EUROPEAN UNIVERSITY INSTITUTE
Department of Economics

Do Relative Factor Prices Matter? The Long Run Demand for Labour in the Irish Manufacturing Sector

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Chapter 1

Introduction

1.1 Introduction

The central topic of this thesis is the estimation of the effect of relative factor prices on the demand for labour in the Irish manufacturing sector. It is divided into two sections, in Part I we estimate the demand for labour relative to capital in manufacturing, and in Part II we estimate the interrelated demands for skilled, unskilled, clerical labour and capital inputs in manufacturing.

1.1.1 Why is the Demand for Labour in Manufacturing Important?

In the 1980s the Irish labour market experienced a severe and prolonged increase in the rate of unemployment (Figure 1.1). Total employment fell by 77,000 between 1980 and 1985, and by 1987 unemployment had reached a peak of almost 18 per cent of the labour force. The long-term effects of this collapse in employment persisted well into the 1990s, so that despite an unprecedented expansion in employment in the 1990s the unemployment rate in 1999 was still marginally above its 1979 level. This in turn has had a profound impact on the economic lives of a generation of Irish workers.

A significant decline in manufacturing employment is at the heart of this collapse in employment in the 1980s. As the Irish economy shifted from a largely agricultural, rural-based economy to an industrialised economy in the latter half of the twentieth century, the share of manufacturing and services in total employment increased and the share of agriculture fell. Figure 1.2[1] charts the rapid rise in the share of manufacturing in total employment between

[1]The data on employment shown here are taken from the Labour Force Survey (LFS). They differ slightly

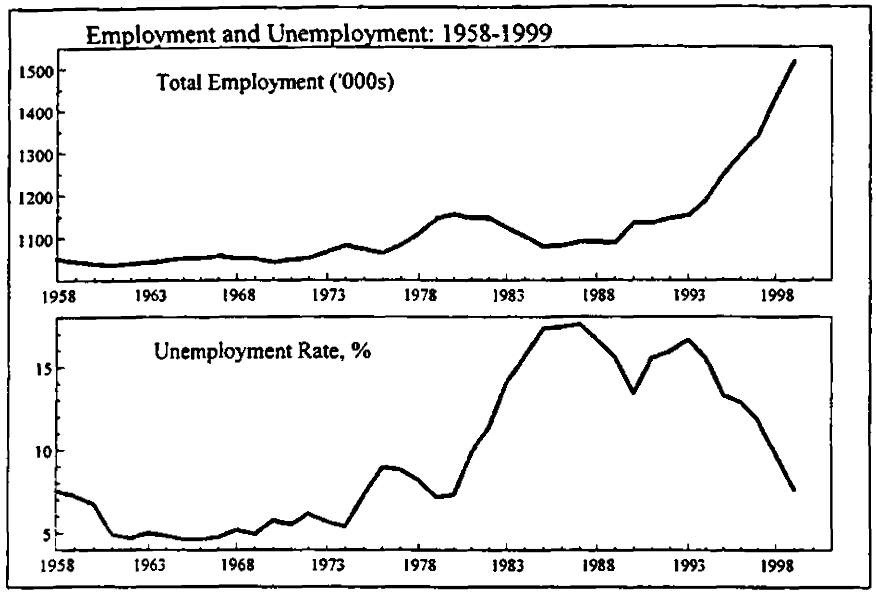

Figure 1.1: Employment and Unemployment in Ireland: 1958-1999

1958 and 1973. In 1973 Ireland joined the European Community, completing the economy's transition to an open traded economy, and employment in manufacturing continued to grow until 1980. From 1980 to 1989, total employment in manufacturing fell by 40,000, agricultural employment fell by 47,000, while employment in services continued to rise (+43,000). Given that agriculture had been in secular decline throughout the 1960s and 1970s, this fall in manufacturing employment was the major contributory factor to the overall fall in employment in that period.

It is the collapse in manufacturing employment in the 1980s, with its attendant long-term consequences for the Irish labour market, that motivated the subject of this thesis. If we are to begin to understand the source of the collapse in employment in Ireland in the 1980s, we need to identify the factors which drove the demand for labour in the manufacturing sector in that period.

from the data used in this thesis, which are based on *Census of Industrial Production* (CIP) data. There has been a growing divergence between these two measures as the manufacturing sector has become increasingly more complex, including a higher proportion of "non-industrial" employment, e.g. marketing research, which is covered by the LFS but not the CIP.

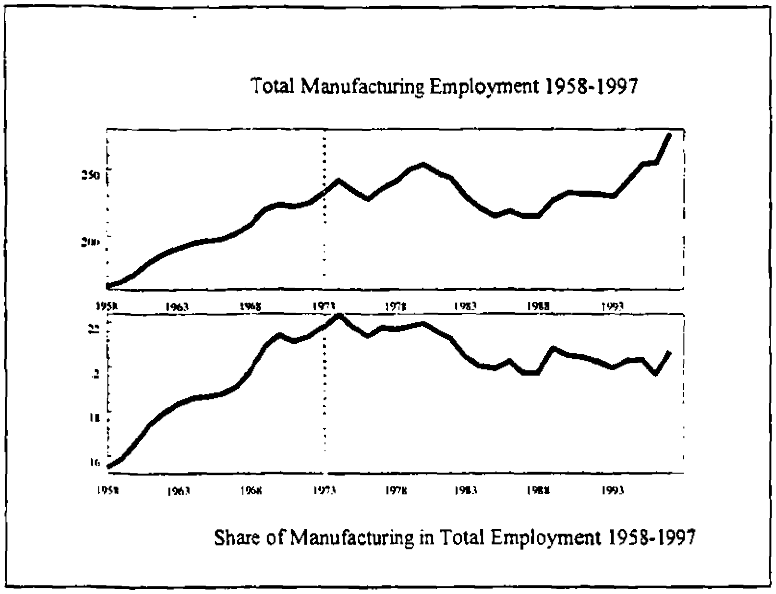

Figure 1.2: Manufacturing Employment and Share in Total Employment: 1958-1997

1.1.2 Why is the Relative Demand for Labour in Manufacturing Important?

During the 1980s there were significant changes in the sectoral composition of Irish industry with rapid expansion in high-technology sectors occurring alongside the decline of traditional manufacturing industries. Concurrent with, and intimately linked to, this change in production was a shift in the occupational structure and educational profile of the Irish workforce towards more highly "skilled" labour (proxied by administrative and technical staff). In Figure 1.3 we can see that this trend towards employing more skilled labour continued in the 1990s, so that the share of "unskilled" labour (proxied by industrial workers) in total employment fell from over 80% in 1979 to 72.5% in 1997.

Figure 1.4 shows indices of employment for skilled and unskilled labour from 1979 to 1997 From this we can see that the collapse in employment in the 1980s was largely driven by a collapse in unskilled employment, which in 1990 was just over 80% of its 1979 level, and in 1997 was still 5% below its 1979 level. In contrast, skilled labour grew marginally in the 1980s before a rapid expansion in the 1990s, so that by 1997 skilled labour exceeded its 1979 employment level by almost 50%.

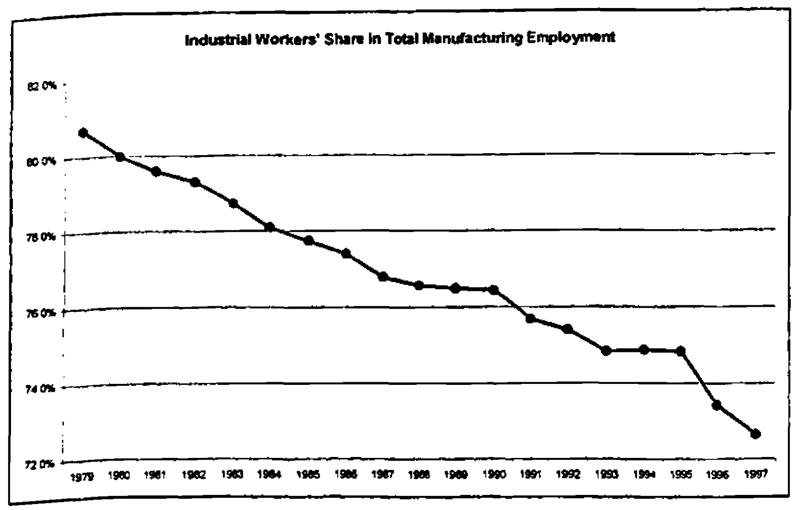

Figure 1.3: Share of Unskilled Labour in Total Manufacturing Employment

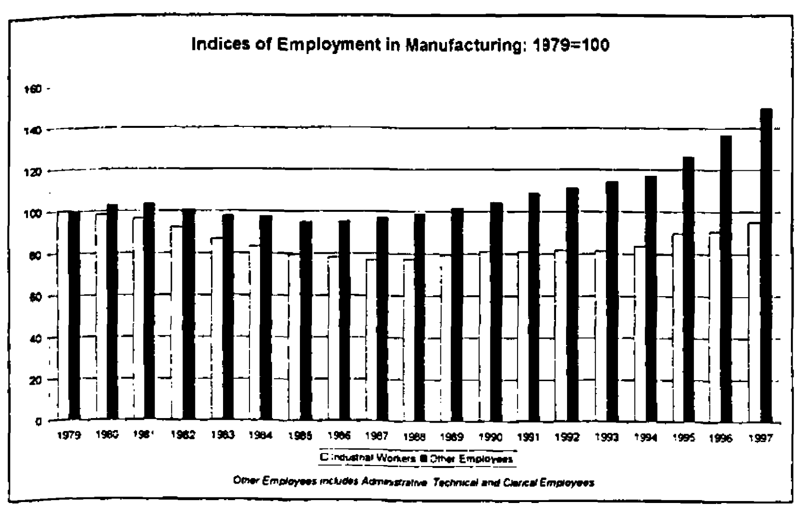

Figure 1.4: Indices of Skilled and Unskilled Employment Growth 1979-1997

These changes in the composition of employment have occurred together with important changes in the Irish labour market and the economy generally:

1. *Rise in Productivity:* The shift towards skilled labour has increased average productivity and the underlying growth potential of the economy.

2. *Rise in Incomes:* Replacing low-wage workers with high-wage workers increased the income of the average worker.

3. *Increase in Inequality:* The shift towards skilled labour, even given broadly unchanged relative wages, has increased unskilled labour's relative disadvantage as unskilled wages moved further below the median wage.

4. *Increase in Profitability:* The shift from low-productivity to high-productivity sectors has led to a reduction in labour's share of value added.

It is these changes underlying the composition of labour that motivated the disaggregation of labour in Part II of this thesis.

1.1.3 The Central Question

The objective of this thesis is to begin to identify the factors which determine the demand for labour in the Irish manufacturing sector. We concentrate on one factor suggested by theory, relative factor prices. The other major factor which drives the demand for labour is the demand for output. However, as discussed later in this chapter, modelling the demand for output is highly complex in the Irish manufacturing sector. Furthermore, if we can pin down the role changes in relative factor prices played in driving down the demand for labour in the 1980s, then this will also help in quantifying what is left to explain, most of which can be attributed to output effects.

The central question addressed is whether, and by how much, movements in relative factor prices change the demand for labour for a given level of output. This is known as the substitution effect and is measured by the constant-output elasticity of demand. To accurately measure the pure substitution effect we need to control for a number of other effects, which may also impact on the demand for labour. The two most important of these are:

- *Output Effect*: This is the other major determinant of labour demand. An increase in one or more factor prices will increase average costs and output prices. This will reduce the demand for output and, thereby, the demand for labour - the output effect.

We control for this by using a cost function specification in estimation. Within this specification the substitution effect is computed holding output constant.

- *Sector Effect*: The demand for labour may differ between sectors because of different underlying production processes. We control for this by identifying three "types" of sector within the manufacturing sector, namely medium-growth, high-growth and declining sectors, and estimating separate labour demand functions for each type.

In addition, we control for scale and technical change in estimation:

- *Scale Effect*: This is a technical effect attributable to non-homotheticity in production. A change in the scale of production can change factor proportions even if factor prices remain unchanged. We control for this by including output as a scale term in the cost function.

- *Technical Change Effect*: The demand for labour may change due to technical advances in production, typically assumed to be labour-augmenting. This means that the same unit of output can be produced with fewer units of labour over time, so-called Harrod-neutral technical change. We control for this by including a time trend in the labour demand equation as an (admittedly crude) proxy for technical change.

In Part I of this thesis we estimate the demand for labour in manufacturing, and the elasticities of substitution and demand, controlling for all of these effects. This gives us an estimate of the pure substitution effect of a change in relative factor prices.

We begin Part II by exploring the changes in the composition of employment in the 1980s. These reflect an increase in the skill-intensity of employment. We disaggregate labour into three stylised categories, skilled, unskilled and clerical labour. We then estimate the own- and cross- price elasticities of demand for each type of labour. This gives an estimate of substitution effects among the different types of labour. The central question addressed in this section is whether movements in relative factor prices have differential effects on the demand for skilled labour relative to unskilled labour for a given level of output.

