this section labour productivity is measured by using the real value of the net output per head in UK manufacturing by employment size class and across the six consistently defined industries in the small firm sector in UK manufacturing for 1973-2002. Before presenting net output at constant prices, the following figures show the net output in current prices in UK manufacturing by employment size class and across the small firm sector in UK manufacturing.
3.5.1 Net output using current prices

Figure 3.14 shows net output per head at current prices.

From Figure 3.14 it can be seen that net output per head is the highest for very large firms (more than 500 employees) and lowest for the small firm sector (less than 100 employees) in 2002. In this year, net output was more than 55% higher amongst large manufacturing firms. However, this has not always been the case since in 1968 the net output per head was greatest amongst firms with 200-499 workers. Even in 1979 the differences between the size classes was fairly small.
From Figure 3.15 it can be seen that the highest-level of net output per head in each period in the small firm-manufacturing sector is in the chemicals industry followed fairly closely by the paper industry. The lowest level of net output in each of the years belongs to the textiles industry. The gaps also appear to have widened over time.

3.5.2 Net output using constant prices

I use only the one-deflator method \(^7\) (Stoneman and Francis, 1994) to calculate net output per head. This deflator is the producer price index for total manufacturing output \(^8\) PLLU (price index) for 2000.

![Figure 3.16 Net output per head at constant prices in UK manufacturing, 1958-2002](image)


Figure 3.16 shows that real labour productivity for each employment size class has increased over time. The labour productivity of the small firm sector is much smaller than that of the large firm sector in each year. However, the difference in net output per head between the small firm sector and large firm sector has also increased over time, for example in 2002; net output in small firm sector was more than 55% lower than that of large manufacturing firms compared with 30% in 1958. Although the large

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\(^7\) I have also measured the net output by using the double deflator method. In general, growth rates of productivity by using double deflation are lower than that using the single-deflator method. However, I also found that the results of the average growth rate are completely different from the one-deflator method and are not consistent with the previous studies, thus these are not reported.

\(^8\) See Oulton (1994).
differences by size band do not become that apparent until 1990 and firms with 200-499 workers even had a higher labour productivity than very large firms in 1968. This does not mean a lower level of TFP for small firms, since small firms in general have lower capital-labour ratios. The next chapter compares TFP growth by size class. Figure 3.17 shows labour productivity in the small firm sector in UK industries.


From Figure 3.17 it can be observed that real labour productivity for all of the industries in the small firm manufacturing sector has increased over time. In particular the chemicals industry has the highest level of net output per head amongst the small firm-manufacturing sectors. The lowest level of net output per head in each of the years belongs to the textiles industry.

Table 3.3 shows the growth rate of real net output per head in UK manufacturing by employment size class.
### Table 3.3 Average annual growth rates of the real net output per head in UK manufacturing, 1973-2002

<table>
<thead>
<tr>
<th>Period</th>
<th>Total</th>
<th>1-99</th>
<th>100-199</th>
<th>200-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958-68</td>
<td>1.87</td>
<td>3.52</td>
<td>3.27</td>
<td>3.37</td>
<td>1.13</td>
</tr>
<tr>
<td>1968-73</td>
<td>2.35</td>
<td>1.01</td>
<td>0.67</td>
<td>1.09</td>
<td>3.79</td>
</tr>
<tr>
<td>1973-79</td>
<td>0.93</td>
<td>1.35</td>
<td>1.21</td>
<td>1.26</td>
<td>0.80</td>
</tr>
<tr>
<td>1979-90</td>
<td>4.02</td>
<td>3.23</td>
<td>3.71</td>
<td>2.95</td>
<td>5.36</td>
</tr>
<tr>
<td>1990-2002</td>
<td>3.33</td>
<td>3.51</td>
<td>2.90</td>
<td>3.82</td>
<td>3.67</td>
</tr>
<tr>
<td>1958-2002</td>
<td>2.72</td>
<td>2.62</td>
<td>2.70</td>
<td>2.84</td>
<td>3.12</td>
</tr>
<tr>
<td>1973-2002</td>
<td>3.09</td>
<td>2.95</td>
<td>2.85</td>
<td>2.96</td>
<td>3.70</td>
</tr>
</tbody>
</table>


From Table 3.3, it can be seen that average growth rates for the period 1963-1968 were higher in the smaller size classes, but this was reversed in the following period with average annual growth rates of 3.8% in the large firm sector and 1% in the small firm sector. In contrast, growth rates were much lower for the period 1973-1979 especially amongst large firms. Average growth rates were very high in the 1980s; for example, the average annual productivity growth rate was 3.23% in the small firm sector and 5.36% in the large firm sector for the period 1979-90. These have remained steady since then. Thus Table 3.3 shows that average growth rates are highest in the large firm sector for all the periods except the period 1958-68 where the average growth rate was 3.52% in the small firm sector and 1.13% in the large firm sector and in the period 1973-79 average growth rate was 0.80% in the large firm sector and 0.93% in the small firm sector (since 1990, there have also been fewer differences by size class). In general, there has been a considerable improvement in labour productivity in UK manufacturing since the 1980s. Again, this accords with other studies, for example, Oulton (1987) finds that the average growth rate of the net output per head rose from 0.7% between 1973 and 1979 to 4.1% between 1979 and 1985 for the firms which have 1000 employees and more.
From Table 3.4, it can be seen that the small firm sector has high growth rates in the textiles, electrical and transport equipment industries. On the other hand, the food and chemicals industries had lower growth rates; for example, the average growth rate for the period 1973-2002 was 1.66% in the food industry compared to 3.64% in the transport equipment industry. Growth rates were generally highest in the final sub period and lowest in the first.

### 3.6 Conclusion

This chapter has aimed to present a historical overview of employment per head\(^9\), wages and output in UK manufacturing by employment size class for 1958-2002, and in the small firm sector for certain industries for 1973-2002. Not all data are available for the years 1958, 1963 and 1968.

The analysis has shown that the share of employment has increased over time for the small firm sector in UK manufacturing. On the other hand, relative labour productivity in the large firm sector has risen more rapidly than in the small firm sector. I have also decomposed the percentage difference in the labour productivity into the size effect (the difference between each size class) and the industry effect (the difference between the whole industry and manufacturing as a whole) for certain industries in the small firm sector. The results show that the size effect is negative in all industries and the food and chemicals industries have the highest negative size effects. While the industry effect has a positive effect in the paper and chemicals industries, it has tended to be highly negative in the textile industry.

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\(^9\) Employment data here are available for total (full and part time) per head.
Within the small firm sector, the textile industry has seen the steepest decline in employment over the past three decades. On the other hand, the paper and electrical industries have seen their shares of employment increase. Moreover, the paper industry had increased its relative labour productivity over time but not to the same extent that wages have increased; as a result, the industry has became less competitive.

As with the nominal values, the real value of net output per head for the small firm sector is smaller than that for the large firm sector. However, in this chapter, I have measured productivity by calculating labour productivity, which was done by initially using relative nominal net output per head. The results showed that relative labour productivity of the large firm sector increased more rapidly over time, and has exceeded that seen in the small and medium sized sectors. In the following chapter, I will break down the growth rate of labour productivity into two components: the growth rate of TFP and the growth rate of factor substitution, which uses both labour and the capital stock.
Appendix 3.1
Standard Industrial Classification (SIC)

The SIC has changed three times (in 1980, in 1992 and in 1997) during the period 1973-2002, making disaggregating difficult. This section will present the classifications for the two-digit level for the SIC 1968 (which covers the period 1973-79), SIC 1980 (which covers the period 1980-92), SIC 1992 (which covers the period 1993-97) and SIC 1997 (which covers the period 1998-2002). The following four tables report two-digit classification for every SIC.

<table>
<thead>
<tr>
<th>Table A3.1 Standard Industrial Classification 1968</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing</strong></td>
</tr>
<tr>
<td>Manufacture of food, beverages and tobacco</td>
</tr>
<tr>
<td>Manufacture of coal and petroleum products</td>
</tr>
<tr>
<td>Manufacture of chemicals and allied products</td>
</tr>
<tr>
<td>Manufacture of metal</td>
</tr>
<tr>
<td>Manufacture of mechanical engineering</td>
</tr>
<tr>
<td>Manufacture of instrument engineering</td>
</tr>
<tr>
<td>Manufacture of electrical engineering</td>
</tr>
<tr>
<td>Manufacture of shipbuilding and marine engineering</td>
</tr>
<tr>
<td>Manufacture of vehicles</td>
</tr>
<tr>
<td>Manufacture of metal goods not elsewhere specified</td>
</tr>
<tr>
<td>Manufacture of textiles</td>
</tr>
<tr>
<td>Manufacture of leather and leather products</td>
</tr>
<tr>
<td>Manufacture of clothing and footwear</td>
</tr>
<tr>
<td>Manufacture of bricks, pottery, glass, cement</td>
</tr>
<tr>
<td>Manufacture of timber, furniture</td>
</tr>
<tr>
<td>Manufacture of paper and publishing</td>
</tr>
<tr>
<td>Other manufacturing industries</td>
</tr>
</tbody>
</table>

Source: ACoP (1968)
<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>SIC 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture of metal</td>
<td>22</td>
</tr>
<tr>
<td>Manufacture of extraction of mineral not elsewhere specified</td>
<td>23</td>
</tr>
<tr>
<td>Manufacture of non-metallic mineral products</td>
<td>24</td>
</tr>
<tr>
<td>Manufacture of chemical</td>
<td>25</td>
</tr>
<tr>
<td>Manufacture of man-made fibres</td>
<td>26</td>
</tr>
<tr>
<td>Manufacture of metal goods not elsewhere specified</td>
<td>31</td>
</tr>
<tr>
<td>Manufacture of mechanical engineering</td>
<td>32</td>
</tr>
<tr>
<td>Manufacturing of office machinery and data processing</td>
<td>33</td>
</tr>
<tr>
<td>Manufacture of electrical and electronic engineering</td>
<td>34</td>
</tr>
<tr>
<td>Manufacture of motor vehicles and parts thereof</td>
<td>35</td>
</tr>
<tr>
<td>Manufacture of other transport equipment</td>
<td>36</td>
</tr>
<tr>
<td>Manufacture of instrument engineering</td>
<td>37</td>
</tr>
<tr>
<td>Manufacture of food, beverages and tobacco</td>
<td>41/42</td>
</tr>
<tr>
<td>Manufacture of textile</td>
<td>43</td>
</tr>
<tr>
<td>Manufacture of leather and leather products</td>
<td>44</td>
</tr>
<tr>
<td>Manufacture of footwear and clothing industries</td>
<td>45</td>
</tr>
<tr>
<td>Manufacture of timber and wood products</td>
<td>46</td>
</tr>
<tr>
<td>Manufacture of paper and publishing</td>
<td>47</td>
</tr>
<tr>
<td>Manufacture of rubber and plastic products</td>
<td>48</td>
</tr>
<tr>
<td>Other manufacturing industries</td>
<td>49</td>
</tr>
</tbody>
</table>

Source: ACoP (1980)
<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>SIC 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture of food and beverages</td>
<td>15</td>
</tr>
<tr>
<td>Manufacture of tobacco</td>
<td>16</td>
</tr>
<tr>
<td>Manufacture of textiles</td>
<td>17</td>
</tr>
<tr>
<td>Manufacture of wearing appeal</td>
<td>18</td>
</tr>
<tr>
<td>Manufacture of leather and leather products</td>
<td>19</td>
</tr>
<tr>
<td>Manufacture of wood and wood products</td>
<td>20</td>
</tr>
<tr>
<td>Manufacture of pulp, paper</td>
<td>21</td>
</tr>
<tr>
<td>Manufacture of publishing</td>
<td>22</td>
</tr>
<tr>
<td>Manufacture of coke and refined petroleum</td>
<td>23</td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>24</td>
</tr>
<tr>
<td>Manufacture of rubber and plastic products</td>
<td>25</td>
</tr>
<tr>
<td>Manufacture of other non-metallic mineral products</td>
<td>26</td>
</tr>
<tr>
<td>Manufacture of basic metals</td>
<td>27</td>
</tr>
<tr>
<td>Manufacture of fabricated metal products</td>
<td>28</td>
</tr>
<tr>
<td>Manufacture of machinery and equipment not elsewhere classified</td>
<td>29</td>
</tr>
<tr>
<td>Manufacture of office machinery</td>
<td>30</td>
</tr>
<tr>
<td>Manufacture of electrical and optical equipment</td>
<td>31</td>
</tr>
<tr>
<td>Manufacture of radio, television</td>
<td>32</td>
</tr>
<tr>
<td>Manufacture of medical and optical instruments</td>
<td>33</td>
</tr>
<tr>
<td>Manufacture of motor vehicles</td>
<td>34</td>
</tr>
<tr>
<td>Manufacture of transport equipment</td>
<td>35</td>
</tr>
<tr>
<td>Manufacture of furniture and manufacturing not elsewhere classified</td>
<td>36</td>
</tr>
<tr>
<td>Manufacture of recycling</td>
<td>37</td>
</tr>
</tbody>
</table>

Source: ACoP (1992)
### Table A3.4 Standard Industrial Classification 1997

<table>
<thead>
<tr>
<th>Sector</th>
<th>SIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture of food, beverages and tobacco</td>
<td>DA</td>
</tr>
<tr>
<td>Manufacture of textiles and textile products</td>
<td>DB</td>
</tr>
<tr>
<td>Manufacture of leather and leather products</td>
<td>DC</td>
</tr>
<tr>
<td>Manufacture of wood and wood products</td>
<td>DD</td>
</tr>
<tr>
<td>Manufacture of pulp, paper and publishing</td>
<td>DE</td>
</tr>
<tr>
<td>Manufacture of Coke and refined petroleum</td>
<td>DF</td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>DG</td>
</tr>
<tr>
<td>Manufacture of rubber and plastic products</td>
<td>DH</td>
</tr>
<tr>
<td>Manufacture of other non-metallic mineral products</td>
<td>DI</td>
</tr>
<tr>
<td>Manufacture of basic metals and fabricated metal products</td>
<td>DJ</td>
</tr>
<tr>
<td>Manufacture of machinery and equipment not elsewhere classified</td>
<td>DK</td>
</tr>
<tr>
<td>Manufacture of electrical and optical equipment</td>
<td>DL</td>
</tr>
<tr>
<td>Manufacture of transport equipment</td>
<td>DM</td>
</tr>
<tr>
<td>Manufacture of not elsewhere classified</td>
<td>DN</td>
</tr>
</tbody>
</table>


The following table shows the aggregation of the sectors that are used in this chapter and the rest of the thesis according to the different SICs.

### Table A3.5 The aggregation of the (two-digit) level according to different Classifications

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture of food, beverages and tobacco</td>
<td>DA</td>
<td>15, 16</td>
<td>41/42</td>
<td>III</td>
</tr>
<tr>
<td>Manufacture of textiles and textile products, leather and leather products</td>
<td>DB, DC</td>
<td>17-19</td>
<td>43-45</td>
<td>XIII, XV, XVII</td>
</tr>
<tr>
<td>Manufacture of pulp, paper and publishing</td>
<td>DE</td>
<td>21,22</td>
<td>47</td>
<td>XVIII</td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>DG</td>
<td>24</td>
<td>25, 26</td>
<td>V</td>
</tr>
<tr>
<td>Manufacture of electrical and optical equipment</td>
<td>DL</td>
<td>30-33</td>
<td>33, 34</td>
<td>IX</td>
</tr>
<tr>
<td>Manufacture of transport equipment</td>
<td>DM</td>
<td>34, 35</td>
<td>35, 36</td>
<td>X, XI</td>
</tr>
</tbody>
</table>
Chapter Four

Estimates of Total Factor Productivity by employment size class

4.1 Introduction

The previous chapter aimed at presenting a historical view of employment, wages and output in UK manufacturing by employment size class, over the period of 1958-2002, and for the small firm sector in some industries, over the period of 1973-2002. The chapter showed that shares and average growth rates of employment increased over time for the small firm sector in UK manufacturing. In order to explain these developments, attention was drawn to differential movements in productivity. This was measured by using labour productivity, normalised by using nominal net output per head relative to nominal output per head for total manufacturing. A principal conclusion was that the relative labour productivity of the large firm sector increased over time and exceeded that of the sectors comprising both small and medium sized firms. The percentage differences in labour productivity were also decomposed into a 'size effect' (the difference between each size class) and an 'industry effect' (the difference between the whole individual industry and manufacturing as a whole). The results show that the size effect was negative in the small firm sector for all industries with the paper industry showing the biggest size effect. While the industry effect has a high positive effect in paper and chemicals industries but it is negative in the textile industry.

In order to understand the underlying causes of these different movements of productivity growth in UK manufacturing by employment size class, this chapter will attempt to divide labour productivity growth into that due to changes in capital intensity and that due to technological change, providing thereby estimates of Total Factor Productivity (TFP) growth by size class in UK manufacturing. Before estimating TFP growth, it is of course necessary to estimate the capital stock. Therefore, my objective in this chapter is first to estimate the gross capital stock in
UK manufacturing by employment size class and in the small firm sector in selected industries and after that use these estimates to estimate the TFP growth for the UK manufacturing by employment size class. We shall commence by discussing the methodology of the TFP growth in section 4.2; Perpetual Inventory Method (PIM) is presented in section 4.3; the problems of estimating the capital stock by size class are shown in section 4.4; section 4.5 presents the methods of estimation and the estimates for the UK manufacturing by employment size class. Section 4.6 will consider estimates of the gross capital stock for the small firm sector in UK manufacturing. Section 4.7 presents the capital-labour ratios and its impact on labour productivity. Section 4.8 provides estimates of TFP growth. Section 4.9 presents some conclusions.

4.2 Methodology of TFP growth

The concept of TFP growth the precise method of its measurement depends upon the concept of the production function. Before proceeding to measurement, this section discusses how the measurement of TFP growth relates to the neo-classical production function.

Although the pioneering work on the TFP concept is usually attributed to Solow (1957), and who gave his name to the ‘residual’ defined as that part of output growth that cannot be explained by the growth in the primary inputs (i.e. capital and labour) (Groth et al, 2004), the link goes back to Tinbergen (1942) (Hulten, 2000). In spite of the fact that Solow was not the first to tie the aggregate production function to productivity, his work is the basis of most studies of productivity growth in the neo-classical tradition. This class of models assumes that returns to scale are constant and that there is perfect competition. In this case it can be shown that the labour and capital shares of net output are equal to the respective output elasticities; starting with the production function:

\[ Q = A(t) \cdot F[(K(t), L(t))] \]  \hspace{1cm} (4.1)

where \( Q \) represents output, \( K \) and \( L \) represent inputs, both capital and labour. The Hicksian \( A(t) \) represents is an index of the level of technology. \( A(t) \) is called Total
Factor Productivity (TFP) (Barro and Martin, 1994) When (4.1) is differentiated with respect to time and divide by \( Q \) we obtain the following equation:

\[
\frac{\dot{Q}}{Q} = \frac{A}{A} + A \frac{\partial F}{\partial K} \frac{\dot{K}}{Q} + A \frac{\partial F}{\partial L} \frac{\dot{L}}{Q}
\]

where dots indicate time derivatives.

Under competitive conditions, the share of capital \( S_K = \frac{\partial Q}{\partial K} \), the share of labour \( S_L = \frac{\partial Q}{\partial L} \) so the equation (4.2) will be

\[
\frac{\dot{Q}}{Q} = \frac{A}{A} + S_K \frac{\dot{K}}{K} + S_L \frac{\dot{L}}{L}
\]

Equation 4.3 can be rearranged as

\[
\frac{A}{A} = \frac{\dot{Q}}{Q} - S_K \frac{\dot{K}}{K} - S_L \frac{\dot{L}}{L}
\]

With constant returns to scale, the Euler condition holds, \( S_K = 1 - S_L \) and equation 4.4 can be rewritten as:

\[
\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - \frac{\dot{L}}{L} - S_K \left( \frac{\dot{K}}{K} / \frac{\dot{L}}{L} \right)
\]

It is useful to rearrange this equation to show the contributions of TFP and the capital-labour ratio (factor substitution) to overall labour productivity growth (as in Sterlacchini 1989). Letting,

\[
q = \frac{Q}{L}, \quad k = \frac{K}{L},
\]

\[
\frac{\dot{q}}{q} = \frac{\dot{A}}{A} + S_K \frac{\dot{k}}{k}
\]

(4.6)
where \( S_k \) is the impact of substituting capital for labour. According to equation 4.6 therefore the growth rate of labour productivity can be broken down into two components: the growth rate of \( TFP \) and the impact of the growth of the capital-labour ratio.

Barro and Martin (1994) note that while the continuous-time formula in equation 4.5 is useful theoretically, although it has to be modified for empirical purposes to discrete time. This is frequently done (see Table 4.2 below) by using the so-called Tomqvist index number. Tomqvist (1936) measures the growth rate of a variable between two points in time \( t \) and \( t+1 \), by logarithmic differences and he uses the average of the factor shares at times \( t \) and \( t+1 \).

If we take the logarithmic of equation 4.4 we get the following equation:

\[
\log[A(t+1)/A(t)] = \log[Q(t+1)/Q(t)] - \{[1 - \bar{S}_t]\log[K(t+1)/K(t)]\} - \{\bar{S}_t \log[L(t+1)/L(t)]\}
\]

where \( \bar{S}_t = [S_t(t) + S_t(1+t)]/2 \) is the average share of labour over the period \( t \) and \( t+1 \).

The measurement of TFP growth typically depends on the use of Tomqvist index number (Caves 1982a, b), which has been used in several studies (as mentioned in section 6.4.1). The Tomqvist index has some desirable properties. In particular it is an exact index especially when it is used with the translog production function (Dievert, 1976). More generally, Hulten (2000) shows that the Tomqvist index is an approximation whose degree of ‘exactness’ depended upon the closeness of translog function to the true production function (Hulten, 2000 p.21).

In empirical applications of the above approach, I therefore need – in addition to knowledge of the capital-labour ratio - knowledge about the share of labour or capital in net output. In this study, output is measured in three ways: gross output, net output and gross value added. The Census of Production defines these concepts as follows:
• Gross output = total sales and work done + increase during the year in the
stock of final goods and work in progress.

• Net output = gross output – purchases + increase during the year in the stock
of materials and fuel.

• Gross value added = net output – cost of non-industrial services received.

They provide for different methods of measuring TFP growth (Oulton and O’Mahony,
1994). First, Hulten’s method which use the final output (Final output= aggregate
value added in manufacturing aggregate plus purchases from outside the
manufacturing sector). Second, the Domar method which uses the ratios of nominal
gross output of each industry to total nominal final output (Domar, 1961). Third
method is the aggregate value added method which uses the value added as a measure
of the output. This third method is the one used most often in practice (see for
eexample Harris and Drinkwater, 2000; Cameron et al., 2005). The ‘net’ measure of
output1 is however used in this chapter, since data for value added are not available by
employment size class.

In the theoretical and applied studies a production function is represented by
aggregate indexes of inputs such as capital, labour, energy and materials. The
representation of the production function at the aggregate level is based on the
assumption that separability allows one to aggregate the separable group of variables
into a single composite variable (Yuhn, 1991). In the production studies, the
assumption that the production technology is weakly separable can be used to justify
the use of value added (or net output) measures of output in studies of productivity
(Richmond, 2000). (Richmond, 2000) for example shows that production functions
that are (weakly or strongly) separable play an important role in facilitating certain
kinds of simplification that are often useful in economic analysis, one of the most
important areas of applications is the study of production functions for value added
(or net output).

---

1 Some studies used the net output as a measure of the output such as Sterlacchini (1989); Ahmed and Wilder (2001).
Before proceeding to the estimates of TFP growth by employment size-class, I need to provide estimates of the capital stock; these estimates are discussed in the following sections.

4.3 Perpetual Inventory Method (PIM)

The Perpetual Inventory Method (PIM) creates an estimate of the capital stock by accumulating past purchases of assets over their estimated service lives (OECD, 2001). This method is used for most studies that estimate capital stock (e.g. Bellak and Cantwell 2004; Lowe, 1990; O’ Mahony and Oulton, 1990; O’ Mahony, 1993).

From the PIM we can obtain both the gross and net capital stocks (Appendix 4.2 shows the difference between the gross and net capital stock), but the question then becomes which type of capital stock is better for use in productivity analysis. In this paper, the gross capital stock is preferred for the following reasons:

1- It is common to use the gross capital stock in the analysis of production and growth since capital assets are likely to retain their output-producing capacity throughout their working lives (O’ Mahony, 1993).

2- In this analysis it is very difficult to calculate the depreciation rate for every size class, so it is more accurate to measure the gross than net capital stock.

3- The gross capital stock provided the original data from which I derived my own estimates of capital stocks by size class.

There are many studies that have estimated the capital stock in UK manufacturing, all of them using the PIM. The following table summarizes these studies.
From Table 4.1 it can be seen that all of these studies use the PIM to calculate the capital stock. PIM is easy to calculate and most of OECD countries use it, which allows for international comparisons, as its methodology is standard and therefore transparent (Albala-Bertrand, 2001). The Office for National Statistics (ONS) has recently provided estimates of the gross capital stock for UK manufacturing for 1948-2003, therefore covering the period of the current study, 1973-2002. These estimates were derived from Perpetual Inventory Method (PIM), which is employed in many counties as well as by the UK\(^2\). Figures 4.1a and 4.1b show these estimates.

\(^2\) Appendix 4.2 gives more details about this method.
Figure 4.1a shows that the gross capital stock has increased over the time for manufacturing as a whole and for the industries considered in this chapter. However, it has decreased in the textiles industry. In general, the average growth rates for the gross capital stock in total UK manufacturing has decreased from 1.9% for the period 1973-79 to 0.36% for the period 1979-1990 and increase to 0.43% for the period 1990-2002 (see Figure 4.4).

From Figure 4.1b it can be seen that the chemicals industry has the highest share of the gross capital stock, whilst the textile industry has the lowest share. For example, the relative gross capital stock in chemicals industry is 16% in 2002, whilst it is 4% for the textile industry. The relative gross capital stock increase over the time for most industries except for the textile industry, which decreased from 8% in 1973 to 4% in 2002.

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3 These six industries represent 67.2% of the total capital stocks in UK manufacturing in 2002.
4.4 The problem of estimating capital stock by employment size class in UK manufacturing

There have been no previous studies performed to estimate the gross capital stock in UK manufacturing based on employment size class. However, since investment data were available by size class, this presented a major challenge in attempting to determine the initial gross capital stock for each class.

There are two main problems that are related to the estimation of the capital stock by size class:

1 - The Annual Census of Production (ACoP) and later the Annual Business Inquiry (ABI) only contains data for total capital expenditure.

2 - Based also on the previous problem, it is not possible to determine a specific retirement rate for the total net capital expenditure for each class.

As a result of these two problems, a method was adopted based upon shares of investment and apportioning the estimated growth in the capital stock for all size classes.

4.5 Estimates of gross capital stock in UK manufacturing

The calculation of the gross capital stock by using a method depends on the investment shares of every class. This has been made possible by the recent production of estimates of capital stocks by the ONS. This method comprises the following steps:

1- Estimation of the initial capital stocks for every class.
2- Apportionment of the change in the total capital stock by using the following equation:

---

4 This method depends on the same method which was used by Jacob et al, 1997; Melachroinos and Spence, 2002; Martin, 2002.
\[ \Delta GCS_i = \frac{\sum \Delta NCE_i}{\sum \Delta NCE_i} \Delta GCS_i \]  

(4.8)

where \( GCS_i \) is the gross capital stock for the class \( i \), \( GCS \) is the total gross capital stock, and \( NCE_i \) is the net capital expenditure for every class (i.e. the value of acquisitions less the value of disposals). The following chart – Figure 4.2 - illustrates the net capital expenditure ratios for every class for the period between 1958 –2002.

The net capital expenditure used in these estimates represents the value charged to capital account and any other amounts that ranked as capital items for taxation purposes during the year (ONS, 1974). This concept has however differed over time; since 1988 it has included the value of assets acquired as leases under finance leasing arrangements (ONS, 1995). In general the net capital expenditure consists of three types of asset (Annual Census of Production, various issues):

1- New building work, which includes the value of new building and other constructional work.

2- Land and existing buildings, which include the value of freeholds and the value or premium payable for leaseholds acquired.

3- Plant, machinery, and vehicles, which include the value of new and second hand plant, machinery, and vehicles acquired or disposed of.

This method may be suitable in this study for the following reasons:

1-The share of the net capital expenditure reflects the importance of every size class.

2-The difference in the definition of the net capital expenditure over time makes use of the share of net capital expenditure much better than using the real value of net capital expenditure, as the net capital expenditure after 1988 includes assets acquired under finance leasing arrangements, thus using the share of net capital expenditure. Because of this, it has been assumed that the change is equivalent across size classes.
3-The problems of calculating a specific retirement rate for every class makes this method better than using the regular method because the PIM method requires using a retirement rate that is calculated according to the type of each asset and this data is not available for every size class.

Figure 4.2 Net capital expenditure ratios in UK manufacturing by employment size class, 1958-2002


Figure 4.2 shows that in 1958 about 80% of capital investment was being carried out by firms of more than 500 employees; however, the share of this group of net capital expenditure decreases over time up to about 1980 before flattening out at around 50%. On the other hand, this ratio has increased over the same period for the smallest size class (less than 100 employees) from less than 10% to around 20-25%. The other size classes have been more stable with some increases in the earlier period.

The various stages resulting in estimates of capital stock by size classes were as follows:

1 - Estimation of the initial capital stock by apportionment of the gross capital stock of the ONS for year 1973 to every class by using the average shares of net capital expenditure for the years 1958, 1963 and 1968.
2 - Using equation (4.8) to calculate the capital stock for the whole period, the net capital expenditure share for each year is used in this equation for every class. The following chart shows these estimates.

![Figure 4.3](chart1.png)

Source: ONS, on line

Figure 4.3 shows that there is a big gap between the gross capital stock in the large firm sector (500+) and the small firm sector (1-99). (see section 4.6.3).

![Figure 4.4](chart2.png)

Source: ONS, on line

From Figure 4.4, it can be shown that average growth rates have decreased over time for the total UK manufacturing level and by employment size class. For the small firm
sector the average gross rate has decreased from 3.2% in 1973-79 to 0.8% for the period of 1990-2002. However, the average growth rate for the large firm sector decreased from 1.5% for the period of 1973-79 to 0.3% for the period of 1990-2002.

4.6 Estimates of the gross capital stock in the small firm sector in UK industries.

This section presents estimates of the gross capital stock for the small firm sector in six industries the period 1973-2002. I pursued the previous steps as follows:

1-Estimation of the initial capital stock by apportionment of the gross capital stock of the ONS for the year 1973 to every class by using the average shares of net capital expenditure for the years 1963 and 1968.

2-Using equation (4.8) to calculate the capital stock for the whole period; the net capital expenditure share for each year is used in this equation for every class. The following figure shows the estimates for the small firm sector in UK manufacturing, for six industries\(^5\) for the benchmark years.

Figure 4.5 Gross capital stocks in the small firm sector in UK manufacturing, 1973-2002

Source: ONS, on line

Figure 4.5 shows the distributions of the capital stock in the small firm sector. The pulp, paper, and publishing industry has the highest value of the capital stock and the

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\(^5\) In chapter 3 I have mentioned that these 6 industries represent about 60% of total employment in UK manufacturing in 2002. There are some industries such as metals and mechanical engineering I cannot get data for all the period due to the change in the Standard Industrial Classification (SIC) over the time.
capital stock increases over the time. On the other hand, the transport equipment industry has the smallest value of the gross capital stock.

Turning to growth rates, the following figure shows the growth rates of the gross capital stock in these industries.

Figure 4.6 Average annual growth rates of gross capital stocks in the small firm sector in UK manufacturing, 1973-2002

Source: ONS, on line

Figure 4.6 shows that the average growth rates of the gross capital stocks are rather different for the various industries. The electrical industry has the biggest growth rates; it increased from 6% in 1973-79 to 8.1% in 1990-2002. On the other hand, textiles, chemicals and food industries have decreased their growth rates over the time.

4.7 Capital – labour ratios in UK manufacturing

Now consider changes in the capital-labour ratio and their impact on labour productivity growth. The capital–labour ratio is the ratio of the value of capital to employment. This ratio depends on the kind of industry, because there are some industries that choose more capital–intensive methods. Moreover, this ratio depends on the size of the firm, as small firms are more labour intensive than large firms. The capital labour ratio or capital intensity reflects the amount of fixed assets allocated to an employee (Ngiik, 2000). We calculate this ratio as follows:

\[ \frac{K}{L} = \frac{\text{Gross Capital Stock}}{\text{Employment}}. \]
Changes in the capital-labour ratio are illustrated in Figure 4.7. It shows the major difference in the capital intensity of large firms compared to all the other size classes. For example the capital-labour ratio was £30,000 in 2002 for the small firm sector, while it was £250,000 in the large firm sector. Moreover the figure also illustrates a major increase in the large firm sector in all periods. The data also suggest that the relative capital-labour ratio has been declining for the small firms sector relative to all the other size classes. This figure also shows that the biggest source of variation is in the 500+ size class.

![Figure 4.7 Capital-labour ratio in UK manufacturing by employment size class, 1973-2002](image)


Table 4.2 details the impact on labour productivity of these changes in capital-labour ratios. It shows important impacts for all classes and all periods, but the key feature is the much higher contribution of capital-deepening to labour productivity growth amongst large firms since 1979 – much higher than the contribution from TFP. For example, TFP growth was 1.04% pa for the large firm sector for 1973-2002, while the impact of factor substitution was 3.66% pa for the large firm sector for the same period. For small firms by contrast, the period since 1979 has witnessed a far smaller contribution from capital-deepening than from technology.
Table 4.2 The impact of capital-labour substitution* in UK manufacturing by employment size class, 1973-2002

<table>
<thead>
<tr>
<th>Period</th>
<th>Total</th>
<th>1-99</th>
<th>100-199</th>
<th>200-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-79</td>
<td>0.81</td>
<td>0.78</td>
<td>1.04</td>
<td>1.15</td>
<td>0.83</td>
</tr>
<tr>
<td>1979-90</td>
<td>1.79</td>
<td>0.38</td>
<td>1.26</td>
<td>1.04</td>
<td>5.23</td>
</tr>
<tr>
<td>1990-2002</td>
<td>1.93</td>
<td>0.8</td>
<td>2.01</td>
<td>3.09</td>
<td>3.64</td>
</tr>
<tr>
<td>1973-2002</td>
<td>1.78</td>
<td>0.77</td>
<td>1.79</td>
<td>2.26</td>
<td>3.66</td>
</tr>
</tbody>
</table>


*Factor substitution = capital share × (annual average growth rates of capital –labour ratio)

Figure 4.8 shows the capital-labour ratios in the 6 industries in the UK manufacturing sector.

Figure 4.8 Capital-labour ratio in the small firm sector in UK manufacturing, 1973-2002


Figure 4.8 illustrates differences between the six industries in terms of capital-labour ratios in small firm manufacturing. Despite the lowest initial ratio in textiles, the rapid growth in capital intensity in this sector meant that by 2002 its capital-labour ratio actually exceeded that for electrical and transport equipment in 20026. However in all of these industries remained ratios remained substantially behind capital-labour ratios in the paper and food sectors and above all in chemicals.

---

6 Capital –labour ratio has increased in the small firm sector in the textiles industry from £4,000 in 1973 to £29,000 in 2002 with average growth rate 625%, whilst this rate was 72% in the chemicals industry.)
Table 4.3 shows that during 1973-79 the impact of this capital-deepening was larger than those for TFP for all the industries. The textiles industry experienced the biggest contribution from factor substitution in most periods and had the largest for the whole period as well (1973-2002); however, this sector has the lowest TFP growth rates. The food industry had the lowest factor substitution growth rates among these industries; for example, the contribution to labour productivity growth from capital deepening was 1.08% per year for the entire period 1973-2002.

Table 4.3 The impact of capital-labour substitution* in the small firm sector in UK manufacturing, 1973-2002

<table>
<thead>
<tr>
<th>Period</th>
<th>Textiles</th>
<th>Food</th>
<th>Paper</th>
<th>Chemicals</th>
<th>Electrical equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-79</td>
<td>2.78</td>
<td>0.78</td>
<td>3.84</td>
<td>1.98</td>
<td>1.82</td>
</tr>
<tr>
<td>1979-90</td>
<td>3.24</td>
<td>0.80</td>
<td>2.17</td>
<td>0.51</td>
<td>1.05</td>
</tr>
<tr>
<td>1990-2002</td>
<td>3.38</td>
<td>1.63</td>
<td>1.39</td>
<td>1.32</td>
<td>3.10</td>
</tr>
<tr>
<td>1973-2002</td>
<td>3.06</td>
<td>1.08</td>
<td>2.27</td>
<td>1.14</td>
<td>2.15</td>
</tr>
</tbody>
</table>


*Factor substitution = capital share x (annual average growth rates of capital − labour ratio)

4.8 Total Factor Productivity (TFP) growth in UK manufacturing

The main purpose in constructing the capital stock measures is to consider the impact of changing capital-labour ratios and hence to generate measures of Total Factor Productivity (TFP) growth. First however, it is useful to present a summary of previous studies in this field, then unravel the techniques that were employed to measure TFP growth. This will be followed by the results of the current study, finishing with a comparison between these and the results of previous studies.

Productivity is measured as a ratio of output to a weighted average of inputs. There are many indices of productivity. Total Factor Productivity (TFP) or Multi Factor Productivity (MFP) growth is one of these indices; it can be thought of as an index of technical progress (Nadiri, 1970). More specifically, TFP may be defined as an index relating the change in output to the change in the combination of labour, capital, and intermediate purchases of inputs consumed in producing that output (Ahmed and Wilder, 2001). In terms of growth, TFP can also be thought of a ‘residual’ – what
remains after subtracting the contribution of an increasing capital-labour ratio from labour productivity.

4.8.1 Previous studies in the measurement of TFP growth

There are many studies that have measured the productivity of the manufacturing sector in the UK and other countries. Most of them have measured the productivity of the total manufacturing industry or that of sectors, but not for employment size classes. In this section we can discuss these studies, and the table 4.4 summarises some of the more relevant studies which measured the TFP growth in UK and US. The year column shows the period of measurement. Area column presented the sector which every study interested in. The method column shows that all of these studies use Tornqvist method. The inputs column presented the production factors which used to measure the TFP growth and the output column shows the output variable which used in the measurement.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Years</th>
<th>Areas</th>
<th>Methods</th>
<th>Inputs</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris and Drinkwater(2000)</td>
<td>1979-89</td>
<td>UK manufacturing</td>
<td>Tornqvist</td>
<td>Labour and capital</td>
<td>Value added</td>
</tr>
<tr>
<td>Oulton and O'Mahony (1994)</td>
<td>1954-86</td>
<td>124 UK industries</td>
<td>Tornqvist</td>
<td>Labour, capital and intermediate materials</td>
<td>Gross output</td>
</tr>
<tr>
<td>Sterlacchini (1989)</td>
<td>1954-82</td>
<td>15 UK industries</td>
<td>Tornqvist</td>
<td>Labour and capital</td>
<td>Net output</td>
</tr>
</tbody>
</table>

Sterlacchini (1989) presented a cross-sectional study for the UK in which inter-industry TFP growth is associated with different indicators of innovative activity. He computed the TFP growth for 15 UK industries for the period of 1954-1982 by using a method that depends on the Cobb-Douglas production function and the share of capital in income. This method measures the TFP growth using the labour
productivity growth and capital labour ratio growth. Moreover, Oulton and O'Mahony (1994) studied the productivity and growth in UK manufacturing for the period of 1954-1986. They used Tornqvist indices of growth rates of TFP for 124 industries.

Suer (1995) measured TFP growth in the UK Chemicals and Allied industries for the period 1955-1988. He used the Tornqvist TFP index to measure the TFP growth. In addition, Harris and Drinkwater (2000) presented a study estimating the capital stock for 1979-89. They used the Tornqvist index for TFP in the manufacturing sector. Cameron et al. (2004) studied the productivity growth in a panel of 14 UK industries since 1970 also using the Tornqvist TFP index. He used a superlative index number. Diewert (1976) defines quantity (price) index as superlative if it is exact for a flexible aggregator (unit cost) function. An aggregator (unit cost) function is flexible if it can provide a second-order approximation to an arbitrary twice-differentiable linearly homogeneous aggregator (unit cost) function.

In the US there have also been many studies that measure the productivity growth in the manufacturing sector. Gullickson (1992) measured the multifactor productivity (MFP) in manufacturing industries for the period 1949-1988 for the two-digit level in the US. Moreover, Weber and Domaziliki (1999) measured the TFPG in the manufacturing sector at the regional level for the period 1977-1989 in the US. Furthermore, Ahmed and Wilder (2001) measured the multifactor productivity trends in manufacturing in the US for the period 1987-96.

In India there are many studies that measure the TFP growth in the manufacturing sector, such as Singh (1996) and Mitra and Veganzones (1998). Most of these studies use the Solow model to estimate the TFP growth. In addition, there are several studies in Malaysia such as that of Ngiiik (2000). He measured the Productivity growth in Malaysia by using the Jorgenson and Gollop model and employing a discrete version of the Divisia index.

Many studies compare the TFP growth across countries. Lysko (1995) measured the manufacturing multifactor productivity in the US, Germany and France for 1956-1993. He used the Tornqvist formula to measure the index number of inputs and outputs.
From the above discussion of the previous studies which measured the TFP growth, it can be seen that all of these studies used Tornqvist index number. Diewert (1976) established that the translog index is superlative by showing that it is exact for the homogenous translog aggregator function, a flexible functional form that has been widely used in recent empirical economic research (see for example, Caves et al, 1982).

4.8.2 Total Factor Productivity (TFP) growth in UK manufacturing

TFP growth rates for the total UK manufacturing industry are measured for the periods 1973-79, 1979-80, 1990-2002 and 1973-2002\(^7\) by using equation (4.8). I use the net output as a measure for the output.

A particular problem encountered in applying equation 4.8 was created by the changes in the Standard Industrial Classification (SIC). The 1968 revision is described in CSO (1968). In this paper this classification covers the period 1973 -1979, and it specifies that there are seventeen orders (III-XIX), which fall within manufacturing (Oulton and O’Mahony, 1994). From 1980 to 1992 another classification was devised (SIC 1980), the numbering system of which is quite different from that of the 1968 SIC. In 1992 there was a further re-classification (SIC 1992). Revision is necessary since, over time, new products and the new industries to produce them had surfaced; hence a review of these changes was called for (ONS, 1993). Moreover, to ensure easy comparability at the European level (ONS, 1996), this classification was made to conform to the European communities’ classification of economic activities (NACE Rev 1)\(^8\). Gross capital stock estimates were based on those reviewed in section 3.4.

TFP growth rates were computed for UK manufacturing industry by employment size class for the periods 1973-79, 1979-90, 1990-2002 and 1973-2002. The labour share is the share of wages and salaries plus the employers’ National Insurance Contributions (NIC) of net output by every class. The capital share is then defined as

\(^7\)Note that I have chosen these periods according to the business cycle in the UK. The first period starts from the first year in the period until 1979 (which has a decline in the productivity). The second period is from 1979 to 1990 (which has a very high productivity growth rate).

\(^8\)Appendix 3.1 shows the aggregation of the sectors which is used in this chapter.
the residual share of net output. The wage data includes in the employees' national insurance contribution, but it does not include the employers' national insurance contribution. There are data for the employers' national insurance contribution for the total level, but not for every size class. To estimate this ratio for every size class I assumed that this ratio could be estimated by using the following equation:

\[ NIR = \alpha_0 + \alpha_1 W_1 + \alpha_2 W_2 + u \]  \hspace{0.5cm} (4.9) 

where \( NIR \) is the ratio of employers' national insurance contribution, \( W_1 \) is the wages and salaries bill per employee in £'s, and \( W_2 \) is the square of wages and salaries per employee. I use here a quadratic equation as the relationship between the wages and the national insurance contribution is believed to be non-linear and the ratio of this contribution increasing when the wage per head increases at an increasing rate. I use 3-digit level (101 sectors) for UK manufacturing in year 1990. The estimated equation is:

\[ NIR = 0.0338 + 0.0000145 W_1 + 0.000000000515 W_2 \]  \hspace{0.5cm} (4.10) 

\( (0.0203) \quad (0.0000) \quad (0.0000) \)

This result permitted an estimate of the ratio of employers' national insurance contribution for every size class for all years and for the 6 industries in the small firm sector. The labour share is then calculated as the share of wages and salaries plus payments for national insurance of net output, with the capital share as the residual share of net output.

Average annual growth rates of the labour productivity were shown in Table 3.3 in section 3.5.2. In this section I break the average growth rates down into TFP and the impact of changes in the capital which are illustrated in Tables 4.2.

<table>
<thead>
<tr>
<th>Period</th>
<th>Total</th>
<th>1-99</th>
<th>100-199</th>
<th>200-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-79</td>
<td>0.12</td>
<td>0.57</td>
<td>0.17</td>
<td>0.11</td>
<td>-0.03</td>
</tr>
<tr>
<td>1979-90</td>
<td>2.16</td>
<td>2.85</td>
<td>2.41</td>
<td>1.89</td>
<td>2.09</td>
</tr>
<tr>
<td>1990-2002</td>
<td>1.36</td>
<td>2.7</td>
<td>0.86</td>
<td>0.70</td>
<td>0.73</td>
</tr>
<tr>
<td>1973-2002</td>
<td>1.27</td>
<td>2.18</td>
<td>1.04</td>
<td>0.68</td>
<td>1.04</td>
</tr>
</tbody>
</table>


* These numbers are standard errors.
From table 4.5 it can be seen that over the whole period, TFP growth was positive for all size classes, but at 2.18% pa, was actually largest for the small firm sector. This was also true for each of the sub-periods which roughly correspond to economic cycles. The second point to note is that there was a marked acceleration of TFP growth for all classes for the period 1979-90. Blackaby and Hunt (1990) and Oulton (1987) argue that there are five main hypotheses to explain this increase in TFP growth in 1980s:

- Technology, in particular the spread of the microelectronic revolution.
- Improved industrial relations.
- capital scrapping.
- labour utilisation.
- Plant closures.

TFP growth was very slow for the period 1973-79, and indeed negative for the largest size class. The earlier period was therefore perhaps rather exceptional. After the acceleration in the subsequent period, growth in TFP was very similar in the latest period (1990-2002) to the long-run average over the whole period. In this regard, Cameron (2003) argues that the reasons for this slowdown and speed-up are related to mis-measurement. This mis-measurement arises for many reasons such as the mis-measurement of output led to an underestimate of the growth in 1970s. On the other hand, in the second group, he argues that these differences in TFP growth are due to the structural changes in the UK economy.

4.8.3 Total Factor Productivity growth in the small firm sector in UK industries

In the previous section I measured the TFP growth in UK manufacturing by employment size class. In this section I measure the TFP growth in the small firm sector for six industries. The main objective of this measurement is to learn if there is a difference in TFP growth in the small firm sector among these industries or not. These estimates were made for six sectors: food, beverage, and tobacco sector, textiles sector, pulp, paper, and publishing sector, chemicals sector, electrical and
optical equipment sector and transport equipment sector. The aggregation of these sectors is shown in the appendix 3.2.

The average annual growth rates of the labour productivity has been calculated for the 6 industries in the small firm sector in table 3.4 in section 3.5.2. In this section I decomposed these average growth rates into TFP and factor substitution, which is shown in Tables 4.3 and 4.6. These are for small firms only.

<table>
<thead>
<tr>
<th>Period</th>
<th>Textiles</th>
<th>Food</th>
<th>Paper</th>
<th>Chemicals</th>
<th>Electrical equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-79</td>
<td>-1.89</td>
<td>0.49</td>
<td>-1.67</td>
<td>-0.01</td>
<td>0.93</td>
</tr>
<tr>
<td>1979-90</td>
<td>-0.52</td>
<td>0.85</td>
<td>1.88</td>
<td>1.61</td>
<td>2.77</td>
</tr>
<tr>
<td>1990-2002</td>
<td>2.15</td>
<td>1.00</td>
<td>2.23</td>
<td>0.89</td>
<td>0.29</td>
</tr>
<tr>
<td>1973-2002</td>
<td>0.43</td>
<td>0.58</td>
<td>1.21</td>
<td>0.98</td>
<td>1.27</td>
</tr>
</tbody>
</table>


Table 4.6 shows an interesting contrast with that for aggregate manufacturing. In comparing the periods 1973-79 and 1980-92, it can be seen clearly from Table 4.6 that total factor productivity growth rates have increased since 1980 in all industries. Textiles, paper, and chemicals had negative TFP growth during 1973-80, but all the industries had positive TFP growth during the other sub periods, with the exception of textiles in 1979-90. The transport equipment industry had the highest TFP growth during the all periods. For example, TFP growth was 2.69% for 1973-2002 in the transport equipment industry, while it was 0.43% in the textiles industry.

4.8.4 Comparison with previous studies

As mentioned in the introduction to this chapter, most studies have focused on comparing productivity among industries. This is reflected in the studies by Sterlacchini (1989), Oulton and O'Mahony (1994), Cameron (2003), and Cameron et
All of these studies are based on growth accounting and use value added as the measure of output, except in the first study where net output was used. However, the question is now: How do these other estimates of TFP growth for UK manufacturing compare with those reported here? All these studies refer to the TFP growth for every industry and not for total manufacturing; the only exceptions to this are results reported by Cameron (2003), Cameron et al. (2005) and Disney (2003), who measured TFP growth in UK manufacturing. They measured TFP growth as 0.15% for the period 1973-79 and 3.02% for the period 1979-90.