In Part II in addition to controlling for the effects listed above, we also control for the following:

- *Firm Turnover Effects*: Changes in the number of firms within sectors can change the demand for labour if the firm exiting or entering the sector is different from the average for the sector. We control for this effect, in the absence of firm-level data, by including the number of firms as an additional variable in the labour demand equation.

Throughout this thesis we focus on the *long run* or static theory of labour demand. This is derived from standard neoclassical theory treating all factor inputs as variable. In recent years there has been substantial research in the international literature devoted to analysing the dynamics of labour demand. This literature explicitly addresses the observed asymmetry in adjustment costs, both in relation to differences between hiring and firing costs and in relation to differences in these costs for skilled and unskilled labour (Hamermesh (1993) Chs. 6 and 7). This work builds on an large body of empirical work on the long run demand for labour -"On such things so much work has been done, and the issues are sufficiently narrowly defined, that we can be fairly certain about the conclusions"(*ibid* p.392). However this is not true for Ireland, where there has been very little empirical work on the demand for labour. The last similar study was done on pre-1973 data, since then there has been far more emphasis on the supply side of the labour market. For this reason we concentrate on the long run demand for labour.

1.2 Methodological Issues

1.2.1 The Irish Manufacturing Sector and the Choice of Labour Demand Function

Over the period 1973-1997 employment in the Irish manufacturing sector[2] rose by just over 14,000 from an estimated 243,000 in 1973 to 257,000 in 1997 (see Figure 1.5). This summary statistic however masks a host of changes both in the aggregate level of employment over this period and its sectoral composition. Employment rose through the 1970s to a peak in 1980 of over 255,000, from there it fell almost continuously to a low of 206,000 in 1988. Between 1988 and 1997 it rose by just over 50,000. Notably Irish manufacturing employment has fared better than the average European experience over the period.

1973 was the year of Ireland's accession to the EU, opening up a large export market for foreign (and domestic) firms locating in Ireland. It also marked the final phase in the movement away from protectionism that began in the late 1950s. High growth and a large influx of foreign investment in the 1970s caused a rapid expansion in manufacturing activities. At this time the authorities undertook an aggressive industrial policy (although arguably the key attraction was a zero-rated corporation tax on exported manufactures) of high cash grants and capital allowances to foreign firms locating manufacturing activities in Ireland.

[2]In this graph "manufacturing" refers to the sum of all activity covered by the Census of Industrial Production. This includes mining, quarrying and turf, and electricity, gas and water in addition to manufacturing activities. In the rest of the thesis, where we refer to aggregate manufacturing sector data, we exclude these sectors unless otherwise stated. See Appendix B.1 for details.

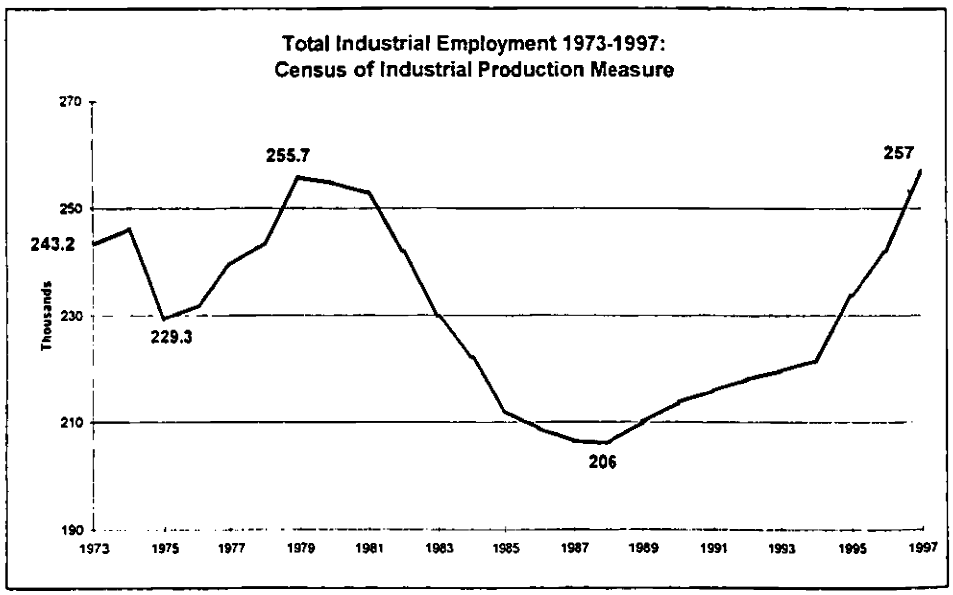

Figure 1.5: Total Employment in Manufacturing Industries 1973-1997

The boom in output, exports and employment in the 1970s was followed by a prolonged recession in the early 1980s with high (historically) real interest rates and rapidly rising unemployment. During this period there was a large-scale shake-out within the manufacturing sector. Ireland, as a late industrialising economy, had a relatively large proportion of so-called "traditional" industries, (relative to its main trading partners viz. UK, USA, Germany) characterised by high labour intensity and low profitability which had been sheltered from competition during the protectionist era (and to some extent through the 1970s because of the one-to-one link with sterling which was finally broken on Ireland's joining the exchange rate mechanism of the EMS in 1979). These industries experienced a massive decline in the 1980s manifested both in terms of zero output growth and declining employment. The net result of this restructuring was a significant fall in total employment in that period. Parallel to this decline in traditional industries, the so-called "modern" high-technology, capital intensive manufacturing sectors continued to grow rapidly through the 1980s, however this growth was not sufficiently employment-intensive to prevent total manufacturing employment from falling by approximately 50,000 in eight years. The economy recovered strongly in the 1990s and ended the decade with an unprecedented expansion in employment and output (leading to the unlikely epithet "Celtic Tiger") with manufacturing employment figures also increasing rapidly.

Because Ireland is a small open economy (SOE) it is extremely vulnerable to world conditions and the manufacturing sector in particular is highly export-oriented. So the firm's output decision (and/or the (re-)location decision of foreign firms) is highly complex. In modelling the Irish manufacturing sector there are difficulties in assuming standard neoclassical behaviour patterns (as determined within Ireland) because often foreign firms in Ireland behave "as if" they were located in their home country and their behaviour mirrors conditions in their home country far more closely than conditions prevailing in Ireland so that their responses to factor prices and output demand may not appear sensible without modelling the multinational firm as a whole.

This latter point may seem strange, but the existence of zero-rated corporation tax on exports until 1980 (and until 1990 for firms in place before Jan. 1 1980) and a reduced rate of 10% on all manufacturing profits from 1980 onwards means that branch plants located in Ireland often engage in substantial "profit-switching transfer pricing" (Stewart (1989)). That is, they underprice their imported inputs (imported from other subsidiaries located outside of Ireland) and overprice their output prices to inflate reported profits earned in Ireland. these profits are then repatriated to their home country. The measured statistics are thereby distorted. This is not an insignificant issue since estimated profit outflows rose from 2.8% of GDP in 1980 to over 9% in 1990 (O'Malley and Scott (1994)) and roughly 15% in 1999.

Fagan and Fell (1994) point to the fact that the evolution of Irish manufacturing output is not closely linked to events in the domestic economy. In a study of coincident and leading indicators of the Irish business cycle, they find that Irish industrial production is only "led" by US industrial production. They conclude that "this confirms the conclusion in Fell (1989) that aggregate Irish industrial output is independent of variables that would normally be expected to influence industrial production."(p.31) This finding reflects the dominance of foreign multinationals in the Irish manufacturing sector.

Because of these complexities in modelling the output decision of firms in the Irish manufacturing sector, we have chosen to model conditional demand for labour functions. These assume cost-minimisation behaviour - a reasonably uncontentious assumption at the local branch/plant level even for multinationally owned firms.

We use the translog cost function to derive long run conditional factor demand equations where all factor inputs are variable.. This is in the class of flexible functional forms where estimated elasticities of substitution and factor shares are allowed to vary over time. This is very important in modelling the Irish manufacturing sector since the switch towards more capital-intensive, high-technology production has coincided with a steady decline in labour's share of value added.

Labour's share of value added in the economy generally has fallen dramatically over the past two decades. In the US and UK this share has remained stable since the 1970s while it has been falling in continental Europe (Blanchard (1997)). The experience in Ireland has been similar to other European countries. Between 1980 and 1997 labour share of non-agricultural value added fell by over 13 percentage points. Much of this decline occurred in the 1980s, during the period of restructuring of the manufacturing sector, where labour's share fell by over 25 percentage points between 1980 and 1997 (Figure 1.6).

1.2.2 Data Constraints and Choice of Econometric Methodology

Our labour demand function is specified as a simple long run economic relationship. However throughout this thesis we also include "short run" dynamics in estimation, and concentrate on the empirical "long run" coefficient estimates. Empirical estimation of static factor demand equations has frequently led to rejection of economic theory restrictions such as homogeneity and symmetry. In addition the residuals in such empirical models have often been found to be serially correlated signalling dynamic misspecification. This suggests that underlying long-run behaviour consistent with economic theory restrictions would be more likely to be captured within a dynamic modelling framework. Full adjustment of all factors within a single period is not necessarily required by economic theory but is imposed in estimating static factor demand systems. By contrast a dynamic specification in estimation can both

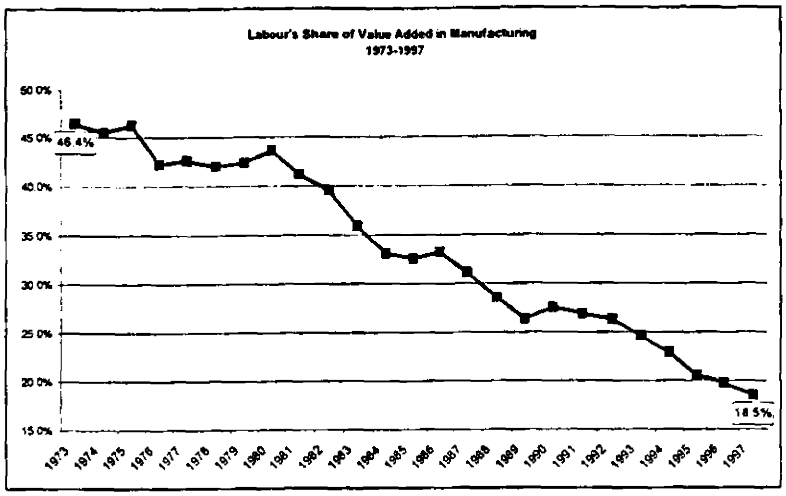

Figure 1.6: Labour's Share of Value Added in Manufacturing

respect the long-run behavioural restrictions and allow for asymmetric short-run responses. Empirical studies incorporating short-run dynamics found that economic theory restrictions were no longer rejected in the long-run (Anderson and Blundell (1982, 1983, 1984) Friesen (1992)).

In Part I we estimate a simple labour demand function using the "encompassing the VAR" general-to-specific modelling methodology. This allows for estimation of the parameters of a generalised labour demand function within a VAR model of the variables of interest. The general-to-specific approach emphasises thorough testing of the model at each stage of estimation for evidence of misspecification. This method provides a welcome transparency in evaluation of the robustness of the final estimation results.

An important feature of the encompassing the VAR methodology is that, if the model is found to be well specified, it allows for estimation of the long-run coefficients of a labour demand equation, our parameters of interest, without full identification of the short-run dynamics. This means that while we always estimate within a dynamic specification, we can focus our attention on the long run parameter estimates if the model is found to be congruent with the data.

The general-to-specific approach is our preferred econometric methodology. However it is very data demanding and therefore only suitable for modelling small systems. In Part II we are forced to adopt a more restrictive methodology for the estimation of the demand for skilled and unskilled labour because the data are only available on an annual basis for 12 years. To tackle the short time span of the data, we pool the sectoral data into three groups of similar sector types. We then employ panel data econometric techniques to estimate a set of dynamic single equation models for each group, using a GMM estimator. These estimate an equation for the demand for skilled relative to unskilled labour, and an equation for the demand for labour relative to capital separately. The estimates are then combined to provide an initial estimate of the constant-output elasticity of demand for skilled labour. Finally we estimate a full system of four dynamic equations for skilled labour, unskilled labour, clerical labour and capital services using nonlinear least squares and FIML estimators.

1.3 Previous Work on Labour Demand

There have been very few studies on labour demand in the Irish manufacturing sector. Most of these have focused on estimating the demand for labour in highly aggregated manufacturing sectors within a general model of the Irish labour market. The only Irish studies on labour demand using disaggregated data were done on pre-1973 data. While these studies can help inform our assessment of our estimated results they do not provide us with directly comparable results. To put our results in an international context, we draw on work done by Hamermesh (1993) summarising a set of stylised facts on labour demand from the international literature.

1.3.1 Previous Econometric Studies of the Demand for Labour in Ireland

There have been a number of econometric studies of the labour market in Ireland over the past twenty years (e.g. Newell and Symons (1990), Barry and Bradley (1991), Browne and McGettigan (1993)). In general the aim of these studies has been to estimate the interaction between labour demand, labour supply and wage determination to contribute to a growing body of literature, both national and international, which debates the origins of the dramatic increase in unemployment in Ireland in the 1980s. These studies attempt to disentangle the overall increase in unemployment into the relative importance of domestic policy factors as against external shocks. Of their nature these studies are highly stylised representations of the workings of the labour market and they all use highly aggregated data.

The only exceptions to this are two studies (Boyle and Sloane,(1982) and Henry(1972)) which used disaggregated individual manufacturing sector level data. Both studies used pre-1973 data. Boyle and Sloane (1982) estimated systems of factor demand equations for three factors, wage-earners, salaried earners and the capital stock over the period 1953-1973 using annual data on 40 manufacturing sectors. Their estimates are based on the translog cost function and they impose all cross-equation restrictions *a priori*. Their estimated elasticities varied depending on whether they include a trend term (proxy for technological progress) in the specification and, for over half the industries included, are not significant. They found that the elasticity of substitution between production workers and capital was greater than the corresponding elasticity for non-production workers and capital. Because their data set ends in 1973 there is no overlap with the data used in this thesis. The only other econometric study was done by Henry (1972), who estimated CES production functions for 14 manufacturing sectors using annual input-output data over the period 1960-1968. The data limitations in this case are due to the paucity of input-output data in Ireland.

The more recent empirical literature on modelling the labour market uses aggregate manufacturing data. Bradley *et al* (1993) estimated a four factor demand system for the stylised 'modern' and 'traditional' manufacturing sectors using annual data from 1970-1987. They use the Generalised Leontief functional form to model the demand for labour, this allows for quasi-fixity of the capital factor in the short-run. Their results indicated little substitution between variable factors in the short-run but significant substitution between quasi-fixed capital and the variable factors in the short-run. In the long run capital was found to be complementary to labour in the traditional sector. Newell and Symons (1990) estimated a simple three-equation model of the aggregate Irish labour market, where labour demand is modelled as a dynamic function of the real wage, the real interest rate, perturbations to aggregate demand and technological progress (proxied by a time trend). The estimated long-run wage elasticity is -2.3. Their results suggested that shocks to real money balances and UK output are important in explaining the pattern of labour demand. Barry and Bradley (1991) criticise the single-sector nature of the Newell and Symons model and look instead at sectoral labour demands estimated within a large macroeconometric model. They model the agricultural, manufacturing and market-services sectors separately. The manufacturing sector factor demand model is based on the parameters of an estimated CES production function. Browne and McGettigan (1993) extend the work done by Newell and Symons. They make a distinction between the traded and non-traded sectors of the economy and model separate labour demand functions for each sector. In the traded sector the demand for labour is significantly influenced by movements in the terms of trade and world demand, while in the non-traded sector labour demand is modelled as a function of domestic GNP. In both sectors they find evidence of a strong negative relationship with the real wage and sluggish adjustment which they argue indicates that employee protection legislation has made labour a quasi-fixed factor of production. Hannan (1993) estimates labour demand functions for the total manufacturing sector using two different measures of the cost of capital. She finds that the estimated elasticity of substitution varies depending on the cost of capital measure used. Her reported results indicate very little evidence of substitution between the demand for labour and capital.

1.3.2 Four International Stylised Facts on Labour Demand

Hamermesh (1993, Chapter 3), in a survey of a wide range of empirical literature on the parameters characterising labour demand, summarises the main findings from this research into seven stylised facts (p.135). Four of these are relevant to our study here:

1. The constant-output elasticity of demand for labour lies in the interval [0, -1].
2. The own-wage demand elasticity decreases as skill levels rise.
3. Capital and skill are complements in production.
4. Unskilled labour is a substitute for capital.

In Part III we assess our parameter estimates of labour demand for the Irish manufacturing sector against these four stylised facts.

1.4 Structure of Thesis

1.4.1 Modelling the Long Run Demand for Labour: Part I

In Part I we estimate a simple long-run labour demand equation, with two factors of production, labour and capital. This is estimated using the encompassing-the-VAR econometric modelling methodology and cointegration analysis. Chapter 2 sets out in detail the theoretical framework and econometric methodology used.

In Chapter 3 we select three sectors representative of different types of activity in Irish manufacturing from a preliminary analysis of 31 manufacturing sectors. These are Metal Articles (medium growth sector), Pharmaceuticals (high-growth sector) and Wool Industries (declining sector). The chapter then presents the estimation results for each of these sectors.

1.4.2 Modelling the Long Run Demand for Skilled Labour: Part II

In Part II we estimate the demand for skilled labour relative to unskilled labour in the Irish manufacturing sector in the 1980s. Chapter 4 examines changes in the structure of employment in the Irish manufacturing sector in the 1980s, using data on 72 Irish manufacturing sectors. A three-way breakdown of employment into skilled, unskilled and clerical workers is constructed, and manufacturing is disaggregated into three groups of high-growth, medium-growth and declining sectors. We then employ shift-share analysis, along with a range of descriptive statistics, to detect whether there has been a shift in the structure of employment towards employing more skilled labour and, if so, whether this shift varied in different sector groups within manufacturing.

In Chapter 5 we present the results of single equation estimates of the long-run demand for skilled labour relative to unskilled labour for the three groups. In Chapter 6 we present the systems estimates of the demand for skilled, unskilled and clerical labour for the three groups.

1.4.3 Conclusions: Part III

Chapter 7 concludes the thesis. We evaluate the robustness of the empirical results, compare them with Irish empirical work and with international stylised facts and discuss their implications.

1.4.4 The Data: Part IV

This thesis uses data from the *Census of Industrial Production* (CIP), which provides annual data on output, employment and wages at a detailed sector level. A significant discontinuity in these data arose in 1973 and again in 1991 when the Central Statistics Office introduced a new classification of sector codes. In both instances, these led to big changes in sector definitions at detailed sector level. Because of these discontinuities, our annual data series are strictly limited to cover the period 1973-1990. In addition to these data, we constructed a cost of capital variable, as described in Appendix B.3.

In Part I we use a quarterly dataset which links annual data from the CIP for the period 1973-1990 with quarterly indices of output, employment and wages for the period 1973Q1-1997Q2[3]. These data cover 31 broad sectors. We interpolate some missing quarterly data at the beginning of the sample period by combining the annual data and deterministic forecasts of the quarterly data series (Appendix B.2).

In Part II we use an annual dataset from the CIP covering the period 1979 to 1990. These data begin in 1979, the first year when disaggregated data on employment and wages were published.

[3]There were no problems of discontinuity in the quarterly data post-1990 as the CSO continued to publish quarterly indices using the old sector codes.

Part I

Modelling The Long Run Demand for Labour

Chapter 2

Theoretical and Methodological Framework

We adopt a general to specific modelling strategy to estimate the demand for labour. This begins by estimating a general model among the variables of interest. These variables include labour, relative factor prices and output, as suggested by the theory of labour demand. If the empirical model is statistically well-specified, it can then be used to test for a long run demand for labour relation among these variables.

The basic theory of the demand for labour is simple. An increase in the wage, *ceteris paribus*, will reduce the demand for labour. This operates through two separate effects. An increase in the wage will raise the price of labour relative to other factors of production, leading to a substitution away from labour in producing a given level of output, the *substitution effect*. An increase in the wage will also increase average cost and hence the output price, leading to a reduction in the demand for output and hence the demand for all inputs, including labour, *the output effect*. The elasticity of demand for labour, which measures the overall responsiveness of labour demand to a change in the wage, is then the simple sum of these two effects.

The demand for labour function can be derived using standard neoclassical theory of the firm. Within this framework unconditional factor demands are derived from the profit function and conditional factor demands are derived from the cost function. Unconditional factor demands, which allow output to vary and therefore require modelling the market for output, encapsulate both substitution and output effects while conditional factor demands, because they are conditioned on output, capture substitution effects alone.

We use the cost function to derive the demand for labour. This relies on the relatively uncontroversial assumption that in the long run all profit-maximising firms will minimise costs. Furthermore it avoids the complexities of modelling the market for output. The demand for Irish industrial output is closely linked to developments in the world economy which are difficult if not impossible to parameterise with a small set of stylised variables. Conditioning on output avoids this problem while still allowing estimation of the substitution effect.

The conditional demand for labour function includes both relative factor prices and output. The relative factor price terms estimate the substitution effect. This tests whether "relative prices matter". Output is included to allow for non-homotheticity in production. Non-homotheticity implies that factor proportions will vary as the scale of operation changes for a given configuration of factor prices, in other words "scale matters". For example it may be more efficient for a large firm to employ a more capital-intensive production process[1]. This is *not* the same as the output effect which measures the effect of a change in output prices on factor demands.

There is a substantial body of literature in this area, which has developed so-called "flexible functional form" specifications of the cost function. These are used widely in empirical work on estimating factor demands. We use the translog fuctional form as a general specification of the conditional demand for labour function, this specification allows restrictions implied by economic theory to be tested on the estimated parameters.

To estimate a long run demand for labour equation we use the "encompassing the VAR" econometric methodology. This begins by modelling a given set of variables of interest as a general unrestricted Vector Autoregression (VAR). This VAR specification describes the stochastic process of each variable as a function of both its own past and the past levels of the other variables of interest. If this is found to provide a statistically adequate representation of the data, then it can be used as a reference framework within which rival economic models and hypotheses, and behavioural restrictions within these models, can be tested for.

This is known as a *progressive modelling strategy* (Mizon, 1995). An important implication of such a strategy is that it is possible to uncover interesting relations between the variables that were not anticipated at the initial design stage. In this way our understanding of the relationships between the variables of interest can be deepened. For example, the variables of interest used in this section in estimating the conditional demand for labour - labour, wages, cost of capital, value-added, output, technical progress - also include variables which allow us to test for two simple wage equation specifications - wages as a function of average labour productivity and wages as a function of total factor productivity.

This methodology is very data-demanding and can rapidly become highly complex as

[1]Hamermesh (1993) illustrates non-homotheticity using an example of leaf raking on his college campus, which varies from an individual worker using a rake near buildings and bushes to an individual worker using a flatbed truck in large open areas.

the dimensions of the VAR increase. We estimate a five-dimensional VAR, which is the maximum possible given the available data, with only two factors in production, labour and capital. The sum of the costs of these two factors equals output net of intermediate inputs, namely value-added. The VAR includes five variables; labour, the price of labour, the price of capital, output and value added. Because of its dimensions, the VAR approach requires a large number of observations in estimation. To increase the number of observations available, we use quarterly rather than annual data covering the period from 1973Q1 to 1997Q2, a total of 98 observations.

The VAR is used to estimate the long run and short run parameters of a general labour demand function without imposing *a priori* theoretical restrictions on the estimates. These estimated coefficients are then used to test for behavioural restrictions, namely cost minimisation, price homogeneity, homotheticity, and also to provide estimates of the elasticities of substitution and demand.

In this thesis we are interested in modelling labour demand. However in the labour market, supply and demand curves interact, and both employment and wages are jointly determined in equilibrium. The encompassing the VAR methodology allows for this simultaneity by estimating a system of equations, with all variables endogenous. In our empirical estimation we consistently found evidence of two long run relations among the variables of interest. We model these as a labour demand and labour supply equation respectively, with the latter specified as a reduced form wage equation.

The structure of this chapter is as follows. Section 2.1 derives the demand for labour function, and discusses interpretation of the elasticities of substitution and demand. Section 2.2 describes the encompassing the VAR methodology in detail. Finally Section 2.3 outlines the VAR used in estimation in Chapter 3, and discusses the implications of specifying the second long run relationship as a reduced form wage equation.

2.1 The Demand for Labour: Theoretical Framework

2.1.1 Neo-Classical Theory of the Firm

Following Varian (1978) we define the **production function** of a single product firm as

$$F(X) = \{Q \text{ in } R : \text{is the maximum output associated with } -X \text{ in } \Gamma\} \qquad (2.1)$$

where(Q, X) is the netput bundle, X is an N-vector of inputs that can produce Q, Γ is the production possibilities set and $F(.)$ is a function which describes the maximum feasible output as a function of the inputs.

The **technical rate of substitution** between factors, which measures the rate at which we can substitute one factor for another in the production process while maintaining a constant level of output $Q^* = F(X_1^*, ..., X_N^*)$, is defined as

$$\frac{\partial X_N(x_1^*, ..., X_{N-1}^*)}{\partial X_1} = -\frac{\partial F(X^*)/\partial X_1}{\partial F(X^*)/\partial X_N} \tag{2.2}$$

where the $X_N(.)$ function describes how much of X_N it takes to produce Q given the other factors. This is a measure of the slope of a given isoquant. With a Leontief technology (limiting case), where factors are used in fixed proportions, the firm has no factor substitution possibilities and the technical rate of substitution is zero. In the case of a linear technology (opposite limiting case), where factors are perfect substitutes, the technical rate of substitution will be infinite, and the profit-maximising firm will employ the factor(s) with the lowest price. To examine the more interesting and realistic case, where there are some limited substitution possibilities between factors, which means the production function will have convex isoquants, we look at the economic behaviour of the firm.