4.9 Conclusion

This chapter provides estimates of the gross capital stock for UK manufacturing by employment size class, estimated both for total manufacturing and for the small firm sector in six industries. The estimates of the capital stocks derived from data on aggregate capital stocks and from ratios of the net capital expenditure of every size class to the total. These estimates were then used to estimate Total Factor Productivity (TFP) growth by using the Tornqvist index. In general, we can say that the size class (500+) experienced the biggest substitution of capital for labour in most individual periods and for the overall time period as well (1973-2002). In comparing the periods 1973-79 and 1980-92, it can be seen clearly that total factor productivity growth rates have increased since 1980 for all the size classes and in the small firm sector in all industries. The average growth rates for labour productivity (which were calculated in Chapter 3) were decomposed into TFP growth and the impact of factor substitution growth. These showed that the largest size class (500+) saw the biggest substitution of capital for labour in most individual periods and for the overall time period as well (1973-2002).

The principal conclusions of the chapter are first that the high growth rate of labour productivity in the large firm sector is related to the high growth rate of factor substitution rather than the TFP growth rate. Second that although capital-labour substitution was by no means unimportant in the small firm sector, it was generally less important in explaining the growth in labour productivity than TFP growth. The
textiles industry has the biggest substitution of capital for labour overall (1973-2002).

While the estimates suggest the importance of technological change in the small firm sector, the precise estimates may be criticised on a number of grounds, such as the assumption of constant returns to scale and the difficulties of using a suitable deflator for every size class. An alternative way of considering technological change is considered in the fifth chapter which is perhaps less open to objection, and which allows me to examine not only the extent of technological change among small firms but also its sources.
Appendix 4.1

Data sources

This chapter depended on two main kinds of data. The first was the net capital expenditure for the UK manufacturing by employment size class for 1958-2002. This data was collected from two sources; the first was the summary of the Annual Censes of Production (ACoP) from the Office for National Statistics (ONS) for 1958-1997; information for 1998 to 2002 was collected from ONS by special request from the ONS because it is not available online by employment size class.

The second kind of data is the gross capital stock (constant prices 1995=100) for 1973-2002, which was collected online from the ONS.
Appendix 4.2

Capital as a factor of production

Capital as a factor of production consists of physical objects produced by the economic system for use in the output of other goods (OECD, 1976). Capital that is considered as a stock includes the value of the capital assets, which are installed in producers units at a given point in time (OECD, 1992). The concept of assets differs over time, but generally consists of buildings, plant and vehicles (see section Table 3.3). Capital stock can be estimated on a gross or net basis, as discussed below.

1-Gross Capital Stock (GCS)
This concept represents estimates of the total value of the existing physical productive assets available in a country (OECD, 1976), but we may say more accurately that GCS measures the value of the assets of any unit (e.g. a firm, an industry or a country). The assets usually consist of three main categories (Martin, 2002; OECD, 1976; Vaze et al., 2003) plant, machinery, buildings and vehicles.

2- Net Capital Stock (NCS)
This concept measures the depreciated value of the gross capital stock (the value of the capital stock after depreciation) (Vaze et al 2003). The concept of capital consumption defines the reduction in the value of the fixed assets used in the production.

Estimates of capital stock in the UK are very old. In 1086 there was the Domesday Book that can still be seen at the Public Records Office in London. Domesday was more comprehensive than the present official estimates of capital stock in UK; the main categories of assets were farm land, livestock, woodlands, grazing land, fisheries, watermills, and so on (Hibbert and Walker. 1977).

In general, there are two main methods for the measurement of the value of the capital stock. The first method is the direct; it depends on the records of the firms such as gathering data on book values and insured values (Lock, 1985) or statistics for fire
insurance, or insurance records (Melachroinos and Spence, 2000). The second method is the Perpetual Inventory Method (PIM).

The gross capital stock can be measured by using PIM as follows:

The gross capital stock (GCS) at year t can be calculated as

\[ GCS_t = GCS_{t-1} + I_t + R_t \]  

(A4.2.1)

where

\[ I_t = \text{real gross investment} \]

\[ R_t = \text{real retirements} \]

Retirements are given by the following equation:

\[ R_t = r_t \cdot I_{t-1} \]  

(A4.2.2)

where \( r_t \) is the retirement rate.

Thus, equation (1) can be written as

\[ GCS_t = (1 - r_t) GCS_{t-1} + I_t \]  

(A4.2.3)

On the other hand, the net capital stock (NCS) allows for depreciation, so the following equation shows that:

\[ NCS_t = (1 - \delta) NCS_{t-1} + I_t \]  

(A4.2.4)

where \( \delta \) is the depreciation rate.
Chapter Five

Employment and technological change in the small firm sector

5.1 Introduction

The aim of this chapter is to examine the sources of technological change in the small firm sector, augmenting the data used in chapters 3 and 4 by specially constructed measures of technological activity. In chapter 4, estimates of the capital stock for different size classes allowed estimates of total factor productivity (TFP) growth for the period 1973-2002 to be made. While the chapter drew attention to the differing growth in capital intensity between the small firm sector and the remaining firms as an important source of the observed differences in labour productivity growth, there are a number of reasons for being sceptical about the ‘residual’ measures of technological change generated. The following are perhaps the most important:

First, the generation of TFP estimates relies on the assumption of constant returns. (e.g. Suer, 1990). It has already been argued in chapter 2 that while constant returns – consistent with a Gibrat process in respect of industrial firm size distributions – may be plausible in describing the growth process of firms above a certain critical size, it seems possible that the bulk of firms in the small firm sector operate at outputs for which average costs are decreasing.

Second, estimates of TFP rely on the use of price deflators. It is well known that TFP measures may be biased if (through product development and innovation for example), the deflators only inadequately or worse, ignore quality change. Moreover, while the use of a single deflator may be adequate for comparing TFP across industries, it seems far less plausible that a single deflator can capture intra-industry developments. We have already observed the important connection between the small firm sector and entrepreneurship initiated by technological change. Much of this entrepreneurship may well be taking the form of product innovation and product development. In this instance, applying industry-wide deflators to the output of the small firm sector may be highly misleading, underestimating the growth in output in this sector.
Thirdly, a major channel for technological spillovers is likely to flow from large firms to smaller firms within a sector. Studies of the knowledge production function have established the importance of both own firm and outside (but within sector) research and development (R&D) - for a review see Griliches (1992). Since R&D is mainly conducted by larger firms, we may reasonably hypothesize that R&D influences technological and entrepreneurial activity among smaller firms but only via a ‘spillover’ effect. A problem here is that the sector – however defined - may not capture all the spillovers involved, unless the sector is defined broadly enough. For this reason, among others, the main focus of the chapter is manufacturing as a whole.

With these limitations on the use and interpretation of TFP statistics in mind, this chapter uses an alternative way of examining the sources of technological change by analysing labour demand, using econometric models. This chapter uses CES production function without any assumption of constant returns to scale.

The plan of the chapters is as follows. Section 5.2 reviews employment change in the small firm sector. Models of labour demand model incorporating technological change are introduced in section 5.3, and an estimating equation derived. In section 5.4, I consider indicators of technological change. Section 5.5 considers data sources and presents calculations of so-called R&D ‘knowledge stocks.’ Section 5.6 shows the technological change and labour demand in the small firm sector. The transfer of technology to the small firm sector and the role of standards are presented in section 5.7. Section 5.8 considers the analysis of labour demand in the small firm sector. Section 5.9 presents a dynamic specification of labour demand in the small firm sector. Panel data analysis of labour demand is presented in section 5.10 and section 5.11 provides the conclusion.

5.2 Employment in UK manufacturing by size class

While the contraction of manufacturing has been the most obvious fact during the period covered in the thesis, developments in employment between different size classes – as emphasized in chapter 3 - has been almost as important. Figure 5.1
reminds us of the general picture for the period 1973-2002. As can be seen, total employment declined over this 30-year period from over 7 million to less than 3.5 millions in 2002. However this decline has been concentrated within the largest size class of firms employing more than 500 persons, where employment contracted from 4.3 million in 1973 – or around 56% of the workforce to just over on third in 2002 (34%). At the same time of course evidence was presented in chapter 4 which suggested that growing capital intensity was a key feature for this size class. Conversely, employment in the smallest size classes has contracted very little. Indeed – despite 1973 being a peak year for UK manufacturing - employment in the small firm sector in UK manufacturing was actually higher in 2001 than in 1973, dipping below the earlier figure only in 2002. As a result, the share of employment among firms employing less than 100 persons rose from 18% to 38% - a figure which now exceeds the share of any other size class.

The pattern of manufacturing employment in the smaller size classes has therefore been quite different over the last 30 years – most remarkably in the very smallest firms. While the last chapter suggested that growing capital intensity is an important part of the story, this does not necessarily reduced the importance of technological change in explaining these developments. For example, the opportunities for substituting capital for labour depend at least in part upon changing technology and process innovation in particular. At the same time these changes among larger establishments may be creating possibilities for smaller firms to adopt rather more
employment friendly product innovations. Accordingly, the next section considers the relationship between technological change and employment in more detail.

5.3 Employment and Technological change

Technological change can be defined as the “advance of technology, such advance often taking the form of new methods of producing existing products, new designs that enable the production of products, with new characteristics and new techniques of organisation, marketing and management” (Mansfield, 1968). Broadly, Mansfield is describing both product and process innovation with the “newness” suggesting the presence of new knowledge acquired through learning and experience.

Typically technological change – although this need not be the case - has been associated with greater efficiency in the use of labour, and interest in the relationship between technological change and employment has a long history, and in Britain since at least the beginning of the 19th century when machine wrecking was common in both the country and in the towns. Concern with the issues connected with the replacement of workers by machines in the 19th century was replaced in the course of the 20th century by a concern with the impact of technological change on the demand for labour force skills. In fact, in the 1970s there was a general fear that technological change might be generally deskilling. Thus for example the central thesis in Braverman (1973) is that the essential dynamic of technological change in capitalist economies is one of ‘deskilling’ associated with mass production techniques. More recently however the emphasis has shifted right around toward the implications of the computer and Information and Communications Technology (ICT) more generally in creating skill biased technological change (Chennells and Reenen, 1999).

Despite the emphasis in much of the literature on labour saving technological change, the actual impact of technological change on employment depends on a trade-off of factors operating at the firm, industry and economy wide levels and the level of analysis at which the analysis is conducted is crucial. Providing labour markets clear of course, technological change at the level of the whole economy will not generate lower employment and possibly unemployment since real wages are presumed to
adjust to clear the market. In many of these macro-economic models technological change is described by exogenous shifts in the production function (as for example in the Solow model of economic growth). More recently however, endogenous growth models have sought to see technological change as the outcome of specific investment decisions either made by individuals to accumulate human capital or by firms to invest in R&D (Crafts, 1996).

At the level of the firm, the distinction that Mansfield (see above) makes between product and process innovation is important. Process innovations impact upon the production function while product innovations impact upon the demand conditions faced by the firm. Whether process innovation stimulates employment is discussed further below. The general presumption however is that product innovation will stimulate employment although it may be noted that where a firm produces several products there may be some negative impact on the demand for these (Chennells and van Reenen 1999).

Perhaps some of the more useful studies of the relationship between technological change and employment have been made at the level of individual industries. This is because such studies embrace not only the direct impact of technical change within particular firms but also the indirect effect operating within the industry. As Pianta (2005) notes in a recent survey, these indirect effects include:

"...the competitive redistribution of jobs from low to high innovation-intensive firms, and the evolution of demand (and therefore output and jobs) resulting from the lower prices due to innovation, given the price elasticities of the industry’s goods" (p. 579)

Empirical analysis of the impact of technological change on employment has been conducted using a variety of different theoretical frameworks. These studies have also used a number of proxies for technology. These are reviewed in the next section.

The most common theoretical framework employed is that suggested by the neoclassical analysis of labour demand based upon cost minimisation or profit maximisation. A simple model based on labour demand which allows for technological change is developed in section 5.4. The literature here usually
emphasises the impact of innovation on processes, i.e. upon the production function, distinguishing between labour saving and capital saving biases to technological change.

In general, the labour demand is any decision made by an employer relating to the firm's employees, their employment, their compensation, and their training (Hamermesh, 1993). The basic labour demand approach in respect of the employment decision is based upon cost minimisation. This can be exemplified using standard graphical techniques, in which each producer seeks to minimise the cost of production conditional upon exogenously given factor prices and production possibilities, given by a production function.

Assume that the following figure illustrates a representative firm in the small firm sector. The diagram illustrates the unit isoquant, a locus of the various quantities of capital and labour needed to produce a unit of output, given technical efficiency in the use of inputs. Firms in the small firm sector may reasonably be assumed to be facing fixed input prices. These prices can be shown by the iso-cost line, which shows different input combinations with the same total cost.

The firm minimizes total costs by producing the level of output $Q_0 = 1$, using labour $L_0$ and capital $K_0$. 
Let us suppose that there is no technological change at all affecting the small firm sector. That does not mean that the representative firm will face unchanged conditions, because typically technological change will be occurring elsewhere and productivity growth will be raising real wages. With unchanged output prices, real product wages, i.e. wages measured in terms of the price of output in the small firm sector, will rise. This will rotate the iso-cost line around point $C_0$ as shown in Figure 5.3.

This means that the representative firm will raise the capital-labour ratio and the optimal situation will move to the point $C_1$. Figure 5.3 shows this situation.
From figure 5.3, it can be seen that the increase in the relative price of labour leads to an increase in the capital-labour ratio. This means that the new optimal point $C_1$ corresponds to an equilibrium level of employment $L_1$. Note that, unlike the price of labour, the cost of using capital services i.e. the rental price of capital is much more likely to be constant in the long run, although the literature does point to cyclical variations in the cost of capital which, for the small firm sector

The precise impact on the demand for labour depends however upon the elasticity of substitution between capital and labour, i.e. the extent to which the representative producer is able to substitute for labour in response to rising real product wages. Formally, this can be written as $\sigma = \frac{d \ln(K/L)}{d \ln(w/r)}$. Where $w$ is the wage and $r$ is the rental price of capital. The elasticity of substitution is approximately the proportionate change in the capital-labour ratio divide by the wages-rental price of capital ratio.

Figure 5.3 shows two possible situations one where substitution between the inputs is impossible and where as a consequence the demand for labour at a given level of output is unchanged ($C_0$ coincides with $C_1$ where $\sigma$ is zero) and one ($C_1$ where $0 < \sigma < \infty$) where there is substitutability between the labour and the capital.
The introduction of technological change clearly complicates the picture. Technological change (conditioned upon output) shifts the unit isoquant inwards allowing output to be produced with less capital than labour. But since technological change may in principle be 'biased' toward one factor or another, the new optimum capital-labour ratio may be different, quite independently of any change in the factor price ratio. For example, the using of computers as primarily capital saving will lead to better stock control.

However a useful benchmark is that of so-called “Hicks neutral” technological change as introduced by Hicks (1932) where neutrality requires that the marginal rate of substitution between capital and labour be independent of technical change; in other words, technical change (in the absence of any change in the factor price ratio) does not alter the capital-labour ratio. Figure 5.4 shows Hicks neutral technological change.

From figure 5.4, it can be seen that a firm is initially in a position of cost minimising equilibrium at point $C_0$ using labour given by the ray point $L_0$ to produce output $Q_0$. One way of examining technical change is to hold output fixed, so that technical progress shifts isoquants inward. If the shift is from $Q_0$ to $Q_1$, technical change is Hicks neutral change since the marginal rate of substitution is preserved at point $C_1$. 
along the line \((K/L)_o\). The proportionate rate of technological change is equal to \((OC_0 / OC_1) - 1\). Typically, however the small firm faces both rises in the real product wage and experiences technological change. Figure 5.5 illustrates this case.

![Figure 5.5 Optimal input combination before and after technological change](image)

From figure 5.5, it can be seen that a firm is initially in a position of cost minimising equilibrium at point \(C_0\) using labour given by the ray point \(L_0\) to produce output \(Q_0\).

One way of examining technical change is to hold output fixed, so that technical progress shift the unit isoquant inward. If the shift is from \(Q_0\) to \(Q_1\), technical change is Hicks neutral change since the marginal rate of substitution is preserved at point \(C_2\). On the other hand, the isoquant \(Q_0\) is tangent to iso-cost line 2 instead of 1 when the real product wage increases. To conclude it can be seen that the total employment change decreases from \(L_0\) to \(L_1\) (from 1 to 2) if we assume that there technological change and to \(L_2\) (from 2 to 3) if we assume that there is neutral Hicks technological change.

Finally, as argued above we need to consider returns to scale in the context of the small firm sector. The book of Marshall is a pioneering work on the returns of scale and the relationship between internal and external economies of scale. In his
Principles of Economics, Marshall (1890) drew a distinction between internal economies of scale (which depend on the internal organisation and management of the resources inside the firm) and external economies of scale (which depend on the overall progress and development of the industrial environment in which firms work or as Marshall said “...which do not directly depend on the size of individual houses of business”) (Prendergast, 1993).

Lazonick (1993) argues that internal economies are reflected in the shape of the cost curve and the level of production, whilst external economies are reflected in a down movement of the cost curve as shown in figure 5.6.

![Figure 5.6 Internal and external economies of scale](image)

Source: Oughton and Whittam (1997)

Marshall identified a number of sources of external economies such as:

- Agglomeration economies associated with the existence and development of local infrastructure and related trades.
- Transport and communications infrastructure provide important examples of such economies that do not depend on the degree of competition.
• The concentration of industry within the local or regional economies increases the growth of skilled labour.

• The spillover effects of research and development (R&D) expenditure and innovation.

Thick market effects have external economics impacts on firms. An example for ‘thick market’ "being the delivery van which travels as many miles on average in good times as bad but delivers more packages when times are good" (Hall, 1988). Thick market effects reduce firms’ costs and improve the firm performance (Cohen and Paul, 2001). (Oughton and Whittam, 1997) argue that the external economies such as transport and communications infrastructure and the spillover effects of Research and Development (R&D) expenditure which was done by the large firms are very important to the small firm sector. In this chapter, we are of course particularly interested in the potential for knowledge-based spillovers between large firms who undertake the bulk of R&D and small firms for whom higher productivity activities may result.

Of course, internal economies are also potentially relevant to productivity growth among small firms, especially if imperfect competition, in the form of monopolistic competition, prevails in most sectors where there are many sellers of products that are close substitutes for one another; each firm has only a limited ability to affect its output price. The pioneering work of Caballero and Lyons (1989) studied the importance of internal and external economies in US manufacturing. They found that internal returns to scale at the sectoral level are not important, whilst they found that external returns are large and significant. In UK manufacturing, Oulton (1996) found that there is no evidence was found for increasing returns which are internal to the industry. On the other hand, Oulton (1996) found that the externalities detected in his paper seem to apply peak to peak such as the business cycle and this not consistent with ‘thick market’ effects.

A suitable production function framework which captures the essence of the approach illustrated above is supplied by the class of production functions displaying a constant
elasticity of substitution – denoted as above by the parameter $\sigma$ (the CES production function). A useful recent example of its use in estimating the impact of technological change on employment is provided by Barrell and Pain (1997, 1999), who investigate the impact of inward foreign direct investment on the major European economies.

The CES function present interesting properties as they include the Cobb-Douglas and the Leontief production functions as special cases (Keller, 1989). Moreover, Keller also argues that the CES function has been widely used in empirical works and it is useful since a large diversity of results may be formed in time series and cross-section studies.

The CES production function can be written as follows (Black and Kelejian, 1970):

$$Q = \left[ \alpha(L)^{(\sigma-1)/\sigma} + (1-\alpha)K^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \quad (5.1)$$

where $Q$ is the flow of output, $L$ is labour input, $K$ is inputs of capital, $h$ denotes returns to scale, $\alpha$ and $\sigma$ are parameters, $\alpha$ can be interpreted as the share parameter and $\sigma$ as substitution parameter reflecting the elasticity of substitution. $1 > \alpha > 0, 1 \geq \sigma \geq -\infty$

Taking the first partial derivative with respect to the labour input and equating the marginal product to the real wage yields as a first order condition:

$$a(h\alpha)^{\sigma/(\sigma-1)} = \beta \frac{W}{P} \quad (5.2)$$

where $\frac{W}{P}$ denotes to the real wage ($W$ is the nominal wage and $P$ is the output price index) and $\beta$ is a parameter ($1 > \beta > 0$). Taking natural logarithms of both sides yields:

$$\ln[\beta^{-\sigma}(h\alpha)^{\sigma}] + \left( \sigma + \frac{1-\sigma}{h} \right) \ln Q - \ln L = \sigma \ln \left( \frac{W}{P} \right) \quad (5.3)$$

Re-arranging (5.3) yields:
The labour demand approach – as exemplified in the recent work of Barrell and Pain - requires us to consider indicators of technological change. In most econometric models of labour demand, this aspect has been captured by the use of a time trend. In other studies, an attempt has been made to be more specific and attempt to suggest a source for the technological change by measuring some aspect of technological activity. The next section considers such measures in more detail, before applying them to a model of labour demand.

5.4 Measuring Technological Activity

In order to consider possible relationships between employment in the small-firm sector and technological change it is first necessary to review indicators which reflect either technological activities directly (associated with the creation of knowledge and essentially an input) or else reflect technological capabilities (which may be associated with the utilisation and diffusion of new knowledge and possibly correlated with inputs), or finally those which (like Total Factor Productivity) attempt to measure the outcomes of such activities.

In empirical analysis a number of different indicators have been used to indicate these dimensions of technological activity. Total factor productivity aside, three measures have been important in the empirical literature:

- Research and development (R&D) measures (either expenditures by firms or counts of personnel engaged in R&D)
- Counts of patents
- Counts of innovations (either self reported or evaluated by ‘experts’ or by reference to publications)

Research and development (R&D) activities comprise creative work “intended to increase the stock of knowledge, including knowledge of man, culture and society and
the use of this stock of knowledge to devise new applications" (Freeman, 1982). R&D is used mainly to obtain new scientific and technological knowledge, to develop new or better products and processes and to apply recently developed knowledge in making significant improvements to existing products or processes (Masoumzadeh and Pickles, 1998).

Measures based upon R&D are frequently used in the literature (for a recent survey of the different measures of technological activity, see Smith 2005) and have many applications. Mansfield (1968) claims that the rate and direction of technological change is heavily reliant on the extent and nature of R&D. Moreover, Terleckyj (1980) finds that R&D has a positive effect on the technological change in US manufacturing. Griliches (1979, 1992) for example finds that R&D stock has a positive effect on the productivity growth in US manufacturing.

For statistical purposes both R&D personnel and R&D expenditures by firms are defined according to the OECD's Frascati Manual (7th edition OECD 2002), which defines R&D in terms of the production of new knowledge or the new application of existing knowledge (Smith 2005). It therefore excludes many activities – such as design, market research or training activities which may be relevant to technological change. Almost by definition R&D measures are 'biased' toward larger firms which are more likely to have formal specialised R&D departments. Moreover, the tax incentives for R&D which exist in some countries may lead firms to classify employment as R&D. Nevertheless, R&D provides a consistent and relatively coherent indicator of resources deliberately directed at technological outcomes and which can be used to provide comparisons both between industries and (because of the internationally standardised definition) between countries. The OECD for example has used the concept of R&D intensity (R&D expenditure divided by value added) to distinguish between 'high-tech', 'medium tech' and 'low tech' industries.

In addition to the bias toward large firms noted above, Patel and Pavitt (1995) observe other limitations to R&D data. First there is a bias toward science-based industries – in chemicals and electrical and electronic industries – where formal R&D departments are more common. In engineering, production engineering and design department may be more important as generators of technology. Second, in breakdowns of R&D
activities by industry, they note that R&D is allocated according to the principal activities of the firm engaging in R&D. This ignores the fact that much R&D is based around the development of processes and associated equipment in many industries. Therefore the share of inventive and technological activity based around mechanical and production engineering is underestimated by the share of R&D undertaken by the mechanical engineering sector of the economy. Finally, the authors discuss the increasing role of software in information processing activities, and the fact that software development takes place (like production engineering) outside formal R&D departments.

The use of patents as a technological indicator has a history comparable to that of R&D. Patents may be defined as “a public contract between an inventor and a government that grants time-limited monopoly rights to the applicant for the use of a technical invention” (Smith 2005, p 158). Based upon a presumption that there will generally be under investment in innovative activity, patents have two objectives: raising the returns (or appropriability) of invention for the inventor, while allowing maximum information about the process or product being protected to be revealed on expiry of the patent, allowing for the greatest diffusion of the new knowledge. As a countable document, with fields tracing inventor (individual or organisation), initial application, geographical location etc., the advent of electronic databases has provided considerable aided researchers in recent years.

As with R&D, there are several limitations to patent data as a measure of technological change. Most importantly perhaps, there is the question of what precisely is being measured, a point emphasised by Griliches in his 1990 survey, where he draws an important distinction between the aspect of the economy that patents actually measure and what exactly economists would like them to measure (Griliches 1990). Perhaps the first economic application of patent statistics is attributable to Schmookler who sought to establish the relevance of demand side incentives as a determinant of the flow of innovations in the U.S., using patents as an indicator of inventive activity. The original attention in his 1951 PhD thesis was that this measure might be able to explain total factor productivity growth in the U.S. economy, but his attempt proved largely unsuccessful (Griliches 1990). In his much cited later work, as Griliches observes, Schmookler had shifted toward seeing patents
as a measure of “work specifically directed towards the formulation of the essential properties of a novel product or process” (Schmookler 1966 p8, quoted in Griliches 1990, p.1670), i.e. towards seeing patents as a measure of input into innovation rather than as a measure of inventive output.