Duality means that an arbitrary cost function summarises all the economically relevant aspects of a firm's technology. This means that we do not need to examine the engineering plans of a firm to explain its demand for output and factor inputs.

The **cost function** of a firm is given by

$$C(P_X, Q) = \min\ P_X \cdot X, \text{s.t. } X \text{ is in } V(Q) \tag{2.3}$$

where P_X is an N-vector of factor prices and $V(.)$ is the input requirement set for Q. This function describes the cost-minimising behaviour of all profit-maximising firms regardless of the structure of the output market. Firms are assumed to be price takers in factor markets so that factor prices are exogenous.

First-order conditions for cost minimisation give

$$\frac{P_i}{P_j} = \frac{\partial F(X^*)}{\partial X_i} / \frac{\partial F(X^*)}{\partial X_j}; i, j = 1, ..., N \tag{2.4}$$

The right hand side term measures the technical rate of substitution given in (2.2), the term P_i/P_j measures the economic rate of substitution - the rate at which factor j can be substituted for factor i with costs unchanged.

The **elasticity of substitution** between two factors is a scalar measure of how 'substitutable' one factor is for another. It measures how the ratio of factor inputs changes as the technical rate of substitution, which is the slope of the isoquant defined in (2.2), changes.

The most commonly used estimate is the so-called Allen-Uzawa partial elasticity of substitution which can be calculated pairwise for any two factors from the partial derivatives of the cost function:

$$\sigma_{ij} = \frac{C(.) \cdot C(.)_{ij}}{C(.)_i \cdot C(.)_j} \tag{2.5}$$

where $C(.)_i$ denotes the partial derivative of the cost function with respect to factor i. The elasticity of substitution is symmetric, $\sigma_{ij} = \sigma_{ji}$, due to symmetry of cross-price effects $C(.)_{ij} = C(.)_{ji}$.

2.1.2 Conditional Factor Demand Functions

In this thesis we are concerned with long run factor demands. In the long-run the profit function is generally not well-defined (for example with constant returns to scale the firm's profits are unbounded) and the optimal level of output produced by the firm also depends on the demand for that output. Therefore "unconditional factor demands"[2] (which condition on the first-order marginal productivity conditions derived from the profit function) cannot be determined without also modelling (or making explicit assumptions about) the output market. By contrast if the short-run were being modelled then the profit function is conditional on certain fixed factors and unconditional (with respect to output) factor demands can be derived in this case.

Conditional factor demands $X(P_X, Q)$, which are derived from the cost function, determine the choice of X^* which minimises the cost of producing Q units of output. These are conditional on the level of output and therefore preclude the necessity of assuming a mechanism for output determination.

Given the assumption of cost-minimisation, we can apply Shephard's Lemma to derive the conditional factor demands from the first order derivatives of the cost function:

$$X_i(P_X, Q) = \frac{\partial C(P_X, Q)}{\partial P_i}, \; i = 1, ..., N \tag{2.6}$$

The fundamental properties of cost-minimisation are that the cost function is monotonic, linear homogenous and concave in factor prices. These imply the following properties for conditional factor demand functions:

1. The factor demand function is homogenous of degree zero in factor prices. This follows from the property that the cost function is homogenous of degree one in factor prices.

[2] In all that follows "unconditional factor demands" means unconditional with respect to output while "conditional factor demands" means conditional on output.

2. Cross-price effects are symmetric and own-price effects are nonpositive. This follows from the property of concavity of the cost function.

In addition to these properties, homotheticity is often assumed for the cost function although it is not a necessary condition for cost-minimising behaviour. If production is homothetic, then the ratio of factor inputs is independent of scale at each factor-price ratio and the cost function can be written as $C(P_X, Q) = C(P_X)Q$.

2.1.3 Functional Forms for the Cost Function

A comprehensive survey by Hamermesh (1986) of the long-run demand for labour listed four functional form specifications commonly used in applied work, namely the Cobb-Douglas technology, the CES (Constant Elasticity of Substitution) technology, the generalised Leontief technology and the translog (Transcendental Logarithmic) technology. Madsen (1991), using data from 15 OECD countries over the period 1960-88, found that the CES and translog technology specifications perform better than the Cobb-Douglas, in terms of being statistically well-specified and satisfying theoretical restrictions, although the latter is the most commonly used method.

The Cobb-Douglas and CES technologies are *a priori* more restrictive than the translog or generalised Leontief . The Cobb-Douglas technology is the most restrictive, constraining the elasticity of substitution to equal one. The CES technology constrains it to be constant. This in turn is a constraint on the more flexible translog and generalised Leontief technologies where the elasticity of substitution depends on the values of factor inputs and factor prices.

The **Cobb-Douglas** functional form specifies the firm's technology as monotonic, convex in factor inputs, homothetic and linear homogenous. It satisfies the law of diminishing marginal returns *a priori* . The cost function form is given as

$$A\Pi_i^N P_i^{a_i} Q \tag{2.7}$$

where $0 < a_i < 1$, $A > 0$ and $\sum_i^N a_i = 1$. The a_i coefficients measure the cost share of factor i (in the dual production space the a_i measure the output share of factor i and the output elasticity of factor i). The restriction that they sum to one implies a constant returns to scale technology (although this assumption can be relaxed). The elasticity of substitution σ is equal to one for all factors (because of homotheticity and log-additivity).

Because the a_i coefficients are constant, factor cost shares are constant by assumption in a Cobb-Douglas technology. Research for the US, where labour's share of value added has been constant for long periods of time, consistently finds that a Cobb-Douglas technology is a good approximation in estimating the demand for labour in a two factor framework:

> "A reasonable estimate of the elasticity of substitution between capital and homogenous labour is one. A Cobb-Douglas function is a good approximation to the structure of two-factor production. " (Hamermesh (1993) [p.392])

However, this restriction is unreasonable in modelling the Irish manufacturing sector since labour's share of value added in manufacturing fell steadily by almost 28 percentage points between 1973 and 1997 (see Chapter 1).

The **translog cost function** relaxes many of these restrictions. It is given by

$$\ln C = \ln \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln P_i + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j + \alpha_q \ln Q + \frac{1}{2}\gamma_{qq} \ln(Q)^2 + \sum_{i=1}^{N} \gamma_{iq} \ln P_i \ln Q \tag{2.8}$$

where P_i is the price of factor i and Q is volume output.

Q is included to test for non-homotheticity of the cost function. The degree of returns to scale r is measured by the inverse of the elasticity of cost with respect to output as follows:

$$r = 1/\varepsilon_{C_Q}, \text{ where } \varepsilon_{C_Q} = \alpha_q + \sum_{i=1}^{N} \gamma_{iq} \ln P_i + \gamma_{qq} \ln(Q)$$

Zero restrictions on the parameters $\gamma_{iq} = 0, \forall i$ imposes homotheticity on the translog cost function. Homotheticity alone does not imply constant returns to scale. This requires further restricting the autonomous parameters α_q and γ_{qq} as follows, $1 - \alpha_q = 0$ and $\gamma_{qq} = 0$, so that the cost function is linear homogenous with respect to output.

We adopt this translog specification in estimation as a 'general' functional form within which various hypotheses can be tested. Differentiating with respect to factor prices and applying Shephard's Lemma (i.e. assuming cost minimising behaviour) gives the cost share, S_i, equations:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i}{C}\frac{\partial C}{\partial P_i} = \frac{P_i X_i}{C} = S_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \gamma_{iq} \ln Q \tag{2.9}$$

where X_i is factor i. Since the cost function is linear homogenous in input prices, the cost shares must sum to one, this adding-up condition implies the following restrictions with certainty:

$$\sum_{i}^{N} \alpha_i = 1, \ \sum_{i}^{N} \gamma_{ij} = 0, \ \sum_{i}^{N} \gamma_{iq} = 0 \tag{2.10}$$

The adding-up condition means that in practice only $N-1$ equations need to be estimated, the parameters of the N^{th} equation can be recovered using the above restrictions. Economic theory restrictions of price homogeneity and symmetry of the cost function imply a further set of restrictions on the parameters:

$$\begin{aligned} \sum_{j=1}^{N} \gamma_{ij} &= 0 \quad \text{(Price homogeneity)} \\ \gamma_{ij} &= \gamma_{ji}, \quad \forall i,j; i \neq j \quad \text{(Symmetry)} \end{aligned} \tag{2.11}$$

The parameters of equation (2.9) can be used to derive point elasticity estimates. Partial elasticities of substitution are given by

$$\sigma_{ij} = (\gamma_{ij} + S_i.S_j)/S_iS_j, i \neq j, \text{ otherwise } \sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i)/S_i^2 \tag{2.12}$$

and price elasticities are given by

$$\varepsilon_{ij} = S_j\sigma_{ij}, \quad \varepsilon_{ii} = S_i\sigma_{ii} \tag{2.13}$$

In the translog specification factor shares and elasticity estimates can vary. The so-called regularity conditions (symmetry, adding-up and linear homogeneity with respect to factor prices) can be formulated as restrictions on the coefficients, these constitute a test of the hypothesis of cost-minimisation.

Homotheticity can be also tested as a further restriction on the cost function parameters, restricting the coefficients on the term $\ln Q$ in (2.9) to equal zero. Homotheticity is not a necessary condition for cost-minimising behaviour.

2.1.4 A Two-Factor, Value-Added Framework

To estimate a set of N conditional factor demands $X(P_X, Q)$ (as derived from the cost function (2.3)) we need quarterly data on $N-1$ factors of production (X), N factor prices (P_X), total expenditure on factors (C), and total volume production (Q).

The following basic accounting identities summarise the relationship between gross output and value-added:

$$\begin{aligned} \textit{Gross Output} &= \textit{Intermediate Inputs} + \textit{Value Added} \\ \textit{Value Added} &= \textit{Wages and Salaries} + \textit{Expenditure on Capital Services} \end{aligned}$$

A *gross output* modelling framework models the demand for at least three factors of production; labour, capital and intermediate inputs. We have annual data for prices and quantities of these three factors and quarterly data for the price of labour, capital and intermediate inputs and the quantity of labour (employment). However we have no quarterly data on quantities for capital or intermediate inputs. This means that to estimate the demand for labour using quarterly data we are restricted to a *value added* framework where we model the demand for two factors, labour and capital. Section 3.9 in Chapter 3 contains a fuller discussion of this data constraint.

A value-added specification for the cost function assumes weak separability with intermediate inputs. Specifically it assumes that there exists a value-added production function $F(L,K)$ which is weakly separable from the gross output production function $G(F(L,K),M)$ within which it is nested (M are intermediate inputs and L and K are labour and capital inputs). Weak separability implies that the cross-partial elasticity of substitution between M and both L and K respectively is unity so that the $G(.)$ function can be represented by a Cobb-Douglas type technology treating the bundle $F(K,L)$ as a single factor. If this assumption is true then the adoption of a value-added framework for modelling L and K is valid. In what follows, weak separability is a maintained but untested hypothesis (it cannot be tested given the data constraint described above).

2.1.5 An Estimating Equation for the Demand for Labour

The two-factor version of the translog factor demand system reduces to a single equation for estimation:

$$S_l = \alpha_l + \gamma_{ll}\ln(P_l) + \gamma_{lk}\ln(P_k) + \gamma_{lq}\ln(Q) + \gamma_{lt}t \qquad (2.14)$$

This is the basic equation we use in estimation in Chapter 3. It includes a time trend, t, as a test for labour-biased technical progress. Adding -up implies $\gamma_{lt} = -\gamma_{kt}$, this means that technical progress must be either labour-augmenting (Harrod neutral $\gamma_{lt} < 0$) or capital-augmenting (Solow-neutral $\gamma_{lt} > 0$) but cannot be both.

Using this equation we can test for cost minimisation, scale effects (non-homotheticity), biased technical progress, a Cobb-Douglas technology (constant labour share), and estimate the elasticities of substitution and demand:

1. *Cost-Minimisation*: Adding-up, symmetry and linear homogeneity with respect to factor prices restrictions imply

$$S_k = 1 - S_l,\ \gamma_{ll} = -\gamma_{lk},\ \gamma_{lk} = \gamma_{kl}$$

2. *Scale Effects*: Homotheticity in production implies

$$\gamma_{lq} = 0$$

3. *Biased Technical Change*: Hicks-neutral technical progress (or no technical progress) implies

$$\gamma_{lt} = 0$$

4. *Constant Factor Shares*: A Cobb-Douglas technology for the firm implies

$$\gamma_{ll} = \gamma_{lk} = \gamma_{lq} = 0 \tag{2.15}$$

which gives $S_l = \alpha_l$, $\varepsilon_{lk} = S_k$, $\varepsilon_{ll} = S_l - 1$ and $\sigma = 1$.