It is also well established that the economic value of patents forms a highly skewed distribution, with many patents having little or no economic value, and just a few have great value. Researchers have used a variety of methods of controlling for this effect, including international patenting, or weighting patents by ‘quality’, measured in terms of patent citations.

Other limitations of patents statistics appear in both cross-section and time series analysis. In cross-sections – particularly those that compare different industries – account needs to be made in ‘propensities to patent’. As the so-called ‘Yale studies’ into the mechanisms by which firms appropriate the benefits from R&D made clear, industries differ considerably in the extent to which patents are important in protecting intellectual property (Levin et al. 1987). The Yale studies were based upon replies from 650 high level executives across 130 industries. They show considerable variation in the extent of patenting per R&D dollar across the industries surveyed. This could be explained by the fact that for many industries, the importance of patents as a means of protecting intellectual property was significantly behind other methods, especially secrecy, lead times, and marketing efforts. Patents were generally found to be more important for product than for process innovation, while the industries for which patents were found to be rated highly in terms of importance were mainly to be found in chemicals and pharmaceuticals. In none of the most heavily sampled industries were patents rated more highly than other methods of appropriability.

When using time series interpretations of patenting activity, other considerations are important. Time series of patent activity need to take account sources of variations in patenting activity which have occurred over time other than those reflecting technological activity, including resource constraints in the patent offices themselves. A ‘surge’ of patenting activity both in the US and Europe in recent years is well documented (Smith, 2005). Clearly reasons for the increase in activity is numerous and so there can be no simple explanation in terms of a rise in inventive activity.
Possible reasons (examined in Jaffee 2000) include changes in the patenting process (especially in the U.S.), expansion of the 'realm of patent ability' to include software and gene sequences, and possible changes in corporate strategic behaviour. Here at least one hypothesis is that a desire on the part of large firms to strengthen their competitive position vis a vis smaller firms. In their 1999 study, Kortum and Lerner establish that – for the US at least – the increasing importance of developments in software and biotechnology cannot alone explain the surge and that the rise is noticeable across technology classes (Kortum and Lerner 1999).

Despite the clear imperfections in the use of either R&D or patent data, this has not stopped economists examining both simultaneously in an attempt to examine the 'productivity' of R&D activity and to determine whether there is any evidence of diminishing returns to R&D expenditures. Of relevance here is that in cross-sectional studies, small firms have been found to generate significantly more innovation in terms of patents than the distribution of R&D suggests. For the US, evidence presented by Bound et al (1984) showed that the ratio of patents per R&D dollar was much higher among small firms and smaller R&D projects, but declined rapidly and that beyond a certain size the relationship is constant.

A problem in drawing inferences about the 'efficiency' of R&D from R&D and patent statistics is that small firms either do not do formal R&D or underreport it, but do instead undertake other technological activities – e.g. in design. There may also be sample selection bias in many datasets with smaller firms consistently under-selected (Griliches 1990). A recent paper by Lim et al (2004) uses the number of 'inventors' in the firms' employment as an alternative indicator. They examine two industries – semi-conductors and pharmaceuticals - and while they are able to replicate the findings regarding the relationship between R&D per dollar and firm size, they find that for semi-conductors the number of patents per inventor actually rises with firm size in semi-conductors while it is broadly constant for pharmaceuticals. The authors here include controls for patent quality.

For the UK, a pioneering study of the relationship between firm size and innovation was conducted at the Science Policy Research Unit (SPRU) in the 1980s (Pavitt et al, 1987). This was based upon an examination of 4378 innovations produced and
commercialised over the period 1945-1982. This more direct source of evidence on technological activity is considered further below, but the authors demonstrate the importance of small firm innovation, especially in supplying productive inputs to larger firms.

The use of both R&D and patent data in applied economics and in econometric work now has a long history. The early contributions of Schmookler in the 1950s have already been highlighted, while Griliches’ use of R&D data also dates back to that period (e.g. Griliches 1958). Beyond questions of the efficiency of R&D, more important in terms of the current study, and one of the central questions in the use of technological indicators has been in the study of economic ‘spillover’ effects, i.e. the existence of a knowledge base on which firms can draw which is over and above their own internal resources but to which firms contribute – a common ‘knowledge pool.’

The review of spillovers by Griliches (1992) suggests that important spillover effects have been revealed using econometric analysis, essentially by augmenting estimates of a production function displaying constant returns to conventional inputs with additional returns from a firms’ ‘own’ R&D efforts as well as ‘outside’ R&D - from firms within the same industry. Griliches’ survey of econometric estimates in this area suggests an elasticity of productivity with respect to outside R&D, of “between half and double that from private R&D.” Not all studies have however found quite as clear evidence for these spillovers. In the 1990s, Geroski and others – in research based upon the SPRU innovations database of the UK (see above) - conducted a number of studies which failed to show any strong evidence of within industry spillover effects either on productivity (Geroski 1991), corporate profitability (Geroski et al 1993) or corporate growth (Geroski and Machin 1993). In a reflection on this work published subsequently, Geroski notes that this conclusion differs from the US studies survey by Griliches, and may be unique to the SPRU dataset, but argues that the within ‘industry’ technique of analysis is very crude since many potential spillovers will operate across official classifications of industries: “what one would really like to do is find some independent means of establishing the ‘technological base’ underpinning the operations of a firm, and then use this information to collect firms together into different ‘technological clusters’ and establish the proximity of each cluster to all of the others”. (Geroski 1994, p154)
What does the spillover literature tell us about the role played by ‘outside’ knowledge as far as small firms are concerned? One study directly relevant to this thesis appears to have considered the question of spillovers between large and small firms explicitly, i.e. between then main source of R&D and potential recipients. Acs and Audretsch (1994) note the earlier studies by Pavitt et al (1987) and their own earlier work regarding the innovative role of small firms (Acs and Audretsch, 1987, 1988, and 1990 cited above) and directly pose the question of where “do small firms get the innovation producing inputs?” Using a framework which derives from the pioneering work of Jaffee (1989) on the role played by geographical proximity in spillover effects, they estimate separate models of innovative activity which allows for a differential effect from both outside university R&D as well as corporate R&D according to firm type (large versus small firms with a cut-off of 500 employees). While the model is similar to Jaffee’s, a noteworthy difference is the use of a ‘count’ of innovations at the state level for 1982 for the dependent variable, whereas Jaffee used a count of patents at state level. The innovation count was provided by the U.S. Small Business Administration (SBA) Innovation Database. This database consists of 8074 innovations introduced into the United States in 1982. 4476 of these innovations were identified in manufacturing industries. These data are classified according to four-digit SIC industries. The authors find that “private corporation R&D plays a relatively more important role in generating innovative activity in large firms than in small firms. By contrast, spillovers from the research activities of universities play a more decisive role in the innovative activity for small firms” (Acs and Audretsch, 1994, p5). They therefore argue that small firms innovate through exploiting knowledge created by expenditure on R&D in large firms and from universities. The use of innovation count data is considered further below.

The brief survey of the literature in this section suggests that the majority of empirical studies investigating the role of knowledge and technological change have used either R&D (essentially an input dominated by larger firms), or patents (more questionable as to what is being measured but generally closely correlated with R&D). The great advantage in empirical work of both these measures is the fact that they can generate data over long periods of time. Both however have weaknesses which need to be borne in mind. These weaknesses have encouraged more direct means of developing
the empirical analysis of the process driving innovation using 'counts' of innovations such as the studies for the U.S. by Acs and Audretsch or those for the U.K. by Geroski and his colleagues discussed above.

There are two main kinds of innovation count – those which are 'objective' in character and those which rely on subjective self-reporting by business units (Smith 2005). The 'objective' approach attempts to count 'significant' innovations, either through expert appraisal (as in the SPRU studies studied above) or on the basis of literature searches – e.g. of trade journals etc – such as the U.S. studies by Acs et al. or in Europe by Kleinknecht and Bain (1993)

The SPRU database provides an annual count of innovations deemed by a panel of experts to represent “the successful commercial introduction of new or improved products, processes and materials introduced in Britain between 1945 and 1983” (Geroski and Walters, 1995). This database contains data about technical innovations in UK manufacturing including many kinds of information such as sources and types of innovations, industry innovation patterns.

Smith (2005) argues that the advantages of 'objective' approach are as follows:

- Technology- oriented approaches have the merit of focusing on technology itself.
- Using the trade journal makes the counting of innovation independent of personal adjustment and allows of external assessment of the importance of innovation.
- Both expert- based and literature based approaches can be backward looking, thus giving a historical perspective on technological development.

The objective approach by contrast is based on subjective or self reported assessments at the firm level. In Europe, the Community Innovation Survey (CIS) which surveys firms on a four-year cycle (1990-92; 1994-96; 1998-2000 and most recently 2002-2004) represents one of the most important research tools in the field. Conducted at an EU level, and based upon an internationally standardised set of questions (the so-called Oslo Manual), the survey seeks to obtain information about
various aspects of innovation which in itself is defined in different ways depending upon the degree of novelty (new to firm or new to market or industry) and whether it is a process or product innovation. The survey seeks information not only on whether firms innovate but also about the resources used, the sources of knowledge, and the outcomes of the innovation. Naturally other characteristics of the firm are also reported. Further discussion of the CIS is postponed until the next chapter, when CIS3, the 1998-2000 survey is used to test hypotheses developed in the current chapter. Much research in Europe has already been conducted using the CIS to develop more understanding of the nature of technological spillovers.

Below, chapter 6 uses the CIS3 data to achieve two objectives. First, to study the relationship between the innovation activity and firm size by using the data which related to innovation activity (such as question 4 and 5). Secondly, building upon hypotheses developed in this chapter, to determine the sources of information relevant to innovation activity by using question 12.

5.5 The Knowledge Stock in UK Manufacturing

The purpose of the current section is to consider estimates of the UK 'knowledge stock' that are relevant from the point of view of the productivity of the small firm sector, and to consider these estimates from both an analytical and a statistical perspective. For the latter, given the econometric model developed later, it will be necessary to consider the time series aspects of these stocks.

The basic methodology of the augmented production function literature discussed above – pioneered by Griliches at the NBER - suggests a simple experiment for the UK. Since most R&D is conducted by large firms of at least 100 employees, a relationship between employment in the sector employing less than 100 employees and R&D conducted in much larger firms, would be of great interest. For a variety of reasons discussed in the last section, the experiment is perhaps best conducted for manufacturing as a whole. These include:

- The fact that we cannot be sure that detailed industry data capture spillovers (see the discussion in the last section)
• Much R&D is based around production engineering; however since industry R&D data are organised around the principal product of firms, much important information may be lost.

Additionally the methodology of the Annual Censuses of Production means that there may be measurement error associated with small firm sector data – as mentioned in chapter 3.

The methodology for construction of knowledge stocks as developed by Griliches, Mansfield (1965) and others is described in Griliches (1979). He also gives an important retrospective discussion in Griliches (1998). The basic idea is that – analogously to the construction of capital stocks - the flow of services available to industry through the generation of knowledge can be proxied by a lagged polynomial of past R&D expenditures. Three major issues in the construction of knowledge are identified by Griliches (1979):

• R&D takes time and impacts upon productivity only with a lag
• Past knowledge depreciates over time as old products and processes become obsolete
• The level of knowledge available to an industry is not only derived from its own R&D since it may also be ‘borrowed’ from other industries.

Regarding the first point, Griliches observes that there are many different types of R&D and several types of lag involved between the original ‘project’, any innovation that takes place as a result of the project, and the impact that such innovation has upon individual firm’s revenues. As far as depreciation is concerned, it is widely believed that there is an important difference between private and social rates of depreciation (e.g. Pakes and Schankerman 1984). The fact that much commercial research may be expected to have a rather short pay back period for the firm concerned does not mean that it does not become useful common knowledge within the industry – not a source of competitive advantage but still impacting in terms of productivity. However, there
is still clearly a positive rate of depreciation of knowledge as technologies evolve and replace earlier technologies.

In practical applications, the construction of stocks has involved making assumptions about the rate of depreciation of knowledge capital and 'initial' knowledge stocks. In circumstances in which R&D expenditures are growing rapidly the assumption that the growth rate of knowledge (K) approximates that of constant price R&D expenditures (R), i.e. $\Delta K / K \approx \Delta R / R$ as in Mansfield (1965). Alternatively, in the context of the augmented production function, the ratio of R&D to output ($q$) may be appropriate (e.g. Griliches and Lichtenberg 1984; in a U.K. context, Buxton and Kennally 2004). Alternatively, and this is the approach adopted below, experiments will be made with R&D stocks with different rates of depreciation, as (for example) in Buxton et al (1991), Swann et al (1996), Coe and Helpman (1995). A further issue, less frequently discussed, concerns the appropriate deflator for R&D. The usual choice is the GDP deflator, but since the majority of expenditures are on personnel, an appropriate choice may well be an index of professional salaries, or possibly some weighted average of the two. If $\delta$ is the rate of depreciation, then the perpetual inventory method implies that:

$$\Delta K_t = K_{t-1} (1 - \delta) + R_t \quad (5.5)$$

The initial knowledge stock is given by: $K_0 = R_1 / (g + \delta)$ where $g$ is the (so far unknown) rate of growth of R&D expenditures prior to period 0. In the estimates below, it is assumed that these expenditures grew in line with manufacturing output over the 10 years previous to the period where the R&D data begin, i.e. 3.6% per annum from 1963-1973. R&D data is that for business expenditure on R&D (BERD) for total manufacturing taken from the OECD's ANBERD dataset which is consistent with the Structural Analysis of Industries (STAN) data also available from the OECD web-site.

The rate of depreciation is a more important consideration than the assumed rate of growth of R&D prior to the starting date, and there will be convergence in the growth rate of R&D stocks over time, regardless of the choice of $g$. Here the literature
stresses the importance of the difference between the social and private rate of depreciation (Pakes and Schankerman 1984), primarily because of spillover effects. To the extent (for example) that innovations are imitated, the private depreciation rate may fall well short of the social rate. Nadiri and Prucha (1993) for example argue that the rate of decay in revenue does not arise from any decay in productivity of knowledge but from the reduction in market valuation which arises due to an inability to appropriate the benefits from the innovation and the obsolescence of original innovation because of new ones.

The following table shows the estimated value of the private depreciation rate from various studies as compiled by Nadiri and Prucha. These are based upon studies of patent renewal rates. The study by Nadiri and Prucha itself uses estimates of a demand function for R&D based upon gross investment in R&D which allows the authors to estimate the depreciation parameter of 12% for the U.S.

<table>
<thead>
<tr>
<th>Source</th>
<th>Range of estimates</th>
<th>Average estimate</th>
</tr>
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<tbody>
<tr>
<td>Pakes and Schankerman (1978)</td>
<td>0.18-0.36</td>
<td>0.25</td>
</tr>
<tr>
<td>Pakes and Schankerman (1986)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1- UK</td>
<td>0.17-0.26</td>
<td></td>
</tr>
<tr>
<td>2- France</td>
<td>0.11-0.12</td>
<td></td>
</tr>
<tr>
<td>3- Germany</td>
<td>0.11-0.12</td>
<td></td>
</tr>
<tr>
<td>Nadiri and Prucha (1993)</td>
<td></td>
<td>0.12</td>
</tr>
</tbody>
</table>

Source: Nadiri and Prucha (1993)

From the point of view of the small business sector, the rate of depreciation of (by definition) outside R&D is also subject to the same principle. Spillover effects are subject to decay in terms of the profitability from entrepreneurial activity, but may still contribute to a ‘pool of common knowledge’ through which productivity if not profitability may increase. In other words, some of the spillover effect will be reflected in certain ‘entrepreneurial’ firms obtaining a competitive edge, and positive private rates of return, while longer term effects will be generally available, through
education, training and (as discussed below) and through forms of 'codified' knowledge. Codified knowledge means public knowledge or 'Common knowledge pool' (King et al, 2005). This kind of knowledge is very easily to share between the firms. It is important factor of production in the knowledge economy (Zack, 1999).

Variation in the UK’s R&D expenditures undertaken by UK manufacturing firms has been quite important over the period considered in this chapter. Figure 5.7 suggests that – as normalised by current price value added to give a measure of R&D 'intensity' – R&D rose in the 1970s from 4-6% of value added, fell back in the 1980s and 1990s before rising again – rather rapidly in the period 1997-2003.

While the growth in R&D intensity is of interest in its own right, the period was one of slow growth for much of UK manufacturing (just 0.3% per annum over the same three decades), this may not imply much growth in constant price R&D expenditures. To obtain the latter, the usual choice is simply the GDP deflator, although as discussed above, an alternative based upon the number of personnel that can be purchased is shown as a possible alternative – constructed through the use of a specially constructed wage and salary index for manufacturing.
From Figure 5.8 we can clearly see that volumes of R&D expenditure have been in decline for two decades after peaking in the late 1970s or early 1980s. The impact of this on the calculated R&D stocks depends of course on the assumed rate of depreciation. Figure 5.9 shows alternative estimates of the year on year % change R&D stock, based upon $\delta = 0.1, 0.2, 0.3$ and $0.5$ as well as simply the % change in the volume of R&D flow. While all the series become negative for a substantial part of the period, it is clear that the time series properties of the alternative measures are rather different.
Table 5.2 shows average growth rates over the period for different estimates of the knowledge stock and for different sub-periods. The first column records the decline in the volume of R&D ($R$) over the whole period, despite rising over the 1970s, as well as the stock at various rates of depreciation. Note that at very high rates of depreciation (perhaps implausibly high) the growth in the stock is negative over the whole period. All indicators suggest that the stock was declining over the period 1990-2002; the position regarding 1973-1979 is however more mixed, with a range of 1.8% (with $\delta=0.05$) to -0.5% per annum ($\delta=0.5$).

<table>
<thead>
<tr>
<th></th>
<th>$R \delta = 0.05$</th>
<th>$R \delta = 0.1$</th>
<th>$R \delta = 0.15$</th>
<th>$R \delta = 0.3$</th>
<th>$R \delta = 0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-2002</td>
<td>-0.7</td>
<td>1.2</td>
<td>0.5</td>
<td>-0.4</td>
<td>-0.5</td>
</tr>
<tr>
<td>1973-1979</td>
<td>2.2</td>
<td>2.9</td>
<td>2.6</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>1979-1990</td>
<td>-1.1</td>
<td>1.8</td>
<td>1.2</td>
<td>0.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>1990-2002</td>
<td>-1.7</td>
<td>-0.1</td>
<td>-1</td>
<td>-1.5</td>
<td>-1.7</td>
</tr>
</tbody>
</table>

5.6 Technological change and Labour Demand in the Small Firm Sector

What evidence is there that the R&D stock impacts upon the demand for labour and employment in the small firm sector? The approach taken here is to estimate a labour demand equation which allows for the impact of technological change. A reasonably general specification based upon the analysis of section 5.3 and the CES production function is as follows. This particular specification allows for non-constant returns to scale; the lower case letters indicate the use of logarithms and the time subscript is suppressed:

$$l = \alpha_0 + \alpha_1 w_a + \alpha_2 g + \alpha_3 r_d + \alpha_4 t + \mu$$ (5.6)

Here, $l$ is the level of employment, $w_a$ is the real product wage, and $g$ is net output evaluated at constant prices in the small firm sector (firms employing less than 100 employees), $r_d$ is our indicator of the UK knowledge stock available in manufacturing., $t$ is a time trend which allows for unobservable influences on $l$ but
which is usually regarded as the result of Hicks neutral technological change. In a dynamic setting, consideration needs to be given to the lags involved. Employment is generally an autoregressive process and so a lagged dependent variable may be appropriate, although in the context of the small firms sector and the high rate of churn discussed in an earlier chapter, it may be that responses to changes in the determinants of labour demand may be relatively rapid in this context and with the annual data to hand. However, the main interest is in the long-run and whether we can detect an influence of (the exogenously determined) knowledge stock on the level of employment. Nevertheless, this chapter will consider a dynamic specification as well as a long-run model.

The simplest model of employment and labour demand with technological change proxied by a time trend provides a natural starting point and a base line model. Table 5.3 displays some relevant summary data for the variables used in the following analysis and required by the basic theory.

<table>
<thead>
<tr>
<th>Table 5.3</th>
<th>Summary Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>data period 1973-2002</td>
<td>mean</td>
</tr>
<tr>
<td>log of employment</td>
<td>l</td>
</tr>
<tr>
<td>log of net output at constant prices</td>
<td>q</td>
</tr>
<tr>
<td>log of real product wage</td>
<td>wa</td>
</tr>
</tbody>
</table>

As can be seen from the final column, employment fell slightly over the period for which there are data, real output grew at around 2.6% per annum, while the real product wage grew reasonably strongly – at around 3% per annum.

Modern time series analysis begins with the idea of stationarity and the order of integration of the underlying variables. This is important because, whenever variables move together over time, statistically significant but spurious relationships may exist between non-stationary variables. An important example of a non-stationary variable is the random walk, displayed by many economic time series (Maddala, 2001).
particular variable is however said to be stationary when its moments (mean, variance, and auto-co-variances) are time invariant. The regression technique of ordinary least squares provides consistent parameter estimates only if the variables are all stationary. However, it is possible for some vector combination of non-stationary variables to be stationary. This vector combination is then said to be co-integrated. Co-integration analysis is particularly relevant in the current context because it allows for the study of long-run relationships without the need to discuss particular short-run dynamic specifications, and it is the long-run relationship between knowledge largely produced by large firms and technological change among small firms that is the primary concern in this chapter.

Testing for stationarity generally involves the idea of a random walk (a series that possesses a 'unit-root'). Such a data generating process can be written as:

\[ y_t = y_{t-1} + \varepsilon_t \]  \hspace{1cm} (5.7)

where the \( \varepsilon_t \) are independently and identically distributed with mean 0 and finite variance \( \sigma^2 \). This model is non-stationary since its variance depends upon the number of time periods over which it is calculated. However if we first difference the above expression, i.e. \( \Delta y_t = y_t - y_{t-1} \) the new series is stationary since both the mean and variance are now constant. When first differencing renders a series stationary, the series is said to be integrated of order one or \( I(1) \). However a more general model of an \( I(1) \) process is generally considered in testing for stationary, which allows for both 'drift' and a deterministic time trend:

\[ y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 t + \varepsilon_t \]  \hspace{1cm} (5.8)

This model has both a deterministic time trend and 'drift' i.e. a non-zero constant term. If the series is a random walk with trend and drift, \( \beta_1 = 1 \), it can be rearranged as:

\[ \Delta y_t = \beta_0 + \beta_2 t + \varepsilon \]  \hspace{1cm} (5.9)
so a common test procedure is to run the regression:

$$\Delta y_t = \beta_0 + (\beta_1 - 1) y_{t-1} + \beta_2 t + \varepsilon \quad (5.10)$$

and test for $\beta_1 - 1 = 0$. This is the Dickey-Fuller test. Note that stationarity requires a one-tailed test of the null that $(\beta_1 - 1)$ where the alternative hypothesis is $\beta_1 - 1 < 0$. More generally however, there is a potential for serial correlation in the error term which will bias the results unless lags of the dependent variable - $\Delta y_t$ - are included. Inclusion of lagged dependent variables produces the augmented Dickey-Fuller (ADF) test.