The elasticities of demand and substitution are calculated as follows:

$$\varepsilon_{lk} = \frac{\gamma_{lk}}{S_l} + S_k,\ \varepsilon_{ll} = \frac{\gamma_{ll}}{S_l} + S_l - 1$$

$$\sigma_{lk} = \frac{\varepsilon_{lk}}{S_K}$$

2.1.6 Interpreting The Elasticities of Substitution and Demand

When there are only two factors, labour (L) and capital (K), the elasticity of substitution is a measure of the curvature of the isoquant:

$$\sigma = \frac{\partial(L/K)}{\partial(P_k/P_l)} \frac{(P_k/P_l)}{L/K)}$$

The **elasticity of demand** for labour is closely related to this. Define the *constant-output* own-elasticity of labour demand ε_{ll} and cross-elasticity of labour demand ε_{lk} as

$$\varepsilon_{ll} = \frac{\partial L}{\partial P_l}.\frac{P_l}{L} \quad \varepsilon_{lk} = \frac{\partial L}{\partial P_k}.\frac{P_k}{L}$$

Then we can derive the following [3]:

$$\varepsilon_{ll} = (S_l - 1)\sigma \quad \varepsilon_{lk} = (1 - S_l)\sigma = S_k\sigma$$

where S_l is labour's share of value added. The constant-output elasticity measures the pure *substitution effect* of a change in relative factor prices on the demand for labour.

The demand for labour is more elastic in the long-run than in the short-run. In the short-run, when the capital stock is fixed, the possibilities for changing factor proportions

[3]See Fallon and Verry (1988, ch.4), Chung(1994) and Hamermesh (1993, ch. 2) for details.

are limited so that the substitution effect is relatively low. In the long-run, when all factors of production can be re-adjusted to their optimum level in the face of changed relative factor prices, the substitution effect is higher.

The substitution effect is only part of the story. Changes in relative factor prices will also change output and therefore the demand for all factors, including labour. However, to estimate this output effect, we need to model the market for output (see Rich(1990)). Define the *variable-output* elasticity of labour demand as ε'_{ll} and cross-elasticity of labour demand as ε'_{lk}. Under constant returns to scale this is

$$\varepsilon'_{ll} = \underbrace{(S_l - 1)\sigma}_{\text{substitution effect}} + \underbrace{S_l\eta}_{\text{output effect}}, \quad \text{similarly } \varepsilon'_{lk} = (1 - S_l)[\sigma + \eta] \qquad (2.16)$$

where η is the price elasticity of demand for output. This elasticity combines both substitution and output effects.

Equation (2.16) is the famous "Hick's decomposition" sometimes referred to as the fundamental law of factor demand. It summarises Marshall's four rules of derived demand (Hamermesh, 1993, pp.24-25):

1. The demand for labour is more elastic, the higher the elasticity of substitution. An increase in wages, or a fall in the cost of capital, makes labour relatively more expensive than capital and this encourages substitution away from labour toward capital in the production process. The higher this substitution effect, the bigger the reduction in labour for a given wage increase and a given level of output.

2. The demand for labour is more elastic, the higher the elasticity of demand for output. The greater the responsiveness of output to a change in prices, the greater will be the change in output and hence, employment.

3. The elasticity of demand for labour is lower, the more inelastic is the supply of capital. An increase in wages will encourage substitution towards capital, thereby increasing the demand for capital. If the supply elasticity of capital is less than fully elastic, this will increase the price of capital, offsetting the initial increase in the relative wage and hence reducing the initial substitution effect.

4. The demand for labour is more elastic, the higher is labour's share in total costs. If labour is a relatively important factor in production, any increase in wages will have a significant impact on costs and output. However, Marshall overlooked the fact that while a high labour share increases the output effect, a high labour share reduces the substitution effect, as can be seen from equation (2.16). In fact the relationship

between the demand for labour and labour share depends on the relationship between the elasticity of demand for output and the elasticity of substitution. If $\eta > \sigma$ then Marshall's rule still applies.

Using conditional factor demands, it is only possible to estimate the substitution effect, or constant-output elasticity. This is a very powerful scalar measure which is fundamental to understanding the underlying technological processes that determine the demand for labour. Firstly, it sumarises the underlying production technology of the firm, which determines the proportions of factors used to produce a unit of output, and the technical rate of substitution between factors. Secondly it measures the likely impact of changes in relative factor prices on total costs, given these proportions and the technical rate of substitution.

2.2 Encompassing the VAR: Econometric Modelling of Long-Run Behaviour

2.2.1 General to Specific Modelling and Cointegration Analysis

In the field of applied econometrics one of the most important developments in recent years has been the advent of what is loosely termed the 'LSE methodology'. This methodology involves the use of a *general-to-specific modelling strategy* in applied econometric work. This means that, for whatever given *specific* theoretical economic relationship(s) we are interested in modelling, here the long run demand for labour, we start with a *general* statistical specification of the variables of interest. We then test the reductions of this general specification which are implied by the specific economic theory of interest using a variety of statistical tools. In this way we are able to discriminate between and compare rival theoretical models within a common embedding reference framework. At each stage of the modelling process the transparency in the choices made by the researcher allows for meaningful evaluation and interpretation of the empirical results. It also means that the empirical results and findings can be replicated.

An appealing feature of the LSE methodology is that it covets all sources and types of information.

> "The essence of this approach is the recognition that potentially valuable information for the analysis of any economic problem can come from numerous sources including, economic theory, the available sample of observations on the potentially relevant variables, knowledge of the economic history of the period under

study, and from knowledge of the way in which the observed data are defined and measured, plus their relationship to the theory variables." (Mizon, 1995, p.1)

This is good news for applied economists who are keen to use all available information but unsure how to proceed. The progressive modelling strategy provides a methodological structure within which the relative informational import of data, theory and stylised facts can be assessed. In this way we can also test our private hunches.

Alongside these methodological developments a second, though related, major development in applied econometrics theory and practice has been *cointegration analysis.* This analysis began as a 'spurious regressions' problem. The problem occurs because many measured economic variables are observed to be non-stationary in their levels[4]. Classical statistical inference techniques are invalid in the presence of non-stationary variables and their application can lead to the estimation of nonsense regressions. This 'problem' of non-stationarity can be removed by appropriate differencing of the data until the differenced series is stationary. However models based on differenced data series tell us nothing of the relationship between the actual *levels* of the variables and this in general is precisely what is of interest to us. Thus differencing involves the loss of potentially valuable information.

The development of cointegration analysis reconciled these two seemingly conflicting objectives, namely the continued use of standard inference techniques and the modelling of the *levels* of non-stationary data. The notion of *cointegration* is that there can sometimes exist relationships between non-stationary variables such that the deviations from these relations are stationary. If such cointegrating relations exist, then they retain the levels information of the non-stationary variables but they themselves behave as stationary variables. Therefore in modelling these cointegrating relations we can make use of standard statistical inference techniques.

The concept of cointegration has proved to have far-reaching implications in applied econometric work even beyond the well-behaved statistical properties of the cointegrating relations. This is because if we do in fact uncover a set of one or more cointegrating relations between a set of non-stationary economic variables then these cointegrating relations estimate directly the *long-run parameters*[5] of one or more statistical relationships between the variables. These estimated cointegrating relations constitute the 'general' statistical model:

[4]A variable is said to be stationary if its distribution function is independent of t. A variable is (second-order) **non-stationary** if its second moment varies with t, so that it has a non-finite variance.

[5]The notion of the long-run applied here is defined in Hendry, 1995 as

"The static or long-run solution of a dynamic stochastic process denotes a hypothetical deterministic situation in which all change has ceased" (Hendry, 1995, p212) various 'specific' reductions of these based on economic theory can then be tested for using standard statistical testing techniques.

We adopt the 'encompassing the VAR' methodological framework of Hendry and Mizon (1993). By encompassing the VAR is meant moving from the unrestricted VAR system, which is a *general reduced form representation* of the variables, to a reduction of the system which is a *specific structural representation* of the variables. If the parsimonious reduction is not rejected then it encompasses the VAR.

2.2.2 The General Statistical Model: A Closed Linear System

As a starting point the estimated VAR model must be given a specified statistical framework. It is assumed that the joint density of the variables is approximated by the normal distribution. In the VAR model the only *a priori* restrictions imposed are the number of lags in the VAR and linearity of the system. Linearity is rendered less restrictive by appropriate transformations of the variables (e.g. taking logarithms) included in the system. The choice of lag length is a trade-off between limitations dictated by the data set length and the need for parsimony, on the one hand, and the necessity for a sufficiently rich dynamic structure to merit the claim to a 'general' system on the other.

Following Hendry and Mizon (1993) we specify a VAR process for the vector of variables of interest, x_t, as follows:

$$A(L)x_t = \varphi D_t + v_t \qquad v_t \quad \sim \quad I_n(0,\Omega) \tag{2.17}$$

$$A(L) = \sum_{i=0}^{p} A_j L^j = I_n + A^*(L)L, \quad A_0 = I_n$$

The lag polynomial $A(L)$ contains all the parameters on the lagged stochastic variables where n is the number of variables in x_t and p is the lag order of the autoregression, assumed finite to exclude a moving average process in the errors.[6] Equation (2.17) specifies a model of the conditional means and variances of the stochastic variables in x_t,

$$x_t \mid \sigma(X_{t-1}^1) \quad \sim \quad N(-A^*(L)x_{t-1} + \varphi D_t, \Omega), t = 1, 2, ..., T$$

where $\sigma(.)$ is the sigma field generated by $X_{t-1}^1 = \{x_1, x_2, ...x_{t-1}\}$[7] and D_t is a $d \times 1$ vector of deterministic variables (constant, centred seasonals, event-specific dummy variables, etc) and we are conditioning on past information from $t-1$ back to 1.

[6]In a general-to-specific approach it is typical to exclude moving average errors. This is because in estimating an autoregressive moving average process, parsimony is important to avoid the problem of redundant common factors and so estimation of such models takes a specific-to-general approach.

[7]A σ-field is a set of subsets of the sample space which is closed under complementation and countable

The parameters $\{A_j\}$ of the VAR and the system error variance Ω are unrestricted. We assume that the initial values of x are fixed, the process is linear, independent, normal, homoscedastic, well-specified and serially uncorrelated. A fundamental assumption is that the parameters $\{A_1, ...A_p, \varphi, \Omega\}$ are constant $\forall t$.

All of these assumptions can be tested, if they are accepted then the estimated VAR is said to be *congruent* with the data. Once such a general system has been found, testing for hypothesised behavioural patterns can proceed. This search for a specific model is always with reference to the congruent general system.

The encompassing the VAR methodology is especially suited to estimating hypothesised long-run relationships because of the recent developments in the literature on integrated variables and cointegration.[8] The fact that most economic time series are not stationary (integrated series) but that linear combinations of them may be stationary (cointegration) has been exploited using the 'encompassing the VAR' framework to test for the presence of long-run relationships between the set of economic variables included in a VAR system. These cointegrating relationships, which capture the statistical relations present between the observed set of data series, form an *a priori* unrestricted system within which to test for various competing or complementary theoretical models and/or commonly accepted stylised facts.

Johansen(1988) reparamaterises the above VAR model in levels and first differences as follows:

$$\Delta x_t = \Pi x_{t-1} + \sum_{i=1}^{p-1} \Pi_i \Delta x_{t-i} + \varphi D_t + v_t \tag{2.18}$$

The reparameterised Π matrices relate to the $A(L)$ parameters as follows,

$$\Pi_j = \Sigma_{i=j+1}^{p} A_i$$
$$\Pi = -(I_n + \Sigma_{j=1}^{p} A_j) = -A(1)$$

Because equation (2.18) is expressed in first differences it is more orthogonal than equation (2.17); there is a reduction in the correlation between the right hand side variables. It gives

unions and intersections (see Spanos 1986 Ch.3). If we denote F as the 'event space' i.e. the set of all subsets of the sample space, then $F_{t-1} = \sigma(X_{t-1}^1)$ is the smallest event space generated by X_{t-1}^1. It is clear that the σ-field grows with t. This formulation is useful as it gives a special mathematical structure to the information set.

[8] A variable is said to be integrated of order d, $I(d)$, if it is stationary after d differences. Given $\epsilon_t \sim (0, \sigma_\epsilon^2)$ as a white-noise process, if we define $x_t = \epsilon_t$ as an $I(0)$ stochastic variable, this means that it is stationary (integrated of order zero) with $x_t \sim (0, \sigma_\epsilon^2)$. Define the $I(1)$ variable y_t such that $x_t = \Delta y_t$. Then $y_t = y_{t-1} + \epsilon_t \sim (0, \sigma_\epsilon^2 t)$ is a process with one unit root. By analogy an $I(2)$ variable has two unit roots, and an $I(d)$ variable has d unit roots.

Π as the matrix of parameters on the *levels* of the x vector of variables. Π here is the **long-run impact matrix**, i.e. it is the summation of the individual parameters on the lagged variables in equation (2.17). It therefore measures the cumulative impact of each variable in each equation.

An important feature of this parameterisation is that although v_t is $I(0)$, the n x_{t-1} variables need not all be $I(0)$. Under the assumption that the x_t variables are either $I(0)$ or $I(1)$ then all the first difference variables Δx_t are $I(0)$, as is the error term by construction. So the LHS of equation (2.18) is $I(0)$ and all the terms on the RHS other than Πx_{t-1} are $I(0)$. Then the term Πx_{t-1} must also be $I(0)$ for balance of the system.