Now consider the simple labour model demand model as expressed in equation 5.4 without the augmented variable(s) indicating technological change. The variables of interest are $l$, $q$, and $wa$ representing (the logs of) employment, output, and the real product wage respectively. As Figure 5.10 illustrates, no clear trend can be seen for $l$ while $q$ and $wa$ may exhibit a deterministic time trend. The ADF tests – reported in Table 5.4 - allow for up to three lags and allow for a trend in the case of $q$ and $wa$. Also included are the adjusted $R^2$ and the Akaike Information Criterion (AIC) for comparative purposes.
Implemented in STATA®, the results suggest that we cannot reject the hypothesis of a unit root in any of the three variables.
Table 5.4

Results of ADF tests
Levels of I, q, and wa
1973-2002

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
</tr>
<tr>
<td>Test- statistic</td>
<td>-1.67</td>
<td>-2.14</td>
<td>-2.49</td>
<td>-1.61</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.45</td>
<td>0.23</td>
<td>0.12</td>
<td>0.48</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.06</td>
<td>0.12</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Akaike Information Criterion*n</td>
<td>-108</td>
<td>-104.92</td>
<td>-100.55</td>
<td>-95.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>wa</th>
<th>with trend</th>
<th>with trend</th>
<th>with trend</th>
<th>with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test- statistic</td>
<td>-2.74</td>
<td>-2.47</td>
<td>-3.38</td>
<td>-2.60</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-3.58</td>
<td>-3.59</td>
<td>-3.59</td>
<td>-3.60</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.22</td>
<td>0.34</td>
<td>0.05</td>
<td>0.28</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.18</td>
<td>0.15</td>
<td>0.28</td>
<td>0.22</td>
</tr>
<tr>
<td>Akaike Information Criterion*n</td>
<td>-104</td>
<td>-97.93</td>
<td>-96.76</td>
<td>-89.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>q</th>
<th>with trend</th>
<th>with trend</th>
<th>with trend</th>
<th>with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test- statistic</td>
<td>-2.87</td>
<td>-2.01</td>
<td>-2.77</td>
<td>-2.76</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-3.58</td>
<td>-3.59</td>
<td>-3.59</td>
<td>-3.60</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.17</td>
<td>0.60</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.19</td>
<td>0.19</td>
<td>0.31</td>
<td>0.30</td>
</tr>
<tr>
<td>Akaike Information Criterion*n</td>
<td>-95.01</td>
<td>-89.78</td>
<td>-88.96</td>
<td>-83.94</td>
</tr>
</tbody>
</table>

Table 5.4 shows the Dickey-Fuller test results for the levels of employment, output and real wages. The estimations of the employment are without time trend whilst the estimations include time trends for both wages and output. It can be seen that for the three variables, that we accept the unit root hypothesis at 5% level with all the four models since the test-static is smaller than the critical value at 5%. In addition the approximations to Mackinnon “p-values” show also favours acceptance. A further frequently used method is Mackinnon’s approximate p-value (Mackinnon, 1994). Mackinnon (1994) has introduced tables show the p-value which used as test of unit roots beside the critical value and t test in Dickey-Fuller test. No specific statistic procedures to compare between the models with no lag, one, two or three lags. The table quotes both adjusted $R^2$ and Akaike Information Criterion*n (this test is a criterion of selecting among models, this test here is adjusted with the number of the
observation (n). If we compare AIC*n to lots of models, the lowest AIC*n being the best model) test shows that the third model with 3 lags is probably the most appropriate because it has the highest value.

In order to see whether the three variables can reasonably be said to be $I(1)$, the first differences are now subject to the same testing procedure. Accordingly figure 5.11 shows $\Delta I$, $\Delta q$, and $\Delta wa$. It suggests that this is possible; although there is no evidence for a trend, there seems to be some increase in the variance in the later years, and more specifically evidence of a ‘spike’ in $\Delta wa$. ADF tests (without trend) are reported in Table 5.5

![Figure 5.11 First Differences of I, q and wa](image)
Table 5.5
Results of ADF tests
First Differences of l, q, and wa
1973-2002

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
</tr>
<tr>
<td><strong>Test- statistic</strong></td>
<td>-4.00</td>
<td>-2.67</td>
<td>-3.46</td>
<td>-1.55</td>
</tr>
<tr>
<td><strong>5% critical value</strong></td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
<td>-3.00</td>
</tr>
<tr>
<td><strong>Mackinnon approx p-value</strong></td>
<td>0.00</td>
<td>0.08</td>
<td>0.01</td>
<td>0.51</td>
</tr>
<tr>
<td><strong>Adjusted R^2</strong></td>
<td>0.36</td>
<td>0.35</td>
<td>0.43</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Akaike Information Criterion*n</strong></td>
<td>-102</td>
<td>-96.09</td>
<td>-94.06</td>
<td>-90.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>lwa</strong></th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5% critical value</strong></td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
<td>-3.00</td>
</tr>
<tr>
<td><strong>Mackinnon approx p-value</strong></td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Adjusted R^2</strong></td>
<td>0.58</td>
<td>0.57</td>
<td>0.60</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Akaike Information Criterion*n</strong></td>
<td>-95.1</td>
<td>-89.06</td>
<td>-85.85</td>
<td>-83.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>lq</strong></th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test- statistic</strong></td>
<td>-7.35</td>
<td>-2.74</td>
<td>-2.7</td>
<td>-2.53</td>
</tr>
<tr>
<td><strong>5% critical value</strong></td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
<td>-3.00</td>
</tr>
<tr>
<td><strong>Mackinnon approx p-value</strong></td>
<td>0.00</td>
<td>0.07</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Adjusted R^2</strong></td>
<td>0.66</td>
<td>0.67</td>
<td>0.67</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>Akaike Information Criterion*n</strong></td>
<td>-89.4</td>
<td>-84.71</td>
<td>-79.57</td>
<td>-74.49</td>
</tr>
</tbody>
</table>

Table 5.5 shows the Dickey-Fuller test for the first difference in the logs of employment, output and real wages without time trends.

It can be seen from the Table that for the employment variable that we reject the unit root hypothesis at 5% level with no lag and 2 lags models since the test-static is bigger than the critical value at 5% and because of the p-value of Mackinnon approx shows that this test is significant as well. To compare between the models with no lag and three lags, Akaike Information Criterion*n test shows that the third model with 3 lags is the best because it has the highest value. Adjusted R^2 values are quite similar for the four models.
For the wages variable, we reject the unit root hypothesis at 5% level with all the models since the test-static is bigger than the critical value at 5% and because of the p-value of Mackinnon approx shows that this test is significant as well. To compare between the models with no lag, one, two and three lags, Akaike Information Criterion\(^n\) test shows that the third model with 3 lags is the best because it has the highest value.

From output variable results, we reject the unit root hypothesis at 5% level with no lag model since the test-static is bigger than the critical value at 5% and because of the p-value of Mackinnon approx shows that this test is significant as well. To compare between the models with different lag lengths, Akaike Information Criterion\(^n\) test shows that the third model with 3 lags is the best because it has the highest value but because of we accept the unit root with it the no lag model should be the best.

Accepting that \(l, q,\) and \(wa\) are essentially \(I(1)\) variables, we can proceed to see whether a co integrating relationship exists between them as suggested by simple labour demand models with Hicks neutral technological change. A simple regression of \(l, q,\) and \(wa\) with the addition of a time trend yields the following result.

\[
l = 9.293 + 0.727q - 0.629wa - 0.002t \quad (5.11)
\]

It can be seen from equation (5.11) that the relationship between the labour demand and output is positive. Moreover, roughly a 1% increase in the output is associated with 0.7% increase in labour demand. This means that the growth rate of labour is lower than that of output, which means that there are increasing return to scale (the degree of returns to scale = 1.2\(^1\) ). On the other hand, the relationship between the real wages and labour demand is negative. 1% increases in the real wages decrease the labour demand by 0.6%, this means that the elasticity of substitution between the capital and labour is 0.629 (see equation 5.4 which, shows that the coefficient of real wages is the elasticity of substitution).

\(^1\) From equation 5.4 it can be seen that the coefficient of output (0.727 = \(\sigma + \left[(1 - \sigma)/h\right]\)) and \(\sigma = 0.629\) so \(h=1.2.\)
For $I(1)$ processes to co-integrate, the residuals need to be stationary, i.e. an $I(0)$ process. The residual plot (Figure 5.12) suggests rather a 'long memory'. More important than the residual plot is the question of whether the result makes economic sense. It implies that technological change contributed nothing to employment change in the small firm sector – at least when employment is conditioned upon output - since the coefficient on the time trend is both close to zero and statistically insignificant.

![Figure 5.12 Residual Plot](image)

One possible reason for the result is the mis-measurement of technological change. The use of a constant time trend is of course questionable, and so the next stage is to consider the impact of the UK knowledge stock which certainly has not grown steadily over time. To provide some focus, the discussion here concentrates on a 'low' (10%) and a 'high' (30%) rate of depreciation (call these $rd_{low}$ and $rd_{high}$ respectively) of the knowledge capital generated by R&D expenditures. Here however a problem presents itself when we consider adding an R&D variable since, as Figure 5.12 above suggested, the percentage change in R&D stocks is far from being stationary. Figure 5.13 shows the log levels of the two series both of which show a clear change in behaviour in the mid 1980s. Figure 5.14 shows the first differences of $rd_{low}$ and $rd_{high}$ in. Similar findings are reported in Buxton and Kennally (2004) in their investigation of the social rate of return in UK manufacturing. Plausibly in 30 years of data, these shifts can be regarded as a "structural shift" in the data generating process, rather than part of the data generating process itself.
As far as the levels - $rd_{low}$ and $rd_{high}$ - are concerned, it is not possible to reject the unit root hypothesis in the series either for the full sample or when the sample is split into the sub-periods 1973-1987 and 1988-2002. Results of these tests are reported in the appendix to this chapter. However, similar experiments with first differences were also unable to reject the unit root hypothesis. Note however that with only a handful of observations, the power of these tests is very low. A more powerful test is to allow for a structural break and test over the full sample. Experimentation with both first differenced series and a step-dummy for the period after the break suggested a shift in the mean for these series dated in the mid 1980s.

![Figure 5.13 Behaviour of log of R&D Capital in UK Manufacturing 1973-2002](image)

![Figure 5.14 R&D stocks at 'low' and 'high' rates of depreciation](image)

Correcting for the change in mean, it was possible to reject the unit root hypothesis and accept stationarity for the first difference in $rd_{high}$ but not for $rd_{low}$, for which the evidence is more varied. More details are supplied in Appendix 5.2. The use of $rd_{high}$ as a single measure of technological change presents problems – not for statistical but
for economic reasons. While a measure closely correlated with the current volume of R&D may be relevant - high R&D may lead to a greater volume of higher value added entrepreneurial activities (associated perhaps with earlier stage stages of the product cycle), there is a danger that the longer term consequences of R&D are being missed. For that reason the next section considers an additional measure of technological activity that may be able to capture this effect. This measure - essentially a count of technical standards similar to the patent counts discussed above is arguable able to proxy for the channel through which the transfer of technology to the small firm sector actually occurs.

5.7 The Transfer of Technology to the Small Firm Sector and the Role of Standards

While interesting and of importance - given the differential character of employment among large and small firms in UK manufacturing - the possible existence of a co-integrating relationship between a measure of domestically produced knowledge and employment in the small firm sector is far from identifying mechanisms which link the two and which are of interest for policy-makers. In addition, the fact that the measure used involved a rather high rate of depreciation of that knowledge - while consistent with a possible value of the private rate of depreciation of that knowledge, is too high to be a plausible value for the social rate of depreciation.

In this section the role of a channel whose importance has only recently begun to be established empirically is considered. This channel is that of 'codified information' - i.e. information that takes the form of readily accessible knowledge in the form (here) of technical information - test procedures, product and process specifications - that communicate elements of a shared technological base - and which frequently takes the form of publicly available industrial 'standards' - published documents which carry the information. Such documents have different origins, but a major provider in the advanced economies and especially in the UK and Europe are national standards bodies (NSBs). In the UK, the NSB is the British Standards Institution (BSI). An important feature of this channel is that these documents (like patents) can be counted in ways that can be sued for econometric analysis.
The word "standard" is defined in the Oxford dictionary as a level of quality or achievement; another dictionary such as Longman defines it as the idea of what is good or normal that some one uses to compare one thing with another. The BSI defines a Standard (with a capital letter) as "a recognised document that defines good practice; it can be applied to products, services or processes". Economists observe that standards can be usefully defined standards in terms of what standards actually do (Temple and Williams, 2002), i.e. in terms of their economic function.

To analyse the economic functions of standards, a taxonomy is required that classifies standards by economic functions (Tassey, 1999). According to their economic functions, standards are classified into four categories (Swann, 2000; Temple and Williams, 2002; Blind, 2004):

1- Compatibility and interface standards
These define the interface requirements which allow different core products to use common complementary goods and services or be connected together in networks (Grindley, 1995). Compatibility or interface standards help to expand market opportunities because they help to increase networks effects or externalities (Swann, 2000; Blind, 2004). It important to observe that standardisation based upon interoperability is not sufficient for economic success in itself (Temple and Williams, 2002).

2- Minimum quality and safety standards
Gresham’s Law - that in markets “bad drives out good” - demonstrates how much damage may be done when buyers find it hard to distinguish high quality from low quality of a good or service before purchase (Temple and Williams, 2002). Minimum quality standards play an important role in overcoming Gresham’s law, making it possible for buyers not only able to distinguish high quality from low quality but also reducing transactions and search costs (Swann, 2000).

3- Variety-reducing standards
Standards limit a product to a certain number of characteristics such as size and quality. This variety reduction performs two different functions (Blind, 2004). First, it
leads to economies of scale by reducing the number of variations of a product. Second, standards can also reduce the risks faced by suppliers - but this also means that they face more competition (Swann, 2002).

4 - Information and measurement standards

Standards introduce description or information about a product or service, such as the hotel star ratings: five-star, four-star etc. This can help to reduce transaction costs, reducing costs of accessing the market (Swann, 2000).

Table 5.6 summarizes these four different functions of standards and shows their positive and negative effects.

<table>
<thead>
<tr>
<th>Table 5.6 Economic Functions of Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive effects</td>
</tr>
<tr>
<td>Negative effects</td>
</tr>
<tr>
<td>Compatibility/interface</td>
</tr>
<tr>
<td>1-Network externalities</td>
</tr>
<tr>
<td>2-Avoiding lock-ins</td>
</tr>
<tr>
<td>3-Increased variety of systems products</td>
</tr>
<tr>
<td>Minimum quality/safety</td>
</tr>
<tr>
<td>1-Correction for adverse selection</td>
</tr>
<tr>
<td>2-Reduction transaction costs</td>
</tr>
<tr>
<td>3-Correction for negative externalities</td>
</tr>
<tr>
<td>Variety reduction</td>
</tr>
<tr>
<td>1-Economics of scale</td>
</tr>
<tr>
<td>2-Building focus and critical mass</td>
</tr>
<tr>
<td>Information standards</td>
</tr>
<tr>
<td>1-Facilities trade</td>
</tr>
<tr>
<td>2-Reduced transaction costs</td>
</tr>
</tbody>
</table>

1-Market concentration 2-Regulatory capture

Source: Blind, 2004

From table 5.6, it can be seen that the productivity enhancing effects of standards related to the reduction of costs, economies of scale and network externalities. However, it is important to realise “regulatory capture” may exist. This is the possibility that some producers may lobby so skilfully that they persuade the regulator
to define regulations in the interest of the producers rather than in the interest of the customer (Swann, 2000). These are usually large scale producers who – because of the fixed costs involved, are able to participate in the production of standards.

Standards can be very useful for both small businesses and large firms. Quality, efficiency and best practice, which can be improved through applying standards, are just as important to small firms as they are to larger firms (BSI, 2005). They can achieve the following targets (DIN, 2000; Temple and Williams 2002; BSI, 2005).

1- Reduce the transaction costs in the economy as a whole, as well as to save for individual firms.

2- Standards allow for improvements in quality, reduce the process time and help firms use innovations.

Turning to the specific influence of standards on technical change standards can influence technical change in several ways. The following table presents a summary.

<table>
<thead>
<tr>
<th>Table 5.7</th>
<th>Summary of the influence of standards on technical change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive effects</td>
</tr>
<tr>
<td>Compatibility/interface</td>
<td>More possibilities of combining system elements, forming network bridges</td>
</tr>
<tr>
<td>Minimum quality/safety</td>
<td>1-Reducing information asymmetries 2- Greater probability of market acceptance of new products</td>
</tr>
<tr>
<td>Variety reduction</td>
<td>Greater probability of market acceptance of new products</td>
</tr>
<tr>
<td>Information standards</td>
<td>Cost reduction, which fosters the accomplishment of critical masses of new products</td>
</tr>
</tbody>
</table>

Source: Blind, 2004

From table 5.7, it can be seen that standards influence technical change in various ways. For instance, variety reduction can be alleviated by standards that do not
determine the exact content or design, but only the performance of a product (Blind, 2004). Moreover, Temple and Williams (2002) note that many technical standards convey valuable technological information. This information provides essential and agreed information for technological innovation. Blind (2004) argues that the reduction of transaction costs that this provides a positive effect on technological change. Innovators can rely upon a common pool of codified knowledge to deliver their own product or process improvements. Standards help firms to meet regulations and this role is especially important for compliance to EU directives.

Standards have origins which are both purely market driven – for example when Volkswagen or Microsoft create product specifications for potential suppliers. These are sometimes called ‘de facto’ standards (Temple and Williams 2002). Other standards are produced by a collaborative process in technical committees – so-called ‘de jure’ standards. In many countries such as the UK or Germany – these standards take the form of open documents published by national standards bodies such as The British Standards Institution (BSI) in the UK and the Deutsche Institut fur Normung (DIN) in Germany. These public documents form an important source of technology and codified information. Moreover they serve as a technology transfer mechanism not just for domestically generated knowledge but also for knowledge produced overseas. At an individual firm level they are considered in the next chapter. Here a ‘count’ of standards made available in the catalogue of the BSI is used as a proxy for the extent of shared codified information available to producers with the general effect, as shown above, of reducing transactions costs. In practice the documents published may serve any or all of the economic functions described above.

The number of standards available – the ‘catalogue’ - is determined by a process of publication of new standards and retirement of obsolete standards which no longer serve a function. A count of the size of the BSI catalogue therefore depends on the following equation (Temple et al, 2005):

$$SCI (t) = \sum_{i=t-\infty}^{i=t} N (i) - \sum_{i=t-\infty}^{i=t} E (i)$$  (5.12)
Where SCI is the measure of the number of the standards catalogue at any point $t$ in time, $N(i)$ is the number of standards published during any year $i$, and $E(i)$ is the number of standards retired or withdrawn during any year $i$. The typical document is relevant to some sector of manufacturing industry. As a result, the relevant pool of knowledge for manufacturing firms can be represented by the size of the catalogue. Such a count was conducted by Temple et al (2004) as part of a project researching the ‘Empirical Economics of Standards’ for the Department of Trade and Industry in London (DTI 2005). The estimates were used to try and establish a co-integrating relationship between productivity, capital and standards at the level of the whole economy for the period 1948 – 2002 (reported in Temple et al 2004 and kindly made available for this thesis). In 1946 there were 1403 standards at mid-year. The catalogue had grown by 2003 to 23,737 an average annual rate of growth of 5.2%. The first difference in the log of the stock – i.e. roughly the proportionate rate of growth in the stock - is shown in Figure 5.10. A rather rapid growth is evident in both the 1950s and 1960s with a noticeable slowdown from the mid 1970s to the mid 1980s. Here – unlike the R&D stocks – we know rather more about the stock’s determination. The fast growth in later years reflects the importance

![Figure 5.15 Growth in the BSI Standards Stock 1947-2003](image)

Because of the longer period over which we have data, tests for a unit root in the standards data are more powerful over a longer period – although as Perron (1989) notes, there is a greater possibility of a regime change. ADF tests on both the log levels ($std$) and the first differences of the log of BSI standards stock ($dstd$) are reported in the Appendix 5.3. They suggest that the first difference may not be
stationary, unless a dummy for the period of slow growth between 1974 and 1985 is incorporated. This however allows us to proceed to the co-integration analysis in the next section incorporating both our measures of technical activity.

5.8 Co-integration Analysis of Labour Demand in the Small Firm Sector

Following our analysis of the stock of standards in the previous section, the final specification for labour demand in the small firm sector of UK manufacturing therefore incorporates both \( rdhigh \) – i.e. the R&D stock calculated using a 30% rate of depreciation – and \( std \) – the BSI standards stock calculated in mid-year. Allowing for a time trend to pick up ‘unobservable’ influences on labour demand in the small firm sector, the new specification becomes:

\[
l = \alpha_0 + \alpha_1 q + \alpha_2 wa + \alpha_3 rdhigh + \alpha_4 std + \alpha_5 yr + \alpha_6 dumies + \mu,
\]

(5.13)

As equation 5.5, \( l \) is the level of employment, \( wa \) is the real product wage, and \( q \) is net output evaluated at constant prices in the small firm sector (firms employing less than 100 employees), \( rdhigh \) is our indicator of the UK knowledge stock available in manufacturing at depreciation rate=30%; \( yr \) is a time trend which allows for unobservable influences on \( l \). Because of structural change in the process generating standards and R&D, the analysis also considered the possibility of structural breaks in the co-integrating relationship. The experiments conducted for this latter possibility included both a possible break in the time trend as well as

Table 5.8 shows the initial specification as above with and without a time trend – equations (1) and (2). These show the results of ADF tests on the residuals-based upon the Mackinnon p-values – at various lag lengths. The preferred lag length, based upon the AIC. These indicate that co-integration is generally accepted. Both equation (1) and (2) indicate a positive role for both R&D and standards in promoting technical change. The time trend still adds nothing to the interpretation in (1) and finally and more importantly the evidence for co-integration is not strong for either specification.
Table 5.8
Long Run Employment in Small Firm Sector
Co-integration Analysis
1973-2002

<table>
<thead>
<tr>
<th>Specification</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Independent variable</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Output</td>
<td>$q$</td>
<td>0.716</td>
<td>0.601</td>
</tr>
<tr>
<td>Real product wage</td>
<td>$w_a$</td>
<td>-0.509</td>
<td>-0.601</td>
</tr>
<tr>
<td>R&amp;D stock</td>
<td>$rd_{high}$</td>
<td>-0.203</td>
<td>-0.281</td>
</tr>
<tr>
<td>Standards stock</td>
<td>$std$</td>
<td>-0.163</td>
<td>-0.233</td>
</tr>
<tr>
<td>time trend</td>
<td>$yr$</td>
<td>0.009</td>
<td>0.000</td>
</tr>
<tr>
<td>dummy variables</td>
<td>$dum_{90}$</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

| CRDW | 1.05 | 1.27 | 1.51 |
| ADF Tests* | Favoured lag length=2 | Favoured lag length=2 | Favoured lag length=3 |
| ADF (0) | 0.007 | 0.002 | 0.000 |
| ADF (1) | 0.007 | 0.002 | 0.000 |
| ADF (2) | 0.069 | 0.002 | 0.000 |
| ADF (3) | 0.105 | 0.144 | 0.000 |

*Figures are the Mackinnon approx p-value

In view of the structural changes in the data process generating the explanatory variables and the possible non-co-integration of the variables, the next step was to investigate possible structural breaks in the co-integrating relationship itself. Experiments with both a slope dummy on the time trend and a step change in the constant yielded broadly similar results, both with a break in 1990. The final specification (3) allows for a time trend, but only after 1990.

From table 5.8, it can be shown from the third specification, which included a dummy valuable, for year 1990 that the elasticity of substitution is 0.6 and it is significant. This means that there is increasing return to scale. The elasticity of substitution is 0.6. On the other hand, the relationship between the labour demand in the small firm sector and both of the R&D and stock of standards are negative.
What are the implications of the preferred specification for long run productivity growth? The following table shows the estimated contribution of each of the contributory factors to the long run growth – not of employment – but of labour productivity.

From Table 5.9, based upon specification 3 in table 5.8, it can be seen that a strong contribution from real product wage (leading to higher capital intensities) and increasing returns. The estimates of the impact of standardisation are also large. R&D does very little because by contrast, because it did not grow. Poor R&D performance of large firms impact on entrepreneurship in the small firm sector. The unobserved factors are the contribution of the time trend. The overall change in the labour productivity is 85.7% for the period 1973-2002 (it is calculated 2.95 % for the period 1973-2002 per annum in section 3.5.2).

| Table 5.9 |
| Long Run Impact on Small Firm Labour Productivity |
| overall % changes |
| 1973-2002 |
| impacts |
| labour productivity | returns to scale | real product wages | domestic knowledge capital | standards | unobserved factors |
| period | 1973-2002 | 85.7 | 22.1 | 52.6 | -0.5 | 16.6 | 5.40 |
| 1973-1979 | 8.1 | 5.1 | 7.4 | 0.9 | 2.6 | 0.00 |
| 1979-1990 | 35.5 | 8.6 | 24.2 | 0.4 | 4.0 | 5.40 |
| 1990-2002 | 42.1 | 8.4 | 21.0 | -1.8 | 9.9 | 0.00 |

5.9 A Dynamic Specification of Labour Demand in the Small Firm Sector

Co-integration analysis allowed for the consideration of the long-run relationship between the variables in the analysis. Although this is the primary concern in this chapter, corroboration of the validity of the results is aided by using the results to provide a dynamic counterpart to the final co-integrating equation above (specification 3 in Table 5.8). This is perhaps particularly important given the autocorrelation frequently found in employment equations. Granger and Engle (1987) showed that this can be done in a second stage and using an Error Correction
Mechanism (ECM) (Maddala, 2001). Suppose that two $I(1)$ variables $Y_t$ and $X_t$ are co-integrated, then the short run relationship can be represented by
\[ \Delta Y_t = \alpha_0 + \alpha_1 \Delta Y_{t-1} + \beta_0 \Delta X_t + \ldots + \beta_1 X_{t-1} + \delta E_{t-1} + \epsilon_t \]  
(5.14)

In this section the short run dynamic relationship between the variables is estimated using equation 5.15 and which incorporates the errors from the co-integrating equation. Since a positive error will reduce the next period’s change in employment the expected sign on the lagged error is negative. The specification allows for both current and one set of lags on both the dependent and independent variables.

\[ \Delta l = \alpha_0 + \alpha_1 \Delta l_{t-1} + \beta_1 \Delta q + \beta_2 \Delta q_{t-1} + \beta_3 \Delta wa + \beta_4 \Delta wa_{t-1} + \beta_5 \Delta rdhigh + \beta_6 \Delta rdhigh_{t-1} + \beta_7 \Delta std + \beta_8 \Delta std_{t-1} + \beta_9 dummy + \beta_{10} E_{t-1} + \mu_t \]  
(5.15)

where $\Delta l, \Delta q, \Delta wa, \Delta rdhigh$ and $\Delta std$ are first difference of employment, output, wages, R&D and stock of standards respectively. Whilst $\Delta l_{t-1}, \Delta q_{t-1}, \Delta wa_{t-1}, \Delta rdhigh_{t-1} \Delta std_{t-1}$ and $E_{t-1}$ are lagged first difference of employment, output, wages, R&D stock of standards and lagged error (from specification 3 in table 5.8) respectively. Table 5.10 shows these results. A spike dummy is also included to allow for the step dummy used post 1990 in the co-integrating regression. Also I use a more parsimonious specification.