Interpreting the Πx_{t-1} term: The Cointegrating Relations

We have seen that when the x variables are $I(1)$, Πx_{t-1} in equation (2.18) is $I(0)$. This means that Π cannot have full rank (otherwise these statements contradict each other). The rank r of Π, where $0 < r < n$, determines the number of independent linear $I(0)$ combinations of the x variables in the system. This is also the number of cointegrating relations.[9]

The reduced rank matrix Π has an interesting interpretation as an 'equilibrium correction' term. If we decompose $\Pi = -\alpha\beta'$, where α and β are two $n \times r$ matrices of rank r, we can rewrite equation (2.18) as the $I(0)$ **vector equilibrium correction model (VECM)**

$$\Delta x_t = \sum_{i=1}^{p-1} \Pi_i \Delta x_{t-i} - \alpha(\beta' x_{t-1}) + \varphi D_t + v_t \tag{2.19}$$

The $\beta' x_{t-1}$ form the r cointegrating $I(0)$ relations and α is the matrix of the weights or "factor loadings" with which each of these cointegrating relations enters into each of the n equations. These α are the short-run adjustment coefficients, which measure the rate at which Δx_t 'corrects' towards the long-run solutions captured by $\beta' x_{t-1}$.

<u>Limiting Cases:</u>

1. If $r = n$, then Π is of full rank. Since Πx_t is $I(0)$ then this means that in this case the x vector will contain only $I(0)$ variables.

2. If $r = 0$, then $\Pi = 0$ and the Πx_{t-1} term drops out of equation (2.18). The VAR is expressed in first differences only and there is no cointegration between the x's. In general formulating a VAR in first differences excludes important levels information captured by the Πx_{t-1} term.

[9] The $n - r$ linearly dependent combinations of the x's are nonstationary $I(1)$ so these are modelled in first differences to map them into $I(0)$ space.

2.2.3 Estimation of the General System

We estimate equation (2.18) using multivariate least squares techniques. Firstly it has to be tested for congruence with the data. This means testing whether the assumptions of linearity, homogeneity, normality and functional form specification are accepted by the data set being modelled. Applying these diagnostic tests implies that the VAR has errors which are approximately normal. At this design stage the issues of parameter constancy, structural breaks in the system and relevant deterministic variables for inclusion have to be addressed. Only once the system has been found to be data-congruent can tests for cointegration be implemented.

The Johansen Maximum Likelihood Estimator

The Johansen(1988) estimation procedure in this framework focuses on estimating the rank of Π using maximum likelihood techniques. The difficulty is that Π is of reduced rank and therefore cannot be estimated directly. So maximisation of the likelihood function leads to a reduced rank regression via a two-step procedure:

1. The log-likelihood function is concentrated in terms of the Π parameters alone by partialling out the effects of all other variables in the system:

   (a) Regress Δx_t on $(\Delta x_{,t-1}, ...\Delta x_{t-p+1})$, D_t. Define the residuals as R_{0t}.

   (b) Regress x_{t-1} on $(\Delta x_{t-1}, ...\Delta x_{t-p+1})$, D_t. Define the residuals as R_{1t}.

2. The concentrated log-likelihood function is maximised with respect to the $n \times r$ α parameters only, treating $\beta' x_{t-1}$ as a variable. This is equivalent to the reduced rank regression

$$R_{0t} = \alpha\beta' R_{1t} + \hat{\varepsilon}_t \tag{2.20}$$

   Solving for the β parameters then reduces to solving the eigenvalue problem :

$$|\lambda S_{11} - S_{10} S_{00}^{-1} S_{01}| = 0 \tag{2.21}$$

   where $S_{ij} = T^{-1} \sum R_{it} R_{jt}$ are the second-moment matrices of the residuals[10], $\hat{\beta}$ is the matrix of solved eigenvectors V normed by $V' S_{11} V = I$[11] and the associated ordered eigenvalues are $1 \succeq \lambda_1 \succeq \lambda_2 \succeq ... \succeq \lambda_n \succeq 0$.

[10] When Π is unrestricted, maximisation yields $\hat{\Pi} = S_{01} S_{11}^{-1}$.

[11] This normalisation is possible because the α and β matrices are not unique.

Testing for the rank of Π.

When Π is unrestricted, all the n eigenvalues are retained and the concentrated log-likelihood function depends on $-\frac{T}{2}\sum_{i=1}^{n}\ln(1-\lambda_i)$, whereas when Π has rank r, the log-likelihood is the same function summed over the r largest $\{\lambda_i\}$ (see Hendry and Mizon, 1993, p.287). Johansen (1988) proposes two alternative tests:

1. **The trace statistic:** Under the null of r cointegrating vectors, a sequential log-likelihood test procedure is implemented using twice the difference between the unrestricted and the restricted log-likelihood function.

$$\eta(r) = -T\sum_{i=r+1}^{n}\ln(1-\lambda_i) \text{ for } r = 0, 1, ..., n-1$$

The Max statistic: This test is based on the idea that a small value of λ_i is less likely to reject the hypothesis that there is a unit root in the characteristic equation of $A(L)$. This can be understood as testing for the number of eigenvalues which are significantly different from zero.

$$\xi(r) = -T\ln(1-\lambda_{r+1})$$

The distributions of these test statistics are non-standard, and vary depending on whether a constant and a trend term are included or not. Critical values have been tabulated by Osterwald-Lenum(1992).

There is no single best method for estimating the number of cointegrating vectors. A Monte-Carlo study on small sample data by Kostial(1994) has indicated that if the signal-noise ratio in the system is low then the trace and max tests underestimate the number of cointegrating vectors. Johansen and Juselius(1994) stressed the importance of prior hypotheses as an arbiter of the final choice of r. As discussed below, our prior hypothesis is for $r \leq 2$. The issue of constancy is also crucial. It is conceivable that the rank of the Π matrix may change over time. Recursive estimation of the eigenvalues and associated trace and max statistics can help to investigate this possibility (see Hansen and Johansen, 1992).

2.2.4 Identifying Restrictions and a Structure for the System

In the methodological framework described in Hendry (1995) a model is said to be identified if it is unique, corresponds to the desired entity and satisfies the assumed interpretation (usually of a theory model). So far the estimated VAR system is an unrestricted reduced form for one or more conditional models and is not identified. We now need to identify a *structure* for the long-run and short-run relations in the system. Structure is defined as "the set of basic, permanent features of the economic mechanism" (Hendry, 1995 p.33). A parameter embodies structure if

1. it is invariant to an extension of the sample period, to regime shifts and to extensions of the information set, and

2. it directly characterises the economic relations under analysis.

Our 'formally identified'[12] estimate of model (2.19) is not invariant. We can see this quite easily by noting that the α and β matrices are not unique. Any linear transformation of β' by a nonsingular $r \times r$ matrix θ will leave Π unchanged:

$$\theta\beta' = \beta^*, \Rightarrow \quad -\alpha\theta^{-1}\theta\beta' = \Pi \quad \text{where } \theta^{-1}\theta = I_r$$

Thus in equation (2.18) we have determined the *dimension* of the cointegration space rather than the actual cointegrating vectors.

A **structural econometric model (SEM)** is a restricted version of the congruent system in equation (2.18):

$$\Gamma_0 \Delta x_t = -\Gamma\beta' x_{t-1} - \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \zeta D_t + u_t \tag{2.22}$$

where $\zeta = \Gamma_D \varphi$. Define $\Phi = (\Gamma, \Gamma_0, \Gamma_1, ..., \Gamma_{p-1})$ (where Φ is $m \times n^*$ with $n^* = np + r$ and $m \leq n$) as a matrix of structural parameters which are restricted. An important feature of this SEM is that the $\beta' x_{t-1}$ cointegrating relations are unchanged by this linear transformation, so we can quite easily separate the identification of the β long-run parameters from identification of the short-run parameters in Φ. This is what we do in the estimation reported in Chapter 3. Because our statistical model is in $I(0)$ space and is statistically well-specified, standard asymptotically χ^2 likelihood ratio tests can be used to test for the non-rejection of the restrictions of the general VAR system which are implied by the structural model.

Identifying the Long-Run Structure: Restrictions on β

The r cointegrating vectors β are not unique. We can test alternative hypotheses about these cointegrating relations, using formulations suggested by economic theory or stylised

[12]Formally identified in the sense of Johansen and Juselius (1994). They define three stages for identification of a model; formal identification = the statistical model, empirical identification = the estimated parameter values, economic identification = economic interpretability of the estimated coefficients.

facts. Identification of the long-run structure can be done in the VECM, as $\beta' x_{t-1}$ is the same in equation (2.19) and equation (2.22). We test for restrictions on β as follows:

$$\beta = (H_1\xi_1, ..., H_r\xi_r)$$

where the $n \times v$ $H_1, ..., H_r$ matrices express the economic hypotheses to be tested against the data. Define R_i as the corresponding $n \times (n - v)$ matrix of restrictions on β_i such that $R_i'\beta_i = 0$ and $H_i = R_{i\perp}$. Then for the restricted β vectors to be identified they need to satisfy the following **rank condition** (see Johansen and Juselius, 1994)

$$\text{rank}(R_1'\beta_1 ... R_r'\beta_r) = \text{rank}(R_1'H_{1\xi 1} ... R_r'H_{r\xi r}) = r - 1 \tag{2.23}$$

The set of restrictions is *formally identifying* if, for all i and $k = 1, ..., r - 1$ and any set of indices $1 \leq i_1 < ... < i_k \leq r$ not containing i, it holds that

$$\text{rank}(R_i'H_{i_1}, ..., R_i'H_{i_k}) \geq k$$

This basically means that the restrictions R_i on vector i must not annihilate the economic hypotheses about the other $r - 1$ vectors so that all the restricted vectors remain linearly independent. If $\text{rank}(R_i) = r - 1$ $(\forall i)$ then β_i (β) is *exactly identified.* If $\text{rank}(R_i) > r - 1$ then β_i is *overidentified.*

Once an identified β matrix is determined it is unique. Johansen (1995) defines the estimator of the **asymptotic conditional variance** of the identified β as

$$T\{H^i\}\{\hat{\rho}_{ij}H^{i'}S_{11}H^j\}^{-1}\{H^{j'}\}, \quad \hat{\rho}_{ij} = \hat{\alpha}_i\hat{\Omega}^{-1}\hat{\alpha}_j$$

where $\beta_i = H_{i\xi i}$ is normalised as $\beta_i = h_i + H^i\psi_i$, and $\{G_i\}$ denotes the block diagonal matrix with blocks G_i. Using this variance matrix, asymptotic inference can be conducted as if the estimators were Gaussian.

Identifying the Short-run Structure: Restrictions on Φ

For unique identification of the SEM there must be $n(n - 1)$ restrictions on the short-run structural parameters in Φ. Define

$$f_t' = (\Delta x_t', (\beta' x_{t-1})', \Delta x_{t-1}', .., \Delta x_{t-p+1}')$$

so that

$$\Phi f_t = \zeta D_t + u_t$$

is the same as equation (2.22) with changed notation. Johansen and Juselius(1994) formulate the identifying restrictions on Φ using

$$\Phi = (H_{1\xi 1}, ..., H_{p\xi p})$$

and the same rank conditions as in (2.23) apply. Typically restrictions on Φ will involve specifying some variables as exogenous and it is useful to test for these restrictions first.

Testing for Weak Exogeneity within the VAR framework

If a variable x_2 is weakly exogenous for the parameters of interest μ in modelling x_t then this means that there is no loss of information about μ by not modelling the process determining x_2. Factor the joint sequential density for the x_t variables into the conditional distribution for the endogenous variables, x_1, $(v \times T), v \leq n$, and the marginal distribution for the exogenous variables, x_2 $((n-v) \times T)$ where Υ contains all the parameters in the joint model of x_t, Υ_1 and Υ_2 are the parameters of the conditional and the marginal distribution respectively, and the parameters of interest μ are all contained within Υ_1:

$$\text{Joint: } D_x(\Delta x_t|\alpha\beta' x_{t-1}, \Delta x_{t-1}, ..., \Delta x_{t-p}, \Upsilon) = \tag{2.24}$$

$$\text{Conditional: } D_{x_1|x_2}(\Delta x_{1t}|\Delta x_{2t}, \alpha\beta' x_{t-1}, \Delta x_{t-1}, ..., \Delta x_{t-p+1}, \Upsilon_1). \tag{2.25}$$

$$\text{Marginal: } D_{x_2}(\Delta x_{2t}|\alpha\beta' x_{t-1}, \Delta x_{t-1}, ..., \Delta x_{t-p+1}, \Upsilon_2) \tag{2.26}$$

Weak exogeneity of the x_2 variables with respect to the parameters of interest μ means that it is valid to model x_{1t} using its conditional distribution (2.25) alone. Such a requirement is violated if both Υ_1 and Υ_2 depend on the same $\{\beta_i\}$ and this forms the basis for the test of weak exogeneity. Decompose the matrix α into $\begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}$, then define

$$\alpha\beta' x_t = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} \beta_{11}' & \beta_{12}' \\ \beta_{21}' & \beta_{22}' \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} \beta_{11}' x_{1t} + \beta_{12}' x_{2t} \\ \beta_{21}' x_{1t} + \beta_{22}' x_{2t} \end{bmatrix}$$

Conditioning Δx_1 on Δx_{2t} as in (2.25) creates the ECM $\{\alpha_{12} - \sum_{12} \sum_{22}^{-1} \alpha_{22}\}\{\beta_{21}' x_{1t} + \beta_{22}' x_{2t}\}$. Then necessary conditions for weak exogeneity of Δx_{2t} with respect to the parameters of interest β_{11} and β_{12} (the first v long-run cointegrating relations) are

1. $\alpha_{21} = 0$. This ensures that β_{11} and β_{12} do not enter in the Δx_{2t} equation.