Table 5.10 shows the dynamic relationship between employment, output, wages, R&D and standards when 5.15 is estimated in full. It indicates a positive role for both R&D and standards in promoting technical change. The relationship between the employment and output is significant and positive, but it is negative between the employment and the wages. Most importantly of course the lagged error is negative and significant. This confirms the acceptance of the long-run relationship; which is further validated given there are no problems with any of the diagnostic tests presented (the AR (1) test for first order residual autocorrelation, the ARCH (1) test for autoregressive conditional heteroscedasticity and the Jarque-Bera test for normality). When a parsimonious specification is used the technical standards still positive, but it is significant. Furthermore the dummy variable is significant.
Table 5.10
Short Run Employment in Small Firm Sector
Error Correction Mechanism (ECM)
1973-2002

Dependent variable \( dl \)

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
<th>Sig.</th>
<th>Coefficient</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged First difference of dependent variable ( dl_1 )</td>
<td>-0.517*</td>
<td></td>
<td>-0.479*</td>
<td></td>
</tr>
<tr>
<td>First difference of output ( dq )</td>
<td>0.700***</td>
<td></td>
<td>0.682***</td>
<td></td>
</tr>
<tr>
<td>Lagged First difference of output ( dq_1 )</td>
<td>0.346*</td>
<td></td>
<td>0.356*</td>
<td></td>
</tr>
<tr>
<td>First difference of Real product wage ( dwa )</td>
<td>-0.549***</td>
<td></td>
<td>-0.496***</td>
<td></td>
</tr>
<tr>
<td>Lagged First difference of Real product wage ( dwa_1 )</td>
<td>-0.242</td>
<td></td>
<td>-0.236</td>
<td></td>
</tr>
<tr>
<td>First difference of R&amp;D ( drdhigh )</td>
<td>0.168</td>
<td></td>
<td>0.200</td>
<td></td>
</tr>
<tr>
<td>Lagged First difference of R&amp;D ( drdhigh_1 )</td>
<td>0.025</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First difference of Standards ( dstd )</td>
<td>-0.192</td>
<td></td>
<td>-0.751*</td>
<td></td>
</tr>
<tr>
<td>Lagged First difference of Standards ( dstd_1 )</td>
<td>-0.567</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dummy Variable ( yr90 )</td>
<td>0.000</td>
<td></td>
<td>0.000*</td>
<td></td>
</tr>
<tr>
<td>Lagged Error (From specification 3 in table 5.8) ( E_1 )</td>
<td>-0.944***</td>
<td></td>
<td>-0.849**</td>
<td></td>
</tr>
</tbody>
</table>

No of observations: 28
F-statistic: 7.99
Pr > F statistic under \( H_0 \): 0.000
Adjusted R\(^2\): 0.74
DW: 2.32
AR (1): 1.62
ARCH (1): 1.23
Normality: 2.12

* * * = significant at 1%
** = significant at 5%
* = significant at 10%

5.10 Panel Data Analysis of Labour Demand

While instructive, the analysis above for the whole manufacturing sector is clearly limited by the lack of power in the statistical tests. One way forward is to increase the number of observations by using data at a sectoral level. This section reports on experiments with sectoral level data constructed to form a panel for econometric analysis. It should be noted that using more disaggregated data also has drawbacks, not least that it may be unable to capture spillover effects, as we saw earlier in the chapter. This is because the spillover channels cut across sectors rather than being contained within them.
For a number of sectors, it was possible to construct data on wages, net-output, employment, R&D and standards. All of these data are available for the period 1985-2002 for eight industries. These industries are food, beverages and tobacco, textile and textile products, leather, paper and publishing, chemicals, rubber and plastic, non-metallic mineral products, and the basic metals and fabrication industries. For an additional four industries, data are available for the period 1985-1997. These industries are office and computing products, electrical and optical equipment, motor vehicles and transport equipment industries. For each sector data was collected across 4 size classes (1-99, 100-199, 200-499 and 500+) the maximum number of cross sections (N) available was therefore 4 x 12 = 48 while the maximum time span (T) was 22.

R&D data was taken from the OECD ANBERD data on business expenditure (however financed) which is classified to sectors according to the principal lines of activity of the reporting firms. Throughout the R&D stock – based on a 30% rate of depreciation has been used – \( r d_{high} \).

A count of standards was possible from 1985 onwards using the PERINORM\(^\circ\) database, produced by a consortium of the BSI, DIN, and AFNOR, the national standards bodies of the UK, Germany and France respectively and available on CD-ROM. Standards were classified to particular industries using a specially constructed set of descriptors based upon the 1992 Standard Industrial Classification and kindly provided by my supervisor. These were used as search terms in the standards abstracts on the database.

\(^2\) In practice no R&D is reported or is zero for this industry. Most estimates therefore exclude it from the panel.
Figure 5.16 illustrates the relationship between the two indicators of technological change (Stock of technical standards and R&D) for the panel in 2002. It can be seen that chemicals industry has the highest value of R&D in UK, whilst textiles industry has the lowest value of R&D in UK. On the other hand, Electrical industry has the highest value of the stock of standards and high value of R&D in UK, whilst paper industry has low value of both of R&D and standards.

The modelling framework employed for the panel data analysis is very similar to that used for the aggregate model. An important exception however was in respect of the price deflators, since detailed price deflators were not available for these sectors, at least over the time period of the sample. As a result, the analysis was conducted using three terms to reflect both the real product wage and the competitiveness of each size class. The first was the real product wage in manufacturing as a whole (\(w_a\)), i.e. the same variable as used in the aggregate analysis. This was augmented to include both sectoral and size influences on competitiveness. The first was a term based upon the ratio of the ‘wage’ (ie labour compensation including employers’ national insurance contributions per employee) of each size class to the average of the sector as a whole and designated by \(relwage1\). The second was the ratio of the sectoral wage to the
manufacturing wage (wages similarly defined) a denoted by relwage2. Both these variables are predicted to have a negative sign and are of interest in their own right, because they carry information about the extent to which firms of different sizes tend to be competitive with each other.

All results reported are based upon the fixed effects estimator – the regression estimating separate constants for each of the 48 size class/sector differences, i.e. the cross sectional pattern reported above. The results are presented in tables 5.11 and 5.12.

Table 5.11 shows results for the entire sample – covering all size classes; it reports four experiments. The first specification reported includes – in addition to the fixed effects – just the controls for competitiveness and the real wage described above. All variables are significant and correctly signed. The results continue to show increasing returns to scale. It can be seen that the coefficient of output is 0.481 this means that there is a case of increasing returns. An increase in output by 1% is associated by an 0.5% increase in the labour demand (there is increasing returns to scale and the degree of returns to scale is 1.5)\(^3\) and the manufacturing real wage and both the controls for competitiveness are significant, with the intra-sector control (relwage1) being rather more important.

The second set of results includes both the logarithms of the R&D stock (rdhigh) and standards (std). Neither has the expected sign, but only rdhigh is significant. The third set of results includes a (common) time trend but has little impact and is insignificant in itself. rdhigh is now significant at the 5% level but still of apparently perverse sign – but could conceivably be associated with employment friendly product innovation.

The third and the fourth set of results is based upon the fact that the inclusion of the real product wage for manufacturing as a whole precludes the use of time dummies to control for common but unobserved effects. The pattern of results is largely unchanged, although it should be noted that both competitiveness terms are now significant.

\(^3\) I calculated by using the same method in note 1 in this chapter.
The last set of results is long run specification. All the coefficients have the same sign and the same level of significance like the fourth specification, but all the coefficients have bigger effect than that of short run. For example the coefficient of the output is 0.759 in the long run; whilst it was 0.228 and this means that the returns to scale will decline in the long run.

Table 5.12 is based upon the same set of specifications as Table 5.11, but restricts the sample to the small firm sector. The number of observations is now rather restricted and that may have influenced the results. Otherwise, the results are rather similar to that for the sample as a whole. Not reported in the table is that the standards stock becomes significant whenever controls for unobserved influences are dropped. It is perfectly possible that the time varying cross-sectional element in the standards stock is highly noisy in character, especially since, over the sample period it was heavily influenced by the European harmonisation process noted earlier.
<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>Derived long-run coefficient¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged dependent variable</td>
<td>0.444***</td>
<td>0.710***</td>
<td>0.699***</td>
<td>0.700***</td>
<td></td>
</tr>
<tr>
<td>output</td>
<td>0.481***</td>
<td>0.232***</td>
<td>0.237***</td>
<td>0.228***</td>
<td>0.759</td>
</tr>
<tr>
<td>relative wage 1</td>
<td>-0.369***</td>
<td>-0.117***</td>
<td>-0.112***</td>
<td>-0.114***</td>
<td>-0.380</td>
</tr>
<tr>
<td>relative wage 2</td>
<td>-0.217***</td>
<td>-0.083</td>
<td>-0.091</td>
<td>-0.212**</td>
<td>-0.707</td>
</tr>
<tr>
<td>manufacturing real product wage</td>
<td>-0.468***</td>
<td>-0.267***</td>
<td>-0.205***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.044*</td>
<td>0.048**</td>
<td>0.054**</td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td>Standards</td>
<td>0.001</td>
<td>0.019</td>
<td>0.023</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>time trend</td>
<td></td>
<td></td>
<td></td>
<td>-0.003</td>
<td></td>
</tr>
<tr>
<td>TIME DUMMIES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>no of observations</td>
<td>916</td>
<td>656</td>
<td>656</td>
<td>656</td>
<td></td>
</tr>
<tr>
<td>F-statistic</td>
<td>797.89</td>
<td>400.86</td>
<td>351.36</td>
<td>129.34</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; F statistic under H₀</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td></td>
</tr>
</tbody>
</table>

*** = significant at 1%
** = significant at 5%
* = significant at 10%
¹The long run coefficient = short run coefficient in specification 4/(1-Lagged dependent variable in specification 4).
Table 5.12 Results of Panel Data Estimation
Small Firms Only
1985-2002

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>Derived long-run coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged dependent variable</td>
<td>$L_1$</td>
<td>0.431***</td>
<td>0.469***</td>
<td>0.464***</td>
<td>0.537***</td>
</tr>
<tr>
<td>output</td>
<td>$q$</td>
<td>0.507***</td>
<td>0.422***</td>
<td>0.399***</td>
<td>0.358***</td>
</tr>
<tr>
<td>relative wage 1</td>
<td>$relwage1$</td>
<td>-0.014</td>
<td>0.013</td>
<td>0.028</td>
<td>0.002</td>
</tr>
<tr>
<td>relative wage 2</td>
<td>$relwage2$</td>
<td>-0.081</td>
<td>-0.097</td>
<td>-0.081</td>
<td>-0.344**</td>
</tr>
<tr>
<td>manufacturing real product wage</td>
<td>$wa$</td>
<td>-0.416***</td>
<td>-0.275***</td>
<td>-0.422***</td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>$rdhigh$</td>
<td>0.031</td>
<td>0.022</td>
<td>0.022</td>
<td>0.048</td>
</tr>
<tr>
<td>Standards</td>
<td>$std$</td>
<td>-0.002</td>
<td>-0.028</td>
<td>-0.050</td>
<td>-0.109</td>
</tr>
<tr>
<td>time trend</td>
<td>$yr$</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME DUMMIES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

| no of observations                                        | 220     | 155     | 155     | 155     |                             |
| F-statistic                                               | 256.63  | 80.11   | 70.96   | 32.37   |                             |
| Pr > F statistic under $H_0$                              | 0       | 0       | 0       | 0       |                             |
| Adjusted $R^2$                                            | 0.98    | 0.98    | 0.98    | 0.99    |                             |

*** = significant at 1%
** = significant at 5%
* = significant at 10%

* The long run coefficient = short run coefficient in specification 4/ (1-Lagged dependent variable in specification 4).
5.11 Conclusion

This chapter has investigated the role of technological change by examining its role in models of labour demand, with a special emphasis on spillovers from domestically produced knowledge – mainly generated by larger firms – and the small firm sector in UK manufacturing. The focus of the investigation was – for a number of reasons – on aggregate manufacturing. Not least this was because of the difficulty of specifying the channels through which spillovers operate.

At the aggregate level, two measures of technological activity were studied, the R&D stock – mostly produced from outside the small firm sector - and the stock of ‘publicly available’ standards. The study revealed that a long-run relationship existed between both of these and employment among small firms in manufacturing. The relevance of standards in this context indicates the potential importance of this spillover channel, and that forms a central focus for the next chapter, which uses firm specific information about precisely this point.

At the level of individual sectors, the panel data evidence was more mixed. While it confirmed the usefulness of models of labour demand, especially in the context of variable returns to scale, it was unable to confirm the role of standards, although the positive significance of R&D on employment was suggestive of the potential importance of product innovation.

Table 5.13 summarises the estimations of the long run employment in the small firm sector by using the co-integration analysis and panel data analysis for the small firm sector in UK manufacturing, 1973-2002.
From Table 5.13\textsuperscript{4}, it can be seen that the relationship between employment and output is positive and the value of the coefficient is quite similar in both of the co-integration and panel data analysis. The relationship between the employment and standards stock is negative in the co-integration analysis whilst it is zero in the panel data analysis. The relationship between employment and R&D stock is negative and the value of the coefficient is quite similar in both of the co-integration and panel data analysis.

Overall, the analysis in this chapter points to the limitations of econometric evidence on data organised at the industry level. Accordingly, the next chapter will consider evidence from a survey at the level of the firm. The role of standards will receive particular attention.

\textsuperscript{4} The real product wage results have not been included in this table as I did not include it in the 4\textsuperscript{th} specification of the panel data analysis
Appendix 5.1
Data Sources

**Aggregate Model**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l$</td>
<td>Log of total employment from ACoP for the period 1973-97 and from ABI for the period 1998-2002</td>
</tr>
<tr>
<td>$q$</td>
<td>Log of net output from ACoP for the period 1973-97 and from ABI for the period 1998-2002 but it is deflated by PLLU (output price index in UK manufacturing)</td>
</tr>
<tr>
<td>$w_a$</td>
<td>Log of wages included National Insurance contribution deflated by PPI. The original data of wages are collected from ACoP for the period 1973-97 and from ABI for the period 1998-2002.</td>
</tr>
<tr>
<td>$s_t$</td>
<td>Log of stock of technical standards from PERINORM© database, produced by a consortium of the BSI, DIN, and AFNOR, the national standards bodies of the UK, Germany and France respectively and available on CD-ROM.</td>
</tr>
<tr>
<td>$r_d$</td>
<td>Log of R&amp;D data is that for business expenditure on R&amp;D (BERD) for total manufacturing taken from the OECD’s ANBERD dataset which is consistent with the Structural Analysis of Industries (STAN) data also available from the OECD web-site.</td>
</tr>
</tbody>
</table>

**Panel model**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$rel_wage1$</td>
<td>Log of the ratio of wage of each size class to the average of the sector as whole. The original data of wages are collected from ACoP for the period 1973-97 and from ABI for the period 1998-2002.</td>
</tr>
<tr>
<td>$rel_wage2$</td>
<td>Log of the ratio of sectoral wage to the manufacturing wage. The original data of wages are from the same sources like $rel_wage1$.</td>
</tr>
<tr>
<td>$r_d high$</td>
<td>Log of R&amp;D at depreciation rate 30% from same source like aggregate level</td>
</tr>
</tbody>
</table>
Appendix 5.2

ADF Tests on R&D low (10% depreciation rate) and R&D high (30% depreciation rate)

Table A5.1
Results of ADF tests
Levels of \( rd_{low} \) and \( rd_{high} \)
1973-2002

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>( rd_{low} ) with trend</td>
<td>-1.98</td>
<td>-1.63</td>
<td>-1.54</td>
<td>-2.88</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-3.58</td>
<td>-3.58</td>
<td>-3.59</td>
<td>-3.59</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.61</td>
<td>0.78</td>
<td>0.81</td>
<td>0.17</td>
</tr>
<tr>
<td>Adjusted R(^2)</td>
<td>0.85</td>
<td>0.92</td>
<td>0.91</td>
<td>0.94</td>
</tr>
<tr>
<td>Akaike Information Criterion*n</td>
<td>-214.16</td>
<td>-226.36</td>
<td>-216.01</td>
<td>-215.95</td>
</tr>
</tbody>
</table>

| \( rd_{high} \) with trend | -2.09 | -2.14 | -1.70 | -1.61 |
| 5% critical value | -3.58 | -3.59 | -3.59 | -3.60 |
| Mackinnon approx p-value | 0.55 | 0.52 | 0.75 | 0.79 |
| Adjusted R\(^2\) | 0.10 | 0.08 | -0.01 | -0.04 |
| Akaike Information Criterion*n | -168.21 | -159.88 | -156.22 | -149.70 |

Table A5.1 shows Augmented Dickey-Fuller tests for the logs of the levels of the stocks calculated with low 10\% (\( rd_{low} \)) and high 30\% (\( rd_{high} \)) depreciation rates. All the results in Table A5.1 show that we cannot reject the null hypothesis of a unit root in any of the models.

Table A5.2 shows Augmented Dickey-Fuller test for the first difference of \( rd_{low} \) and \( rd_{high} \) (\( dr_{dlow} \) and \( dr_{dhigh} \)).
Table A5.2

Results of ADF tests
First differences of rd\textsubscript{low} and rd\textsubscript{high}
1973-2002

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>dr\textsubscript{dlow}</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
</tr>
<tr>
<td>Test- statistic</td>
<td>-1.52</td>
<td>-1.44</td>
<td>-0.80</td>
<td>-1.04</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.52</td>
<td>0.56</td>
<td>0.82</td>
<td>0.74</td>
</tr>
<tr>
<td>Adjusted R\textsuperscript{2}</td>
<td>0.05</td>
<td>0.00</td>
<td>-0.08</td>
<td>-0.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>variable</th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
<th>no trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>dr\textsubscript{dhigh}</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
<td>no trend</td>
</tr>
<tr>
<td>Test- statistic</td>
<td>-2.16</td>
<td>-2.10</td>
<td>-1.27</td>
<td>-1.49</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-3.00</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.22</td>
<td>0.24</td>
<td>0.64</td>
<td>0.54</td>
</tr>
<tr>
<td>Adjusted R\textsuperscript{2}</td>
<td>0.12</td>
<td>0.08</td>
<td>-0.02</td>
<td>-0.04</td>
</tr>
<tr>
<td>Akaike Information Criterion*</td>
<td>-169.57</td>
<td>-160.84</td>
<td>-156.66</td>
<td>-150.52</td>
</tr>
</tbody>
</table>

All the results in Table A5.2 show that we cannot reject the null hypothesis of a unit root in any of the models at least at the 5% significance level. In the next stage however a once and for all structural shift in the mean of the first difference is allowed for. 1990 was chosen after experimentation as the date of the shift. The augmented Dickey-Fuller test is now based upon the residuals which allows for a step change in the mean of the first differences after 1990. Results are shown in Table A5.3
Table A5.3
Results of ADF tests
Residuals of \textit{drdlow} and \textit{drdhigh}
1973-2002

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{drdlow}</td>
<td>no trend</td>
<td>-3.04</td>
<td>-3.01</td>
<td>-1.97</td>
</tr>
<tr>
<td></td>
<td>5% critical value</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-2.99</td>
</tr>
<tr>
<td></td>
<td>Mackinnon approx p-value</td>
<td>0.03</td>
<td>0.03</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Adjusted R(^2)</td>
<td>0.23</td>
<td>0.22</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Akaike Information Criterion*(n)</td>
<td>-203.87</td>
<td>-194.60</td>
<td>-186.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>variable</th>
<th>no lag</th>
<th>1 lag</th>
<th>2 lags</th>
<th>3 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{drdhigh}</td>
<td>no trend</td>
<td>-3.68</td>
<td>-4.11</td>
<td>-3.03</td>
</tr>
<tr>
<td></td>
<td>5% critical value</td>
<td>-2.99</td>
<td>-2.99</td>
<td>-2.99</td>
</tr>
<tr>
<td></td>
<td>Mackinnon approx p-value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Adjusted R(^2)</td>
<td>0.31</td>
<td>0.36</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Akaike Information Criterion*(n)</td>
<td>-166.84</td>
<td>-161.53</td>
<td>-156.38</td>
</tr>
</tbody>
</table>

Table A5.3 suggest that adjusting for the change in the mean, that the \textit{drdhigh} is a stationary series in all of the models and AIC*\(n\) and R\(^2\) show that 2 lag model is the preferred model. There is no confirmation in these results that \textit{drdlow} is stationary in the no lag and 1 lag model. The co-integration analysis in the text therefore proceeds only with R&D stocks as evaluated with the higher value of depreciation.
Appendix 5.3

ADF Tests on standards

<table>
<thead>
<tr>
<th>Table A5.4</th>
<th>Results of ADF tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std 1973-2002</td>
<td>1 lag 2 lags 3 lags</td>
</tr>
<tr>
<td>level of std</td>
<td>with trend with trend with trend</td>
</tr>
<tr>
<td>Test- statistic</td>
<td>-3.52 -2.41 -2.97</td>
</tr>
<tr>
<td>5% critical value</td>
<td>-3.49 -3.50 -3.50</td>
</tr>
<tr>
<td>Mackinnon approx p-value</td>
<td>0.04 0.37 0.14</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.81 0.82 0.84</td>
</tr>
<tr>
<td>Akaike Information Criterion*n</td>
<td>-386.82 -380.00 -377.73</td>
</tr>
</tbody>
</table>

| First differences of std (dstd) | no trend no trend no trend |
| Test- statistic | -2.35 -1.68 -1.78 |
| 5% critical value | -2.93 -2.93 -2.93 |
| Mackinnon approx p-value | 0.16 0.44 0.39 |
| Adjusted R² | 0.11 0.12 0.11 |
| Akaike Information Criterion*n | -375.04 -369.62 -360.35 |

| Residuals of dstd | no trend no trend no trend |
| Test- statistic | -4.15 -3.28 -3.32 |
| 5% critical value | -2.93 -2.93 -2.93 |
| Mackinnon approx p-value | 0.00 0.02 0.01 |
| Adjusted R² | 0.22 0.17 0.17 |
| Akaike Information Criterion*n | -379.97 -370.81 -362.14 |

As discussed in the text, a similar procedure was adopted for the series for standards. Table A5.4 shows Augmented Dickey-Fuller tests for the level, first difference and the residuals of standards (std). The results of the level show that we can reject the null hypothesis of a unit root with the 1 lag model but we cannot reject the unit roots with 2 and 3 lags models. There is no clear indication of stationary in the first differences of std (dstd). However when we allow for a mean shift for the period 1974-89 (again obtained after experimentation), the residual ADF test allows us to reject the null unit root clearly. AIC*n test suggests that the 3 lags model is the preferred model because it has the highest value (most information).
Chapter Six

Sources of innovation information in the small firm sector in UK manufacturing: analysis using the CIS3 data

6.1 Introduction

This chapter aims to achieve two objectives: first, to study the relationship between firm size and innovation in UK manufacturing, and second, to determine the sources of innovation information in the small firm sector in UK manufacturing. Chapter 5 analysed technological change and labour demand among small manufacturing firms using data from the Annual Census of Production (ACoP) and Annual Business Inquiry (ABI), i.e. on aggregate data. This chapter uses the Community Innovation Survey (CIS3) covering the period from 1998-2000. The survey is based upon data at the firm level. As noted in chapter 1, most of this thesis defines small firms as those with fewer than 100 employees. In this chapter however, the nature of the CIS3 data makes it both possible and desirable to, use the European Commission’s definition, which is firm’s with fewer than 50 employees.

Chapter 5 ended with the conclusion that there is relationship between both the R&D stock, the stock of standards, and labour demand in the small firm sector in UK manufacturing. The relevance of standards indicates the importance of this spillover channel. This chapter seeks to confirm the results in Chapter 5, and finds further evidence regarding the sources of technology for small firms.