2. $\{\alpha_{12} - \sum_{12} \sum_{12}^{-1} \alpha_{22}\} = 0$. This ensures that β_{21} and β_{22} do not enter in the Δx_{1t} equation.

In estimation Johansen (1995, p.122) shows that if $\alpha_2 = 0$ then x_{2t} is weakly exogenous for the parameters (β, α_1) and it is valid to estimate these from the conditional model (2.25). Where cross-equation restrictions are imposed which link the conditional and marginal models, weak exogeneity is likely to be violated.

The α parameters provide information about the adjustment processes of the system and can help in identifying p, the lag length[13]. As we have seen, exogeneity is not crucial to the determination of unique β vectors. However tests for weak exogeneity can be used in the identification of a unique cointegrating vector because if only one cointegrating vector enters into a given equation then this exogeneity restriction, together with normalisation, uniquely identifies that vector.

Conditioning and the Structural Econometric Model (SEM)

The VAR system is a statistical model for the data which is an unrestricted reduced form (UVAR) for one or more structural econometric models. To move to a more parsimonious model (PVAR) we reestimate equation (2.19) using the restricted cointegrating vectors $\hat{\beta}'x_t$ estimated in the first stage as regressors along with the Δx_t variables. If some variables have been found to be weakly exogenous, then we can condition on these variables in formulating the SEM. At this point it is statistically valid to apply standard conditional inference techniques in testing alternative restrictions on the parameterisation of the model. These SEMs must be estimated using maximum likelihood techniques. The PVAR forms a framework within which it is possible to test alternative hypotheses, by estimating different "specific" SEMs as reductions of the "general" PVAR. If an SEM is not rejected by tests for congruence and model reduction (typically a likelihood ratio test of over-identifying restrictions) then it is said to encompass the VAR.

2.3 The Empirical Model

2.3.1 The Unrestricted VAR

The general long run demand for labour equation, defined in (2.14), includes five variables, namely, the labour share, the cost of labour, the cost of capital, "real" value added and a time trend:

$$S_l = \alpha_l + \gamma_{ll} \ln(P_l) + \gamma_{lk} \ln(P_k) + \gamma_{lq} \ln(Q) + \gamma_{lt} t \qquad (2.27)$$

[13]They have been used in modelling labour demand. Engsted and Haldrup (1994) use these estimated adjustment coefficients to test for a model of linear quadratic adjustment costs under rational expectations using sectoral Danish manufacturing data.

1. *Log Specification:* All of the behavioural variables are expressed in logs except the labour share variable. There are two alternative approaches to modelling the labour share variable. The first is to include it directly in the unrestricted VAR specification. The second is to include the log of its component variables, labour, cost of labour and value added, separately, since
$$S_l = \frac{L.P_l}{Y}, \Rightarrow \ln S_l = \ln L + \ln P_l - \ln Y$$
In this case all behavioural variables included in the VAR are defined in logs, and the labour share, S_l, can be approximated in logarithmic form using the expansion
$$ln(\epsilon + x) \approx ln\epsilon + \epsilon^{-1}x, \text{ for } x \approx 0$$
so that, defining $S_l = \epsilon + x$, where $\epsilon = \bar{S}_l$ and $x = S_l - \bar{S}_l$, gives
$$S_l \approx \underbrace{(lnL + lnP_l - lnY)}_{\ln S_l} \bar{S}_l - ln(\bar{S}_l)\bar{S}_l + \bar{S}_l$$
We adopt this approach because including the labour share variable directly in the UVAR is equivalent to imposing an *a priori* cointegrating relation between labour, the cost of labour and value added, which may not be valid. Furthermore, it has the added advantage that all variables included in the system are expressed in logs. This facilitates testing other labour demand specifications, including the Cobb-Douglas technology. Andrews (1988), in a general specification of " the kind of labour demand equations typically estimated", includes all variables in logs.

2. *Value Added in Real Terms:* There are definitional problems with the Q variable. Within a value-added framework, this variable should measure "real" value added. However there are no data on value-added deflators so we use real gross output as a proxy. This complicates interpretation of the coefficient γ_{lq}; while it may be capturing non-homotheticity it could also be signalling a rejection of weak separability of value added from gross output.

3. *I(1) or I(0):* The methodology in the previous section assumed that the variables included in the VAR, the x's, are either I(1) or I(0). This may not always be a reasonable assumption, especially in relation to price terms, and log price terms, which are sometimes found to be I(2) in empirical work. In the presence of I(2) variables the statistical analysis of equation (2.18) becomes far more complicated. If we define $\alpha_\perp$ and $\beta_\perp$ as matrices orthogonal to α and β, and $\Psi = \frac{\delta A(z)}{\delta z}|_{z=1}$ as the mean lag matrix, then if $\alpha_\perp \Psi \beta_\perp$ has rank $n - r$ the process in equation (2.17) has no I(2) components (Johansen, 1995, Ch.4). This can be tested for.

4. *Dummy Variables.* Centred seasonal dummies and a trend term are included in the initial UVAR. In addition, we include, where appropriate, dummy variables to capture regime shifts or policy changes not captured by the small number of variables included in the model. Clements and Mizon (1991) argue that one of the main reasons for including regime shift and event specific dummy variables is to capture the effects of deterministic non-stationarities in the data. Impulse dummies change the intercept of an I(1) model and shift dummies change the linear trend of the model.

5. *Hours Worked as Source of Extra Information:* We use numbers employed rather than hours worked as the labour variable since any long run changes in the demand for labour will be reflected in changes in numbers employed and because the data on hours worked and hourly wages is more limited than the data on employment and wages[14]. Average hours worked is a procyclical variable measuring short run adjustments in labour demand: in a recession firms may hoard labour by reducing average hours worked while in an expansion firms may increase average hours for the same stock of employees. However, sudden changes in hours worked can impact on the demand for numbers employed. In designing the initial specification of the UVAR, and in particular in identifying dummy variables, we use hours worked as a source of extra information.

6. *Reparameterisations.* The two variables $\{p_l, p_k\}$ are reparameterised as $\{p_l, p_k - p_l\}$. This facilitates interpretation of the estimated coefficient γ_{lk} on relative prices.

The full set of behavioural variables included in the initial UVAR are $\{l, p_l, q, y, p_k - p_l\}$, defined as l log employment, q log volume output, y log value-added, p_k log cost of capital, p_l log cost of labour. Lower case letters denote logarithms.

2.3.2 Steps in Estimating the Model

There are a number of logical steps involved in estimation of the UVAR. Prior to testing hypotheses suggested by economic theory, the UVAR must first be tested for congruency. Once a congruent system has been found, then the dimensions of the cointegrating space are determined.

The Data

In Chapter 3 estimation of the UVAR uses quarterly data covering the period 1973Q1 to 1997Q2. Section 3.9 contains more detail on these data, which are defined as follows:

[14]Data on hours worked and hourly wages are based on survey rather than census data and have a more limited time span than the data on employment and wages, see Part IV for details.

1. **Employment L**

   This variable measures the numbers employed (excluding outside piece workers) in each sector in the middle week of the last month of each quarter.

2. **Cost of Labour P_l**

   This variable measures the annual wage bill per worker including non-wage labour costs.

3. **Value Added YV**

   The variable YV measures annual net output at quarterly intervals. This is a close proxy for value added, although it will generally be a little higher. See Section 3.9 for details.

4. **Labour Share of Value Added S_l**

$$S_l = \frac{L \cdot P_l}{YV}$$

5. **Volume Production Q**

   The variable Q measures annual gross output at constant 1985 prices at quarterly intervals.

6. **Cost of Capital P_k**

   We define the *pre-tax cost of capital* as

$$P_{Kt} = p_{It} \frac{(1 - g_t)}{(1 - \tau_t)} (i_t - \gamma_t + \delta) \qquad (2.28)$$

   where p_I is the price of investment goods, γ is the rate of change of investment goods prices, δ is the rate of economic depreciation, i is the nominal rate of interest, g is an average measure of the present value of tax allowances and investment grants and τ is the rate of corporation tax.

The Search for a Congruent System

1. *Diagnostic Tests.* These test for autocorrelation, heteroscedasticity and normality of the residuals. The test statistics used are (see Doornik and Hendry (1997) for details):

$AR(5,.)$ which is a Lagrange multiplier test statistic for fifth order serial correlation in the residuals. Under the null of no serial correlation it has a $\chi^2(5)$ distribution presented here in an $F(5,.)$ form.

$ARCH(4,.)$ This is an LM statistic for testing fourth order autocorrelated squared residuals, under the null it has a $\chi^2(4)$ distribution presented here as an $F(4,.)$ statistic.

$N(2)$ tests the null of normal skewness and kurtosis, this has a $\chi^2(2)$ distribution under the null of normal residuals.

$H(,)$ tests the null hypothesis of unconditional heteroscedasticity and has an approximate $F(,.)$ null distribution.

vec tests are the corresponding tests on the vector residuals.

2. *Chow Tests.* Chow tests for structural breaks are shown in graphical form. The "Chow Test" graphs show tests of parameter constancy in the estimated model. These tests are constructed as follows. The model is estimated over an "initialisation period" $t = 1 \rightarrow M - 1$ where the full sample runs from $t = 1 \dots T$. The model is then recursively updated in each year for $t = M \dots T$. The one-step forecast test (1-STEP) tests for parameter change in year t against the model estimated over $t = 1 \dots t-1$. The forecast F-Tests (FORECAST) test for parameter change against the model estimated over the initialisation period $t = 1 \dots M-1$ (the number of forecasts goes up in sequence from N= M to T). The break-point F-tests (BREAKPOINT) test for parameter change against the model estimated over the full period $t = 1 \dots T$ (the number of forecasts goes down in sequence from N=T-(M-1) to 1).

3. *Parsimony.* In all cases we begin with a lag length of 5 and test for valid reductions of this. The data set we use runs over a period of 25 years from 1973 to 1997. The degrees of freedom in the VAR system are $Tn - (pn^2 + dn + n(n+1)/2)$ so that it is easy to lose degrees of freedom very quickly. Increasing the lag length by one reduces the degrees of freedom by n^2, increasing the number of deterministic variables by one reduces the degrees of freedom by n, increasing the number of variables by one changes the degrees of freedom by $T - ((d-p) + (2p+1)(n+1))$ which is a decreasing function of n.

The Cointegration Space

1. *Which variables to restrict to the cointegrating space?* In initial testing, the trend term is included in the cointegrating space, as a proxy for slowly changing technical progress (see equation (2.27) above). The constant is not restricted to lie within the

cointegrating space. An intercept term in $I(1)$ space is a linear trend, to restrict this to lie within the $I(0)$ cointegrating space is equivalent to restricting all variables to manifest no growth.

2. *What do the "unrestricted" relations tell us?* Prior to hypotheses testing, examination of the reduced form unrestricted relations can be used to get an initial picture of the unrestricted coefficient estimates.

2.3.3 Economic Analysis of the Cointegration Space

To allow for meaningful interpretation of the relations between the data, we test for structure on the cointegration space. This can be done in two stages, testing restrictions on the long run parameters first:

> "Instead of estimating the restricted short-run and long-run parameters simultaneously it seems reasonable, in view of the super-consistency of the estimated long-run parameters, to estimate first the restricted long-run parameters from the reduced form error-correction model with no restrictions on the short-run parameters" (Johansen (1995) p.112).

A model of the labour market will generally include at least two equations, modelling demand and supply simultaneously[15]. Labour supply equations are typically normalised on the price of labour, and are therefore referred to as the wage equation (see Andrews (1988)).

The VAR specification we use facilitates estimation of such a system of simultaneous equations. All variables are endogenous within the empirical model and, as described in the previous section, more than one cointegrating relation can exist between the variables of interest. Among the five variables included in the VAR, our prior hypothesis based on theoretical considerations and previous experience was for a maximum of two cointegrating relations; a labour demand equation and a wage equation. Identification of a third or fourth equation among such a small number of variables would have proved difficult to interpret on theoretical grounds.

Empirical tests, reported in the next chapter, failed to reject this hypothesis of two cointegrating vectors. Define the coefficients for the first two reduced form cointegrating vectors as:

$$\begin{pmatrix} & l & p_l & q & y & p_k - p_l & t \\ \beta_1: & \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} \\ \beta_2: & \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} \end{pmatrix}$$

[15] Models of the labour market will sometimes also include a third structural equation or identity, determining unemployment (Andrews (1988)).