The chapter is organised as follows. The next section discusses the relationship between innovation and productivity growth in the small firm sector by developing

\footnote{This chapter draws on a paper written with my supervisors Paul Temple and Stephen Drinkwater. This paper was presented in the Scottish Economic Society conference on 26 April 2006.}
some simple hypotheses regarding the uses of information by innovative firms. Section 3 provides a broad comparative analysis of the differences in innovative behaviour between small firms and other firms in CIS3. Section 4 examines the relationship between innovation activity and firm size. Section 5 discusses the information sources for innovation in more detail, using Question 12 of CIS3. Section 6 then presents an econometric analysis that relates information sources to performance outcomes. Section 7 concludes the chapter.

6.2 Innovation and Productivity growth

While the importance of technological change for productivity growth is well recognised, the relationship between innovation and productivity growth is much less well understood and extremely complex. The situation is not improved by the flexibility of the concept of innovation, although most definitions do feature both the idea of novelty and the idea that innovation is intensive in its use of knowledge and information. Innovation is the introduction of something new, such as a method of production, an idea (Allen and Sriram, 2000). Mansfield (1968) argues that innovation is the key stage in the process leading to the full evaluation utilization of an invention or the creation of a new type of industrial organization. However in empirical applications it is probably generally accepted that discussion of innovation has been helped by the Schumpeterian trilogy of ‘invention, innovation, and diffusion’ and this conceptual distinction has clearly informed the Community Innovation Survey (CIS) on which this chapter is based. The Survey distinguishes between ‘product’ and ‘process’ innovation and innovations which are new to the firm and those which are new to the market, resulting in four different definitions of innovation, the broader definitions coming closer to the idea of technology diffusion, i.e. the process by which innovation spreads and is adopted by the relevant user population. Although, the CIS has just completed its 4th round (CIS4), the results in this chapter are based on CIS3 which surveyed firms for the period 1998-2000. In fact, Schumpeter himself identified five forms of innovation (Deakins and Freel, 2003): the introduction of a
new good, the introduction of a new method of production, the opening of a new market, the conquest of a new source of supply of raw materials, as well as new forms of organization.

The relationship between information, innovation and productivity outcomes is illustrated in Figure 6.1, adapted from Chakrabarti (1990), and was originally developed for a series of manufacturing case studies. It is important to note that in the case of product innovation, productivity increase is achieved through product differentiation and relative price increases, as well as through the more traditional channel of cost efficiency in production. In many competitive situations it is often difficult to distinguish between product differentiation and product innovation with the latter frequently involving new combinations of product characteristics (as for example noted in Swann, 2000). In a series of important papers, von Hippel (e.g. 1976, 1994) has described the concept of 'sticky knowledge' and how problem-solving efforts in innovation are concentrated upon inter-firm relations where knowledge is 'sticky' (i.e. costly to transfer between firms). In this type of innovative process, the locus of problem solving lies within a process of interaction with customers who become a primary source of information. Symmetrically, it might be expected that process innovations on the other hand will frequently depend upon product innovation and differentiation in the supplying industry. The role of equipment investment may be particularly important in this regard, with both knowledge generation and human capital formation an outcome of equipment investment activity. Plausibly this type of interaction may explain the oft-discussed difference between growth accounting estimates of the rate of return from capital investment and the social rate of return as provided by econometric estimates (see for example Crafts 1996).
Given this general framework, why should small firms differ from larger firms both in the decision to commit resources to innovation and in the process itself? There are many possible differences between small firms and large firms in their role as innovators, Storey (1994) argues that the ability of smaller firm to provide something marginally different, in terms of service or good, which distinguishes it from other goods or service provided by larger firms. If this is the case, differentiation and specialization in product characteristic space may be the source of a relative advantage for small firms, i.e. in product as opposed to process innovation (see for example Hoffman et al, 1998).
Management texts frequently draw attention to organisational differences, especially in the relative merits of flexibility against routine. The following table for example (drawn from Deakins and Freel 2003) is suggestive of the advantages and disadvantages of small firms in innovation activities.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential for growth through differentiation strategies</td>
<td>Difficulties accessing finance for growth</td>
</tr>
<tr>
<td>Government schemes established to facilitate small firm innovation</td>
<td>High transaction costs involved in accessing schemes</td>
</tr>
<tr>
<td>Some regulations are applied less rigorously to small firms</td>
<td>The relative unit cost of regulatory compliance is higher for small firms</td>
</tr>
<tr>
<td>Lack of bureaucracy; greater risk acceptance; rapid decision-making</td>
<td>Lack of formal management skills</td>
</tr>
<tr>
<td>Suffer less from routinisation</td>
<td>Suffer more from uncertainties and associated costs</td>
</tr>
<tr>
<td>Flat management structures and local project ownership are likely</td>
<td>High staff turnover, little formal training</td>
</tr>
<tr>
<td>Flexibility and rapid decision-making may make firms attractive partners</td>
<td>Firms suffer from power asymmetries in collaboration with larger partners</td>
</tr>
<tr>
<td>Nearness to market ensures fast reaction to changing market requirements</td>
<td>Little or no market power, poor distributions and servicing facilities</td>
</tr>
<tr>
<td>Efficient and informal internal communication facilitates rapid internal problem solving</td>
<td>Lack of time and resources to forge external technological linkages</td>
</tr>
</tbody>
</table>

Source: Deakins and Freel, 2003

Of course, in economics, Schumpeter's (1942) hypothesis regarding the relationship between size, market power and innovation has been extensively investigated since Schumpeter (1942), the idea that size may confer some advantage on firms deploying resources in order to innovate has provided a staple for over forty years in the empirical literature¹. Schumpeter's original ideas embraced both the impact of size *per se*, as well as the impact of market structure, i.e. that market power- *ex ante* – was more conductive to innovation than competition. At least the promise of *ex-post*

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¹ Section 6.4 will examine the Schumpeter's hypothesis.
market power is of course generally regarded as a condition for innovation.

The advantages relating to firm size are generally recognised as consisting of some or all of the following (see e.g. Simeonidis, 2001; Cohen, 1995):

- The fixed costs and economies of scale associated with the innovation process requiring large sales volume.
- Potential for economies of scope.
- Access to external finance.
- Risk diversification.
- Insofar as large size is associated with market power, large firms may be better able to appropriate returns from innovation.

Note that the first four of these amount to capital market imperfections. There are however some counter-arguments. Simeonidis in particular notes the possibility of control loss in large bureaucratic organisations, echoing the management literature cited above. Empirical evidence on the role of size per se on innovation is rather mixed, and has been dogged by both econometric and by measurement issues. The focus in many studies on R&D expenditures or employment- at best an input into the innovation process- may of course bias the results in favour of large firms that have formal R&D departments and against smaller firms who may have individuals who are performing similar roles but are not so classified. Patents on the other hand- also frequently employed- vary considerably in their use-both though time\(^2\) and according to the so called ‘appropriability conditions’-across industries\(^3\). Precisely because of the continuing debate about the measurement of inputs and outputs relating to innovation, surveys such as the CIS may be extremely valuable in extending our knowledge. Accordingly the next section proceeds to use CIS3 to produce some basic data, considering various definitions of innovative activity by firm (establishment) size.

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\(^2\) Witness the considerable global 'patent surge' in the last 25 years (see Jaffee, 2000)

\(^3\) The classic study of appropriability is that by Levin et al (1989) that concluded that in most industries patents were much less important in protecting innovations than secrecy and lead times.
6.3 Comparative Analysis using the Community Innovation Survey

CIS3 – the third Community Innovation Survey - was conducted in the UK for the period 1998-2000, and based upon a sampling frame derived from the Office for National Statistic’s Inter-departmental Business Register. However, firms with fewer than 10 employees are excluded from the frame. This is the third iteration of the survey which covers all sections C-K of the Standard Industrial Classification (SIC) 1992. For reasons discussed in chapter 1, we shall concentrate on the manufacturing sector (Section D). As Table 6.2 shows, the CIS3 sample was based upon 8172 firms in total, 3440 of which were in manufacturing – the focus of this thesis. Within manufacturing, details of employment in 2000 were given for 3384 firms.

| TABLE 6.2  
CIS3  
The Sample Characteristics |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>classification by number of employees in 2000</td>
<td>All</td>
</tr>
<tr>
<td>Small Firms 0-49</td>
<td>4,675</td>
</tr>
<tr>
<td>Medium 50-249</td>
<td>2,082</td>
</tr>
<tr>
<td>Large 250+</td>
<td>1,244</td>
</tr>
<tr>
<td>Missing</td>
<td>171</td>
</tr>
<tr>
<td>TOTAL (exc missing)</td>
<td>8,001</td>
</tr>
</tbody>
</table>

Since observations are by firm (and broadly representing the population of firms in the UK in general, the dataset is particularly rich in observations on small firms although as mentioned above, firms below 10 employees (micro firms) at the time of that the sampling frame was established, i.e. some time prior to 1998, were excluded. Nevertheless over half the firms employed less than 50 workers in the year 2000 and this formed our sample of ‘small firms’. Inclusion in the sample depended upon answering the key questions regarding innovation (i.e. there are no missing
observations for these questions). While missing observations are few for the employment question, the problem of sample attrition for subsidiary questions is important, with response rates varying from 40% upward (Mercer 2004). For the sources of information question however, the response rate was good (79% of those included in the sample). For other questions this was less true, especially for detailed information regarding the patterns of innovation related expenditures.

As discussed above, CIS3 allows for a number of definitions of innovation and innovation activity. Note that since the sampling frame was established with a considerable lead compared to the period 1998-2000 of the survey, I am not sampling ‘new firms’ where entry may be associated with innovation itself, but I am considering incumbents with an age of several years at least and for which innovation was a ‘discrete event’ over the sample period.

Sample characteristics based upon the various definitions are given in Table 6.3. The broadest measures whether an enterprise is in any expending resources on either searching for an innovation or has actually innovated. These are called ‘innovation active’ firms (Mercer 2004), which are recorded as either:

- Innovating
- Having abandoned or not completed an innovation
- Expenditures on innovation related resources (R&D, design, innovation related expenditures on equipment etc)
- Longer term R&D commitments
- Formal cooperation arrangements related to R&D

Table 6.3 shows that roughly half of all firms in the sample were innovation active by this definition, but that manufacturing firms were considerably more likely to be active. Among the largest size group (250+) nearly 80% were active, while among the smallest nearly half were active, close to the percentage for the entire
sample. Respondents were asked about reasons for non-activity: the main reason was one of perceived profitability, but ‘prior innovation’ was also important, and there is some reason for removing such firms from the sample as a robustness check.

### TABLE 6.3

**Innovation Variables**

<table>
<thead>
<tr>
<th>Innovation Active</th>
<th>All</th>
<th>Manufacturing</th>
<th>All</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Firms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>2,052</td>
<td>870</td>
<td>43.9</td>
<td>49.2</td>
</tr>
<tr>
<td>Medium</td>
<td>1,191</td>
<td>676</td>
<td>57.2</td>
<td>67.0</td>
</tr>
<tr>
<td>Large</td>
<td>827</td>
<td>477</td>
<td>66.5</td>
<td>78.5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>4,070</strong></td>
<td><strong>2,023</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Innovation</th>
<th>All</th>
<th>Manufacturing</th>
<th>All</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Firms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>724</td>
<td>330</td>
<td>15.5</td>
<td>18.7</td>
</tr>
<tr>
<td>Medium</td>
<td>547</td>
<td>327</td>
<td>26.3</td>
<td>32.4</td>
</tr>
<tr>
<td>Large</td>
<td>456</td>
<td>285</td>
<td>36.7</td>
<td>46.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,727</strong></td>
<td><strong>942</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Novel product Innovation</th>
<th>All</th>
<th>Manufacturing</th>
<th>All</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Firms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>322</td>
<td>168</td>
<td>6.9</td>
<td>9.5</td>
</tr>
<tr>
<td>Medium</td>
<td>227</td>
<td>138</td>
<td>10.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Large</td>
<td>217</td>
<td>144</td>
<td>17.4</td>
<td>23.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>766</strong></td>
<td><strong>450</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process Innovation</th>
<th>All</th>
<th>Manufacturing</th>
<th>All</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Firms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>601</td>
<td>287</td>
<td>12.9</td>
<td>16.2</td>
</tr>
<tr>
<td>Medium</td>
<td>465</td>
<td>277</td>
<td>22.3</td>
<td>27.5</td>
</tr>
<tr>
<td>Large</td>
<td>408</td>
<td>253</td>
<td>32.8</td>
<td>41.6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,474</strong></td>
<td><strong>817</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Novel Process Innovation</th>
<th>All</th>
<th>Manufacturing</th>
<th>All</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Firms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>183</td>
<td>87</td>
<td>3.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Medium</td>
<td>146</td>
<td>95</td>
<td>7.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Large</td>
<td>147</td>
<td>89</td>
<td>11.8</td>
<td>14.6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>476</strong></td>
<td><strong>271</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The survey now distinguishes between product and process innovation. For product innovation, firms were asked whether they had introduced a ‘new or significantly improved’ product between 1998-2000, whether or not it was already on the market. If it was new to the firm’s market, then this is classified as ‘novel product innovation’. Table 6.3 shows that among the smallest firms in manufacturing, 19% were product innovators by the wider definition, of whom approximately one half were novel product innovators. Note that whereas one half of the largest size group were also novel product innovators (24% against 47%) this proportion is actually lower for the medium sized firms – (13% against 32%). This may be a result of the definition of novel product innovation and that fact that typically small firms operate in smaller markets.

A similar definition follows for process innovation, which refers to new or improved processes, which are either new to the firm (a process innovation); if they are new to the industry, they become a novel process innovation. It is worth remarking that process innovators are a rarer breed than product innovators. This is particularly true for smaller firms in manufacturing. Note that less than 5% of small manufacturing firms regarded themselves as novel process innovators – around one-half of the percentage for novel product innovation.

Having defined the various definitions of innovation and some of the features of the distribution of innovation in the sample, it is useful (and possible given the sample size) to consider some conditional probabilities. Given that I observe a far higher proportion of the larger firms who are innovation ‘active’ – consistent with a fixed cost interpretation since the majority reporting reasons for inactivity quote ‘market conditions’ rather than ‘factors hampering innovation’ or ‘previous innovation’ (Mercer 2004 p17) – I now consider the proportion of innovation active firms who actually innovate. Table 6.4 shows some overall percentages while Table 6.5 gives a breakdown in terms of 9 manufacturing sectors.
### Table 6.4
**Innovation conditioned on Innovation activity**

**Manufacturing**

<table>
<thead>
<tr>
<th></th>
<th>Product Innovation</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small Firms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-49</td>
<td>330</td>
<td>37.9</td>
<td></td>
</tr>
<tr>
<td>50-249</td>
<td>327</td>
<td>48.4</td>
<td></td>
</tr>
<tr>
<td>250+</td>
<td>285</td>
<td>59.7</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>942</td>
<td></td>
</tr>
</tbody>
</table>

| **Novel product Innovation** | | | |
| Small Firms 0-49 | 168 | 19.3 |
| Medium 50-249 | 138 | 20.4 |
| Large 250+ | 107 | 22.4 |
| **TOTAL** | | 413 |

| **Process Innovation** | | |
| Small Firms 0-49 | 287 | 33.0 |
| Medium 50-249 | 277 | 41.0 |
| Large 250+ | 253 | 53.0 |
| **TOTAL** | | 817 |

<p>| <strong>Novel Process Innovation</strong> | | |
| Small Firms 0-49 | 87 | 10.0 |
| Medium 50-249 | 95 | 14.1 |
| Large 250+ | 89 | 18.7 |
| <strong>TOTAL</strong> | | 271 |</p>
<table>
<thead>
<tr>
<th>Sector</th>
<th>Total</th>
<th>Small</th>
<th>All Other</th>
<th>Small</th>
<th>All Other</th>
<th>Small</th>
<th>All Other</th>
<th>Small</th>
<th>All Other</th>
<th>Small</th>
<th>All Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, drink, tobacco</td>
<td>259</td>
<td>38.8</td>
<td>62.1</td>
<td>39.5</td>
<td>42.0</td>
<td>21.1</td>
<td>18.0</td>
<td>52.6</td>
<td>52.0</td>
<td>10.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Textiles, clothing etc</td>
<td>208</td>
<td>36.6</td>
<td>64.7</td>
<td>28.9</td>
<td>54.5</td>
<td>13.3</td>
<td>27.3</td>
<td>22.2</td>
<td>49.1</td>
<td>11.1</td>
<td>20.0</td>
</tr>
<tr>
<td>Paper etc</td>
<td>517</td>
<td>50.2</td>
<td>49.8</td>
<td>28.4</td>
<td>45.8</td>
<td>15.5</td>
<td>17.6</td>
<td>40.0</td>
<td>53.5</td>
<td>11.0</td>
<td>14.8</td>
</tr>
<tr>
<td>Chemicals</td>
<td>388</td>
<td>67.8</td>
<td>32.2</td>
<td>81.2</td>
<td>18.8</td>
<td>41.1</td>
<td>58.9</td>
<td>29.5</td>
<td>27.3</td>
<td>14.7</td>
<td>22.6</td>
</tr>
<tr>
<td>Metals and Metal Products</td>
<td>462</td>
<td>44.3</td>
<td>55.7</td>
<td>71.1</td>
<td>28.9</td>
<td>29.4</td>
<td>70.6</td>
<td>30.8</td>
<td>69.2</td>
<td>30.8</td>
<td>69.2</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>249</td>
<td>53.6</td>
<td>46.4</td>
<td>79.2</td>
<td>20.8</td>
<td>48.8</td>
<td>51.2</td>
<td>31.8</td>
<td>31.8</td>
<td>31.8</td>
<td>31.8</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>522</td>
<td>66.5</td>
<td>33.5</td>
<td>77.3</td>
<td>22.7</td>
<td>55.2</td>
<td>44.8</td>
<td>28.3</td>
<td>21.7</td>
<td>28.3</td>
<td>21.7</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>339</td>
<td>43.9</td>
<td>56.1</td>
<td>68.1</td>
<td>31.9</td>
<td>44.6</td>
<td>55.4</td>
<td>23.6</td>
<td>76.4</td>
<td>23.6</td>
<td>76.4</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>440</td>
<td>45.1</td>
<td>54.9</td>
<td>65.4</td>
<td>34.6</td>
<td>44.6</td>
<td>55.4</td>
<td>23.6</td>
<td>76.4</td>
<td>23.6</td>
<td>76.4</td>
</tr>
<tr>
<td>All manufacturing</td>
<td>3,384</td>
<td>49.2</td>
<td>50.8</td>
<td>71.3</td>
<td>28.7</td>
<td>49.2</td>
<td>50.8</td>
<td>28.7</td>
<td>50.8</td>
<td>28.7</td>
<td>50.8</td>
</tr>
<tr>
<td>All industries and services</td>
<td>8,001</td>
<td>43.9</td>
<td>56.1</td>
<td>60.7</td>
<td>39.3</td>
<td>43.9</td>
<td>56.1</td>
<td>39.3</td>
<td>56.1</td>
<td>39.3</td>
<td>56.1</td>
</tr>
</tbody>
</table>
6.4 Innovation, firm size and market structure

In his *Theory of Economic Development* (1912) and in *Capitalism, Socialism and Democracy* (1942), Schumpeter proposed two major alternative patterns in innovative activities (Malerba and Orsenigo, 1995). The first one, labelled as Schumpeter Mark I or "creative destruction" (see, Breschi et al, 2000), is proposed in the earlier *Theory of Economic Development, 1912*. In this work, Schumpeter examined the typical European industrial structure of the late nineteenth century characterised by many small firms. According to this view, the pattern of innovative activity is characterised by technological ease of entry in an industry and by a major role played by new firms in innovative activities. Breschi et al (2000) mention that firms introduce this kind of innovation did not innovate before: it is called “widening”.

The second one, labelled Schumpeter Mark II or “creative accumulation" (see Malerba and Orsenigo; Breschi et al, 2000), is proposed in *Capitalism, Socialism and Democracy*. In this later work, Schumpeter discussed the relevance of the industrial R&D for technological innovation and the key role of large firms. According to this view, the pattern of innovative activity is characterised by the prevalence of large firms who innovate on a more routine basis. Breschi et al (2000) call this “deepening”.

Schumpeter’s Mark II hypothesis regarding the relationship between size and innovation has been investigated many times in the years since his death. The following table shows some of these studies.
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Country</th>
<th>Data</th>
<th>Dependent Variable</th>
<th>Firm size</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scherer (1965)</td>
<td>448 large industrial corporations from Fortune 500</td>
<td>US</td>
<td>Cross section</td>
<td>Patents issued in 1959</td>
<td>3 measures of firm size for 1955</td>
<td>Patents increase with firm sales but at less than proportionate rate</td>
</tr>
<tr>
<td>Scherer (1984)</td>
<td>196 industries</td>
<td>US</td>
<td>Cross section</td>
<td>Patent counts</td>
<td>US industries</td>
<td>In more than half of these industries, patents increase with industry sales but at less than proportionate rate</td>
</tr>
<tr>
<td>Acs and Audretsch (1987)</td>
<td>8074 innovations by 4 digit industry, 4476 in manufacturing</td>
<td>US</td>
<td>Cross section</td>
<td>Numbers of innovations appearing in trade journals by 4-digit industry 1982</td>
<td>Firms with more than 500 employees constitute large firms</td>
<td>Explains variation in relative advantage in small versus large firms with reference to capital intensity</td>
</tr>
<tr>
<td>Cohen et al (1987)</td>
<td>196 industries</td>
<td>US</td>
<td>Cross section</td>
<td>R&amp;D intensity</td>
<td>US industries</td>
<td>Size variable had not a statistically significant effect on R&amp;D intensity</td>
</tr>
<tr>
<td>Audretsch and Acs (1991)</td>
<td>732 large firms</td>
<td>US</td>
<td>Cross section</td>
<td>Numbers of innovations</td>
<td>Firms with more than 500 employees</td>
<td>Innovations increased less than proportionately with firm size</td>
</tr>
<tr>
<td>Patel and Pavitt (1992)</td>
<td>660 large firms</td>
<td>US</td>
<td>Cross section</td>
<td>R&amp;D expenditure</td>
<td>Firms with more than 500 employees constitute large firms</td>
<td>Most industries increases in R&amp;D expenditure with firm size were not significantly different from proportional in 11 sectors</td>
</tr>
</tbody>
</table>
It can be seen from Table 6.6 that some studies have indeed found a positive relationship between firm size and technological change (Scherer, 1965, 1984). On the other hand, there are some studies have identified no relationship or even a negative one (Cohen et al, 1987). Audretsch and Acs (1991) argue that there are two mean reasons for these inconsistent findings. The first is that different measures have been used to quantify technical change (e.g. Patents, R&D). The significance of these different measures has already been commented upon in chapter 5. The second reason is that most studies examining the relationship between firm size and technical change has had to use a truncated distribution of firm sizes where either no or few small firms were included.

In this section we build on the model of Scherer (1965), who studied the relationship between the patenting and sales, using the following equation to identify the relationship between innovation and firm size:

\[ P_i = \alpha_4 + \alpha_2 S_i + \alpha_3 S_i^2 + \alpha_4 S_i^3 + \epsilon_i \]  

(6.1)

where \( P \) is patents and \( S \) is sales.

Scherer (1965) found a positive relationship between the patents and sales (section 5.4 has introduced more details about the patents as a measure of technological activity). Audretsch and Acs (1991) used the same model but they used the number of innovations (Section 5.4 has presented more details about this innovation database) as
a dependent variable instead of the patents but they also found a positive relationship between the innovation numbers and sales.

Roges (2004), used a probit model to study the relationship between innovation activity (Question in Australian survey from 1994 to 1997). This question is “Did the business, in the last year, develop any new products or substantially changed products or introduce any new or substantially changed process”. The author found a positive relationship between the innovation activity and size.

In this section the model of Scherer (1965), Audretsch and Acs (1991) and Rogers (2004) are developed, using logit and probit models to study the relationship between the Innovation Activity (IA) and sales.

The following equation will be estimated

\[
IA_i = \alpha_1 + \alpha_2 TU_i + \alpha_3 TU_i^2 + \alpha_4 TU_i^3 + \alpha_5 SI_i + u_i \quad (6.2)
\]

From equation (6.2) it can be seen that we use the innovation activity as a dependent variable (This is a dummy variable which has value 1 if the firm has engaged in any innovation activity or 0 otherwise (King et al, 2005)). On the other hand we use the total number of standards/Goss Value Added (standards intensity (SI)) and turnover (TU) as independent variables. Standards intensity is used here as a measure of industry characteristics (see section 5.7 for more details about the measurement of standards) capturing their importance as a source of information. Moreover, I use variables as control for unobserved heterogeneity such as regional dummies and market size dummies (market size dummies works as measure of firm characteristics). I follow the Scherer (1965) model which allows for non-linear impacts of size on innovation. When IA is regressed non-linearly on TU, the second derivative \( d^2 AI / dTU^2 \) of the estimated function expected to be positive, IA is increasing at an increasing rate with TU, and so innovation activity must generally be increasing more than proportionately with turnover. A negative second derivative implies the opposite relationship.

Logit and Probit models were used to estimate equation 6.2. If we have a regression model
\[ y_i^* = B_0 + \sum_{j=1}^{k} B_j X_{ij} + u_i \]  

(6.3)

where \( y_i^* \) is not observed. It is called a 'latent' variable takes values 1 and 0 (dummy variable). The logit and probit models differ in the specification of the error term \( u \) in equation 6.3 (Maddala, 2001).

The probability of the 'latent' variable in the logit model can be measured by using equation 6.4 (Gujarati, 2003).

\[ P_i = \frac{1}{1 + e^{-(B_0 + B_{x_i})}} \]  

(6.4)

The probability of the 'latent' variable in the probit model can be measured by using the equation 6.5:

\[ P_i = F(B'x_i) = \frac{\exp(B'x_i)}{1 + \exp(B'x_i)} \]  

(6.5)

where \( p_i \) is the probability of the 'latent' variable, \( B'x_i \) is the estimated value of the 'latent' variable. Equation 6.2 was run on the all manufacturing firms by using the logit and probit models. The variables used for this estimation can be found in Table 6.7. Table 6.8 shows the results of these estimations.
### Table 6.7 Explanatory variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards Intensity (SI)</td>
<td>Count of BSI standards relevant to the 2-digit SIC in which enterprise is bases for 2-digit level/Gross Value Added for 2-digit level.</td>
</tr>
<tr>
<td>Innovation Activity (IA)</td>
<td>(Dummy variable) indicating whether enterprise undertakes innovation activity?</td>
</tr>
<tr>
<td>PRODINOV</td>
<td>Dummy variable taking value 1 if the firm has introduced a product which is new to the firm</td>
</tr>
<tr>
<td>PROCINOV</td>
<td>Dummy variable taking value 1 if the firm is introduced a process which is new to the firm</td>
</tr>
<tr>
<td>PRODNOV</td>
<td>Dummy variable takes value 1 if the firm has introduced new product which is new to the market</td>
</tr>
<tr>
<td>PROCNOV</td>
<td>Dummy variable takes value 1 if the firm introduces new process which is new to the market</td>
</tr>
<tr>
<td>Turnover (TU)</td>
<td>Market sales of goods and services including export and taxes except VAT</td>
</tr>
<tr>
<td>Market size dummies</td>
<td>3 dummy variables as control for unobserved heterogeneity</td>
</tr>
<tr>
<td>Regional dummies</td>
<td>11 dummy variables as control for unobserved heterogeneity</td>
</tr>
</tbody>
</table>

### Table 6.8 Innovation Activity

<table>
<thead>
<tr>
<th></th>
<th>Logit Model</th>
<th>Probit Model</th>
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<tr>
<td>Dependent Variable</td>
<td>IA</td>
<td>IA</td>
</tr>
<tr>
<td>Explanatory Variables</td>
<td></td>
<td></td>
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<tr>
<td>TU*1000</td>
<td>coeff 0.012700, s.error 0.002000, sig ***</td>
<td>coeff 0.067600, s.error 0.002000, sig ***</td>
</tr>
<tr>
<td>TU2*(1000)^2</td>
<td>coeff -0.000002, s.error 0.000004, sig ***</td>
<td>coeff -0.000003, s.error 0.000001, sig ***</td>
</tr>
<tr>
<td>TU3*(1000)^3</td>
<td>coeff 0.000000, s.error 0.000000, sig ***</td>
<td>coeff 0.000000, s.error 0.000000, sig ***</td>
</tr>
<tr>
<td>SI</td>
<td>coeff 0.662632, s.error 0.300431, sig **</td>
<td>coeff 0.407372, s.error 0.184352, sig **</td>
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<td>Market dummies</td>
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<td>yes</td>
</tr>
<tr>
<td>Regional dummies</td>
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<td>yes</td>
</tr>
<tr>
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<td>3177</td>
</tr>
<tr>
<td>Wald test chi2(18)</td>
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<td>257.09, sig ***</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*** = significant at 1%  
** = significant at 5%  
* = significant at 10%
From Table 6.8 it can be seen that the relationship between the innovation activity and turnover is positive for the all firms and the small firms, but it is insignificant for other firms. Moreover the relationship between the standards intensity and innovation activity is positive and significant for all firms, small and other firms. These results support the Schumpeterian hypothesis about the positive relationship between the innovation and firm size. It can be seen that the coefficient of the squared turnover ($TU^2$) is negative and this means that the innovation activity may be increasing at a decreasing rate with $TU$. However the presence of a significant and positive term in the cube of turnover means that the relationship may be more complex. Moreover, the market and regional dummies are positive and significant at 1% and 10% respectively. $R^2$ is low in all the estimations in this chapter, however, given cross section data is used this is not unexpected. Table 6.9 shows the marginal effects of every independent variable on the probability of the innovation activity.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explantary Varibles</th>
<th></th>
</tr>
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<td>$TU^*1000$</td>
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<td></td>
</tr>
<tr>
<td>$TU^2(1000)^*2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$TU^3(1000)^*3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>Market dummies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regional dummies</td>
<td></td>
</tr>
<tr>
<td>No of observation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wald test chi2(18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo R2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.9 shows that there are positive effects on the probability of undertaking Innovation Activity from the standards intensity and the turnover. On the other hand,
there is negative effect from the squared turnover and this means that the marginal
effect of turnover is increasing at decreasing rate.

How to estimated probability of a firm being innovation active is illustrated in figure
6.2 by using the estimated equation in table 6.8. I suppose that the data represents a
chemical firm located in London and sells its product in the national market.

Figure 6.2 shows the estimated probabilities for small firms sizes up to the change in
value of the turnover (e.g. £250000, £500,000, .....£2,500,000), the probabilities of
innovation activity were determined by computing the cumulative probabilities
associated with various *IA* (see equations 6.4 and 6.5).4

From Figure 6.2, which shows both probit and logit estimates. It can be observed that
there is little to choose between these alternatives but that neither shows any simple
positive relationship between turnover and innovation activity. While the probability
of innovation activity increases slightly for the very smallest sizes until the turnover
reaches £750,000, it then decreases rapidly up to about £1.5 million before increasing

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4 I calculate these values by using NORMDIST function in EXCEL.
again. Note that at higher levels the probability approaches 1. I think this figure shows that small firms are associated with innovation more than the large firms.

The next set of results – reported in Table 6.10- uses other measurement of innovation activity (PRODINOV, PROCINOV, PRODNOV and PROCNOV-see table 6.7) as the dependent variable, but the sample is restricted to those firms who are classed as innovation active (IA=1). The results are similar to those in table 6.8 showing that there is positive relationship between every kind of innovation and firm size. Moreover, the market and regional dummies are positive and significant at 5% and 10% respectively.

It can be seen that the coefficient of the squared turnover \((TU^2)\) is negative and this means that the innovation activity is increasing at a decreasing rate with \(TU\), and so innovation activity must generally be increasing less than proportionately with turnover. Standards intensity variable has a positive effect for new-to-firm product innovation (PRODINOV) is but insignificant. On the other hand standards intensity has a significant and negative effect for the measurement indicator for new-to-market process innovation (PROCNOV).
6.5 Sources of Information

Evidence from labour demand equations at the aggregate level of manufacturing Chapter 5 suggested that technical standards might represent an important mechanism through which small firms enhance productivity. Is there support for this in the CIS? Evaluation is made possible through the ‘sources of information’ question. It is important to know how firms relate to external sources of information, as innovation is increasingly complex, requiring the co-ordination of multiple inputs. Firms can gain guidance, advice from both of public and private sources (Stockdale, 2002).

Question 12 of CIS3 asked respondents to indicate, on a scale of 0-3 (0=not used, 1-3= Low, medium, or high importance), “sources of knowledge or information used in your innovation activities”. These sources are (UK Innovation Survey, 2001), with variable descriptors in parentheses:
1- Within the enterprise (IFWITHIN)
2- Other enterprises within the enterprise group (IFOTHENT)
3- Suppliers of equipment, materials, components or software (IFSUPPL)
4- Clients or customers (IFCLIENT)
5- Competitors (IFCOMPET)
6- Consultants (IFCONSLT)
7- Commercial laboratories/R&D enterprises (IFRDLABS)
8- Universities or other higher education institutes (IFUNIV)
9- Government research organizations (IFGOVT)
10- Other public sector (e.g. Business Links, government offices (IFOTHPUB)
11- Private research institutes (IFPRI)
12- Professional conferences, meetings (IFCONF)
13- Trade associations (IFTRADE)
14- Technical/trade press, computer databases (IFTECH)
15- Fairs, exhibitions (IFFAIRS)
16- Technical standards (IFSTAND)
17- Health and safety standards regulations (IFHEALTH)
18- Environmental standards and regulations (IFENVIRON)
Table 6.11 summarizes some of the information form responses to this question by recording the percentages that regard each source as being of ‘at least some relevance’ (i.e the score >= 1) among manufacturing firms, for the total and out three size classes. A number of features stand out:

• First, as I might expect, internal resources are less important for small firms than for other firms, although:
• Second, the use of any given source is less for smaller firms than for larger firms.

• Third, the most important sources outside the firm are located close to the market, and reflect what might be called ‘local knowledge bases.’

• Fourth ‘Vertical linkages’ - as suggested by our Figure 6.1 – are rather more important than ‘horizontal linkages’ with competitors.

• Fifth, direct attachment to what might be called the ‘science base’ – in the form of either universities, private research labs, or government research labs is strictly limited.

• Finally, the other sources – ‘distributors of knowledge’ are of rather greater importance than the science base. In particular attention should be given to the relevance of all three kinds of standards – as we saw in more detail in chapter 5, these may be thought of as technical documents which convey various kinds of information and functionality regarding inter-operability, and quality\(^5\).

The role of standards – which feature prominently as an external source of information - calls for some comment. The question in the survey links standards – with regulations in the case of health and safety and environmental standards. As Swann (DTI 2005) reports, these documents are rather different in that they both impede innovation – through for example variety reduction – while at the same time provide important technical information and reducing transactions costs. For example, a product innovator may find it easier to source inputs with a relatively standardised supply chain. As Swann – using the CIS3 - establishes, this means that standards simultaneously both constrain and inform – i.e. the greater the importance of standards in a particular sector, and the more information they provide, the more respondents in the CIS are likely to cite standards as an impediment to innovation. However, as King et al (2005) establish, much of the information content of the ‘catalogue’ of standards available catalogue’ of standards available to manufacturers

\(^5\) For an introductory discussion of what standards do and how National Standards Bodies help them do it, see Temple and Williams (2002). For an empirical assessment, see DTI 2005.
from the British Standards Institution consists of methods of technical testing for product characteristics. For smaller producers in particular, access to a measurement and testing industry based upon public standards may be essential for demonstrating and hence marketing certain performance characteristics. In the view (and indeed the econometric analysis) of King et al (2005), the measurement and testing sector, together with instrument manufacturers, provide a key mechanism for spillover effects emanating from research being undertaken in government sponsored measurement laboratories. They find positive spillover effects impacting upon the propensity to innovate.

Finally (and importantly) mention must be made of the relationship between standards and regulations. Since the late 1980s, the ‘new approach’ to EU directives (see Temple and Williams 2002) – in for example provisions for the safety of toys, have used standards as a means of ensuring that firms adhere to the directive without having to detail specific technical methods of achieving the desired characteristics. Standards which worked in this regard – helping firms to achieve lower cost solutions to achieving the stated objective – have aided productivity but of course counterfactually – productivity is higher than it would be in the absence of the standard but lower than it would be in the absence of the directive.

6.6 Econometric Analysis of Performance Outcomes

Establishing the precise nature of the links between standards and productivity requires more than simply evaluating their perceived importance as a source of information. Here, The Community Innovation Survey allows me to link these sources of information with a variety of performance outcomes all of which have a productivity implication. Question 11 considers the effects of innovation, asking respondents to “indicate the impact that your innovation activities have had on your enterprise in the period 1998-2000.” There are nine possible outcomes, the first three representing product/market oriented outcomes (1-3), four representing possible process type outcomes (4-7) and two representing ‘other’ outcomes, but which are of importance for the impact of standards as we saw above. Once again their identifiers –
for the econometric analysis, which follows are added in parentheses. In each case the range of response is 0=none, 1=low, 2=medium, 3=high. The ordered logit model provides a suitable estimation technique in these circumstances. The ordered logit model similar to logit model as mentioned in equation 6.3. The main difference in the ordered logit model that $y_i^*$ is ‘latent’ variable but it takes values 0,1,2 and 3 in this model.

1- Increased range of goods and services (FRANCE)
2- Opened new market or increased market share (FMKSHARE)
3- Improved quality of goods and services (FQUALITY)
4- Improved production flexibility (FLEXIB)
5- Reduced unit labour costs (FLABOUR)
6- Increased capacity (FCAPAC)
7- Reduced materials and energy per produced unit (FMATERL)
8- Improved environmental impact or health and safety aspects (FENVIRON)
9- Met regulations or standards (FREGS)

Without necessarily establishing any formal causal model, it is nevertheless of great interest to estimate what might be termed the information intensity of various types of information source for different innovation outcomes, and specifically use this to compare small firms (under 50 employees) with all others. Although there may be a case for including both the information sources with measures of resource inputs (as in Swann, 2000), in practice it was found that the considerable co-linearity introduced (e.g a formal R&D department does tend to generate useful information!) and more importantly, the degree of sample attrition to be powerful.  

Besides the 18 sources of information- the identifiers can be found in section 6.3, a number of additional variables were used. Access to assets complementary to innovation is often important (particularly for small firms) and collaboration and networking are increasingly important as an alternative to contracts as a form of knowledge transfer and sharing. A dummy variable is therefore used to indicate any form of collaboration activity related to innovation (coopdum). The other set of additional variables relates to fundamental idea - discussed above - of the ‘absorptive

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6 Further of course, the model is restricted to manufacturing, whereas Swann samples from all industries.
capacity' of an organisation to new knowledge. I include here both a measure of size - the log of employment in 2000 (lemp00) - and of others graduates (propsci) and of other graduates (propoth). Finally - in all the reported results - controls are reported for unobserved heterogeneity. These included industry dummies- for the nine sectors reported in table 5, as well as 'market size dummies In CIS3, firms are asked to specify their 'largest k=market' as either local, regional, national, or international.

Results are reported in tables 6.12 and 6.13 the former for all manufacturing firms less than 50 employees and the latter for all firms with 50+ employees, creating roughly equally sized samples. The main points to note are as follows:

Regarding differences between the two sets of estimates, these are perhaps more remarkable for their absence. However, the biggest difference between larger and smaller firms is that the latter are extremely dependent upon equipment suppliers a source of information (ifsuppl). In every case the estimated coefficients are highly significant for the smaller firms and greater than for the comparable outcome among the bigger firms. Paradoxically, suppliers of equipment remain an important source even for the three market oriented outcomes (FRANGE, FMKSHARE, FQUALITY). The role of clients (ifclient) is quite similar for both of the large firms and small firms. Second, we should note that while significant differences might be anticipated in the importance of internal sources of information (ifwithin) and although point estimates are for generally lower for small firms the difference are not large.

Direct information from the science base - either universities or government - does not seem to be a key input into the innovation process, while trade fairs do for both classes of firms. Swann (2002) however reminds us of the need to distinguish between direct and indirect sources of information and the distribution mechanisms as such as trade fairs or standards and other forms of codified knowledge may be important in the supply chain of information (King et al, 2005).

Human capital variables were only rarely significant, and in one instance perverse unless sciences graduates stand in the way of flexibility! Employment (lemp00) within
the size bands did not seem to be related to performance outcomes, except for the process oriented outcomes among smaller firms.

A very similar pattern emerges across size classes for our cooperation dummy (coopdum). This seems to be important in market oriented outcomes rather than process outcomes.

Finally, standards seem to be important in helping all firms meet regulations. As we saw above, this is an important component of EU Commission policy and appears to be quantitatively important and could easily be missed in conventional analysis of productivity movements.
<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>FCAPAC</th>
<th>FMATERL</th>
<th>FENIRON</th>
<th>FREGS</th>
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<td>EQUALITY</td>
<td>FFLEXIB</td>
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<td>YES</td>
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</tr>
<tr>
<td>Pseudo R2</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.14</td>
</tr>
</tbody>
</table>

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**Notes:**
- Coefficients marked with *** are statistically significant at the 0.01 level.
- Coefficients marked with ** are statistically significant at the 0.05 level.
- Coefficients marked with * are statistically significant at the 0.10 level.
6.7 Conclusions

This chapter has found that there is a positive relationship between the firm size and innovation. Focusing on the information intensive nature of innovation, this chapter explored the relationship between information sources and innovation outcomes, contrasting small firms (less than 50 employees) with their larger counterparts in manufacturing.

The chief conclusion concerns the differing role of information sources in innovation activities for a range of performance outcomes. It is found for small firms, that information obtained suppliers of equipment and materials are important in influencing the whole range of performance outcomes. This is somewhat paradoxical and may have been thought less important for product innovation, but may be explicable in terms of the role-played by equipment in determining performance characteristics in product innovations (see King et al, 2005). The importance of standards for capital investment may be important here, since mechanical and electrical engineering, as was seen in chapter 5, are rather activities which use standards intensively. The importance of standards was moreover confirmed in their ability to help firms meet health and environmental regulations.
Chapter Seven

Conclusions

This thesis has studied the productivity growth of the small firm sector in UK manufacturing, measuring both labour productivity and TFP growth. It also has examined the relationship between labour demand and technological change in the small firm sector. This contribution confirms the relevance of technological change in the sector. Chapter six considered the sources of information which helped drive innovation in the small firm sector while analysing the relationship between firms' size and innovation by using the CIS3.

As mentioned in chapter one, the main objective of this thesis is to answer six research questions. Chapter 2 tried to answer the first question relating to the determinants of the size distribution of firms in an industry. The review of the literature on the size and growth of the firm conducted in chapter 2 led to the conclusion that the role played small firm sector must be seen as something rather different to that of other firms, and that, while smaller firms may to some extent be competing with their larger counterparts, their role is also to some extent complementary. The important role that Schumpeter (1934) saw small firms as playing is related to what of initiating 'creative destruction', through introduction of totally new products The view of the mature Schumpeter which contrasts with this and which saw innovation as being dominated by large firms with monopoly power, has led to a considerable exploration of the relationships between firm size, market structure and innovation.

The available literature does not in fact conclude that large firms have a monopoly or that 'ex-post' market power necessarily makes for more innovation. However, some studies have found a positive relationship between firm size and technological change.

Chapter 3 introduces an answer to the second question by studying differences in the growth rates of employment, output and labour productivity among the different size classes for the period 1973-2002 both for total manufacturing and for the textile, food,
paper, chemicals, electrical and transport equipment industries. The results show that the share of employment of the sector has increased over time, but that this as occurred at the same time as a fall in labour productivity relative to large firms. A decomposition of the percentage difference in the labour productivity into a ‘size effect’ (the difference between each size class) and an ‘industry effect’ (the difference between the whole industry and manufacturing as a whole) have shown that the size effect is negative effect in all industries and the paper industry has the highest size effect. The industry effect has a positive effect in paper and chemicals industries but it is negative in the textile industry.

Within the small firm sector, the textile industry has seen the steepest decline in employment share over the past three decades. On the other hand, the paper and electrical industries have seen their shares of employment increase. Moreover, the paper industry had increased shares of relative labour productivity over time. This raises the third question which studies the reasons for slower productivity growth and the role-played by capital intensity. These are examined in chapter 4.

In chapter 4, specially constructed estimates of the capital stock by size class are developed. After estimating the gross capital stock we begin to estimate the Total Factor Productivity (TFP) growth by using a Tomqvist index, widely used in productivity studies. In general, we can say that the size class (500+) has a greater substitution of capital for labour for the whole period (1973-2002) as well as most sub-periods. In comparing the periods 1973-79 and 1980-92, it was seen that total factor productivity growth rates have increased since 1980 for all the size classes and in the small firm sector in all industries.

Decomposing observed differences in labour productivity growth rates into total factor productivity and changes in capital-intensity, the findings suggest that the higher growth rate of labour productivity in the large firm sector is related to the growth of capital intensity rather than any differences in rates of technological change between sectors, pointing to the importance of technological change in the small firm sector.
Chapter 5 discussed certain limitations in the methodology of chapter 4 and adopted an alternative approach based upon the analysis of labour demand and the impact on employment of technological change, using estimates of the ‘knowledge stock’ created by large firms and made available (through technological spillovers) to the small firm sector. This was based both upon Research and Development (R&D) expenditures and stocks of technical industrial standards. This analysis provides an answer to the fourth question which studies the relationship between the labour demand and technological indicators) in the small firm sector in UK manufacturing during the period 1973-2002. Econometric models of labour demand for total manufacturing suggest positive impacts on productivity for both measures. The model is supplemented by panel data, which shows more mixed results, possibly because the spillover effect is not contained within the industries used in the study.

Chapter 6 sought confirmation of the results in chapter 5 and further evidence regarding the sources of technology for small firms. Based upon the third Community Innovation Survey (CIS3) covering the period 1998-2000, the fifth question concerning the ‘Schumpeterian hypothesis’ regarding the relationship between firm size and innovation was tested. While it was found that there is a positive relationship between innovation and firm size, considerable evidence for the ‘active learning model’ in the small firm sector is also established, and hence motivating a study of the sources of information for small firms and how they might differ for large firms.

Accordingly, I tried to answer the sixth question regarding the sources of innovation information in the UK manufacturing by employment size class, introducing a second model studying the role of information sources for innovation activities for a range of performance outcomes and finds that for small firms, information obtained from suppliers of equipment and materials are important in influencing performance. Standards, moreover, are important in enabling small firms to meet environmental and health regulations, confirming some of the analysis in chapter 5.

From the above discussion, summarizing the thesis I suggest that there are three main conclusions in this thesis:
• The first relates to the importance of technological change. I measured technological change by using two techniques. The first depends on the measurement of labour productivity growth. Labour productivity growth rates show that the small firm sector has growth rates lower than the large firm sector, and this labour productivity growth can be decomposed to TFP growth and factor substitution growth rates. The TFP growth results show that TFP growth rates in the small firm sector are bigger than in the large firm sector during all periods. Within the small firm sector, the transport equipment industry had the highest TFP growth rates during all periods. Factor substitution growth rates show that the large firm sector's rates are much higher than that of the small firm sector. The second technique depends on using an econometric model to study technological change and its impact on labour demand. This econometric model measures the elasticity of substitution between capital and labour, and finds increasing returns to scale. It also confirms the importance of technological change in the small firm sector.

• The second conclusion concerns spillovers of knowledge and technological change indicators to the small firm sector, a process captured by using an econometric model which analyses the impact of the stock of R&D expenditures and the stock of technical industrial standards on labour demand in the small firm sector.

• The third conclusion related to the active learning model. I have studied the effect of sources of innovation on the small firm sector by using active learning. This model shows that in the small firm sector, the information obtained from suppliers of equipment and materials is important in influencing performance. Furthermore, standards are important in enabling small firms to meet environmental and health regulations. Based on CIS3, the Schumpeterian hypothesis, related to the relationship between a firm's size and innovation, was tested, and a positive relationship was found.

From the above discussion, I can say that the spillovers of R&D to small firm sector are important and that standards are an important mechanism through which R&D
conducted by both domestic firms and globally. However, there is little known about the real effects of government innovation policies on private R&D spending by large firms.

Another role for the government could be monitoring the research projects and improving the information available to the small firm sector for innovation, to promote the diffusion of technology.

I consider the following three areas as further challenging research tasks.

- First, I have tried to study if there any difference in the labour productivity among the full time and part time employment among the size classes in UK manufacturing; but the problem is the lack of the data because they are available only from 1995 and 1996.

- Second, because this thesis is based on the UK manufacturing sector, there would be value in studying the relative productivity growth in the small firm sector in other G7 economies and across the OECD countries. Such a study would show the difference in the relative productivity of the small firm sectors between these countries.

- Third, it would be very helpful to analyse productivity growth in the small firm sector in Egypt (my country). Egypt's small firm sector includes micro firms (1-4 employees) and small firms (5-14 employees), and employment in the small firm sector constituted 88% of total employment in the manufacturing sector in 1996 (Ministry of Foreign Trade in Egypt, 2003); but the problem is the lack of the data because they are available only from 1986 and 1997. Furthermore, there is no innovation survey in Egypt. Ideally, over time a questionnaire similar to the Community Innovation Survey in the UK, to study the sources of innovation in the small firm sector in Egypt, will become available. Moreover, it would be great idea to study the effect of the diffusion of the stock of technical standards on productivity in Egypt.
In summary, this thesis finds that average growth rates of labour productivity in the small firm sector in UK manufacturing are lower than those of large firms; and that the higher growth rates in the large firm sector are related to the growth rates of factor substitution. The study also shows a positive relationship between both the stock of R&D expenditures, and the stock of technical industrial standards, and labour demand. Moreover, there are spillovers from R&D expenditures to the small firm sector. Finally this thesis finds a positive relationship between innovation and firm size in UK manufacturing and, for small firms, information obtained from suppliers of equipment and materials is important in influencing performance.

"Praise is to Allah who, by his blessings, all good things are perfected"
References


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