This VAR model is ordered so that the dependent variable in the first equation is labour (l) and in the second equation is labour costs (p_l). We can then specify the first and second cointegrating vectors as a demand for labour equation and a wage equation respectively.

The First Cointegrating Vector β_1: A Labour Demand Equation

Because the data are all expressed in logs, some manipulation of the β coefficients is necessary to arrive at the translog specification. The underlying behavioural parameters of equation (2.27) can be recovered from the first estimated cointegrating vector as follows:

$$\beta_1 \text{ is } \{\beta_{11} \cdot l + \beta_{12} \cdot p_l + \beta_{13} \cdot q + \beta_{14} \cdot y + \beta_{15} \cdot (p_k - p_l) + \beta_{16} \cdot t\}$$

so that

$$S_l = \left(\{-\beta_{13} \cdot q - \beta_{15} \cdot (p_k - p_l) - \beta_{16} \cdot t\} \cdot \bar{S}_l\right)$$

where $\{\cdots\} = \ln S_l$ given $\beta_{11} = 1; \beta_{12} = 1; \beta_{14} = -1$, and

$$\begin{aligned} \gamma_{lk} &= -\overline{S_l} \cdot \beta_{15} \\ \gamma_{lq} &= -\overline{S_l} \cdot \beta_{13} \\ \gamma_{lt} &= -\overline{S_l} \cdot \beta_{16} \end{aligned}$$

Hypotheses tests on the first cointegrating vector include:

1. $\beta_{11} = 1; \beta_{12} = 1; \beta_{14} = -1$: Translog Technology and Price Homogeneity. This specifies the labour share as a function of relative factor prices.

2. $\beta_{16} = 0$: Hicks-neutral Technical Progress.

3. $\beta_{13} = 0$: Homotheticity.

4. $\beta_{15} = 0$: Cobb-Douglas Technology.

These are tested separately and jointly. Each of these restrictions is tested as a χ^2 Likelihood Ratio test.

The Second Cointegrating Vector β_2: A Reduced Form Wage Equation

The second cointegrating vector is specified as a reduced form wage equation by normalising on p_l. Firstly we omit the relative price term $p_k - p_l$ from the equation, this is sufficient to identify the second cointegrating vector. This identification specifies the wage as a function of output, labour, value added and time, $p_l = f(q, l, y, t)$. From there we test two alternative specifications for a simple wage equation. The first specifies wages as a function of average labour productivity, the second specifies wages as a function of total factor productivity (proxied as the value-added intensity of output).

1. $\beta_{21} = 1; \beta_{23} = -1 :\Rightarrow p_l = f(q - l, y, t)$ This specifies the wage as a function of productivity, value added and time.

2. $\beta_{21} = 0; \beta_{23} = -\beta_{24} :\Rightarrow p_l = f(y - q, t)$ Given $q = qv/p_q$, this gives $p_l = f(y - qv, p_q)$. This specifies the wage as a function of the value added intensity of output, output prices and time.

The small number of variables included in the VAR means that estimation of a full structural wage equation, which would include variables such as the tax wedge, the unemployment rate, etc., is not possible. However, the estimated wage equation can throw some light on the functioning of the labour market - an outcome of the progressive modelling strategy.

Tests of Weak Exogeneity in the Cointegrating Space

Define the α adjustment coefficients for the first two cointegrating vectors as

$$\begin{pmatrix} l & \alpha_{11} & \alpha_{12} \\ p_l & \alpha_{21} & \alpha_{22} \\ q & \alpha_{31} & \alpha_{32} \\ y & \alpha_{41} & \alpha_{42} \\ p_k - p_l & \alpha_{51} & \alpha_{52} \end{pmatrix}$$

We test for weak exogeneity of each of the model variables in turn:

1. $\alpha_{11} = \alpha_{12} = 0$ Labour Weakly Exogenous. If this is *not* rejected then this would suggest that the empirical model has failed to identify a labour demand equation and that the first cointegrating vector ought to be normalised on another, endogenous, variable in the system.

2. $\alpha_{21} = \alpha_{22} = 0$ Labour Costs Weakly Exogenous. If this is *not* rejected then this would suggest that the empirical model has failed to identify a wage equation and that the second cointegrating vector ought to be normalised on another, endogenous, variable in the system.

3. $\alpha_{31} = \alpha_{32} = 0$ Output Weakly Exogenous.

4. $\alpha_{41} = \alpha_{42} = 0$ Value Added Weakly Exogenous.

5. $\alpha_{51} = \alpha_{52} = 0$ Relative Factor Prices Weakly Exogenous.

2.4 Conclusion

In this chapter we describe the theoretical and methodological framework we use in estimating a conditional demand for labour function. This specifies a VAR in five variables, labour, the cost of labour, value added, relative factor prices, output, which can be used to model the long run demand for labour. In the next chapter we turn to the empirical results of estimating this VAR in three diverse manufacturing sectors.

Chapter 3

Estimating The Long Run Demand For Labour

3.1 Introduction

This chapter reports the results of estimating a long run demand for labour function for three Irish manufacturing sectors. We disaggregate the manufacturing data into different sectors because of the heterogeneity of production within Irish manufacturing. The labour demand function is derived from the theory of firm behaviour, with an assumed underlying production function which summarises the technology of the firm. Therefore our objective is to estimate the labour demand of a set of firms (sector) which are as similar as possible (defined by their common manufacturing activity).

We use data from different annual, quarterly and monthly sources so that we can exploit all available information. This is very important in order to have sufficient observations to make the data-demanding econometric methodology feasible. Using these data we generate a databank of quarterly variables on employment, output, value-added, wages and the cost of capital for 31 sectors covering the period 1973-97. The construction of this databank involved the derivation of a cost of capital variable and interpolative forecasting of some missing quarterly data at the beginning of the sample period (see Part IV).

The structure of the chapter is as follows. Section 3.2 examines some key performance indicators for 31 manufacturing sectors. From this analysis we select three sectors representative of the diversity of activities within the manufacturing sector. In Sections 3.4, 3.5 and 3.6 we describe the empirical results of estimating the long run demand for labour in these three sectors. Section 3.7 concludes with a discussion of the empirical results.

3.2 Selection of Three Stylised Sectors for Analysis

In this section we examine annual data for 31 sectors from the Census of Industrial Production (CIP) covering the years 1973-1990. The census data stop in 1990 because large discontinuities in the CIP from 1991 onwards confound direct comparison with these earlier years. As we are primarily interested in identifying three behaviourally diverse sectors, omission of the 1990s from the selection process does not significantly affect the choice of sectors, since much of the restructuring within the manufacturing sector occured in the 1980s. Furthermore, this discontinuity is not a problem in estimation, because quarterly survey indices are used to extend the census data out to 1997Q2[1]. The 31 sectors are listed in Table 3.6 in Section 3.8.

3.2.1 Some Comparative Statistics on 31 Manufacturing Sectors

Size, Ownership and Exports in 1990.

Table 3.7 in Section 3.8 contains indicators on the size of the different manufacturing sectors in 1990, where size is measured both in terms of the number of firms and gross output in each sector. The table also includes measures of the export-intensity of each sector and the percentage of foreign-owned firms in each sector. This latter measure is used as an indicator of the ownership profile of the different sectors.

In 1990 the Office and Data Processing sector (NACE 33) had the highest gross output at £2,076 billion closely followed by the Manufacture of Dairy Products sector (NACE 413). These two sectors also had the largest average firm size, measured as gross output per firm. The lowest recorded gross output was produced by Leather and Footwear (NACE 44451) at £78 billion, while the sector with the smallest average firm size was Timber and Wooden Furniture (NACE 46).

Looking at the ownership and exporting profile of the different sectors, there are three sectors - Office and Data Processing (NACE 33), Pharmaceuticals (NACE 257) and Instrument Engineering (NACE 37) - which had the highest percentage of foreign-owned firms and the highest proportion of their output exported (close to 100% in each sector). These three sectors are typical of the so-called high-technology, high-growth sectors which are dominated by foreign multinationals in Ireland.

[1]In 1991 changes in the definitions of variables, sectors and coverage of the CIP have introduced very substantial discontinuities in CIP data in that year. These changes also led to long delays in the publication of annual *census* data for the 1990s (for example the 1991 CIP data were not published until August 1998). In the interim the CSO continued to publish quarterly and monthly *survey* data using the old sector definitions.

There were only three sectors which exported less than 20% of their output in 1990 - Bread, Biscuits, Flour and Confectionery, 4% (NACE 419), Grain Milling and Animal Feedstuffs, 6% (NACE 416422) and Printing and Publishing, 13% (NACE 473474).

In general Irish industry is highly export oriented with 62% of total manufacturing output exported in 1990 while only 15% of gross output was produced by non-exporting firms. Of the total 4,602 firms, 797 were foreign-owned.

Output, Employment and Average Productivity

Tables 3.8, 3.9 and 3.10 in Section 3.8 give details on the growth in volume output (Q), employment (L) and average labour productivity (measured as Q/L) over the period 1973-90. The Office and Data Processing sector (NACE 33) recorded the highest growth in both output and employment followed by the Pharmaceuticals sector (NACE 257). Manufacture of Dairy Products (NACE 413) had the highest share of gross output over the period, 11%, while Electrical Engineering (NACE 34) had the highest share of employment at 7%. Motor Vehicles (NACE 35) recorded the largest fall in gross output over the period (-72.5%), it was the only sector with a negative overall growth in productivity, while Leather and Footwear (NACE 44451) recorded the largest fall in employment (-82.4%).

It is useful to compare two distinct sub-periods within the sample, namely 1973-81 and 1981-90. The former relates to the period when Ireland was adjusting to accession to the EC in the late 1970s. Ireland experienced a boom in growth, notwithstanding the impact of the first oil crisis, and recorded unemployment was historically low. During this period significant changes occured in the structure of the manufacturing sector. Nine sectors had negative annual growth rates in output during this period, however this was more than compensated for by the boom in the other 22 sectors with average annual growth in total manufacturing output at 4.5%. Sixteen of the sectors recorded negative average annual growth in employment while total manufacturing employment grew by an average of 0.3% per annum.

In the second sub-period, 1981-90, Ireland experienced a prolonged recession. This period also corresponds to the move from the one-to-one link with sterling to participation in the exchange rate mechanism of the EMS. Average growth in total manufacturing output in this period was 6.9%, higher than the 1973-81 period, however average annual growth in total manufacturing employment was -1.5%. The manufacturing sector was becoming increasingly capital-intensive, during this period growth in average productivity was very high at 8.6% per annum.

Value Added

Tables 3.11 and 3.12 in Section 3.8 give details on the change in labour's share of value-added and the ratio of value-added to gross output respectively. There was a dramatic fall in labour's share of value-added in manufacturing of over eighteen percentage points between 1973 (46%) and 1990 (28%). This trend continued into the 1990s (see Lane (1998)) with a further fall of nine percentage points between 1990 and 1997 (19%). There has been a similar, though less pronounced, rise in the share of value added in gross output in manufacturing industries.

Four sectors have an average labour share of value added below 30% - Pharmaceuticals (NACE 257, 10%), Office and Data Processing (NACE 33, 16%), Other Food (NACE 41rem, 20%) and Instrument Engineering (NACE 37, 29%) - while the average for the total manufacturing sector is 38%. These four sectors are all highly export oriented and three of them are predominantly foreign owned. The extremely low labour share for Pharmaceuticals and Office and Data Processing suggests a problem with overestimation of "true" value added in the data as a consequence of profit-switching transfer pricing[2]. Wool (NACE 431) recorded the highest increase in labour share of value added over the period, more than twelve percentage points, while Other Food (NACE 41rem) recorded the highest decrease.

The two food processing sectors, Slaughtering, Preparing and Preserving of Meat (NACE 412) and Manufacturing of Dairy Products (NACE 413), had the lowest value-added per unit of gross output on average over the period while Tobacco (NACE 429) recorded the highest increase in value-added per unit of gross output.

Figures 3.21, 3.22, 3.23, 3.24 and 3.25 in Section 3.8 plot the evolution of the share of value added in gross output over the period 1973-90 for all of the sectors. Over the period this share rose by almost 9% in the total manufacturing sector (Figure 3.25). This is a significant increase, it reflects the changing sectoral composition of the manufacturing sector and suggests that there have been significant technological advances over this period so that a given unit of intermediate inputs generated 9% more value added in 1990 than in 1973. This is an important consideration in the modelling exercise described later in the chapter. Further evidence of these technological changes in the manufacturing sector can be seen in Figures 3.26, 3.27, 3.28, 3.29 and 3.30 in Section 3.8 which plot the evolution of average productivity over the period 1973-90. Output per worker for the total manufacturing sector tripled over the period and rose particularly rapidly in the 1980s (Figure 3.30).

[2]Section 4.3.2 in Chapter 4 contains a full definition of profit-switching transfer pricing.

3.2.2 Three Sectors: Medium Growth, High Growth and Declining

In selecting sectors for individual study it was decided to (i) choose sectors as different from each other as possible, and (ii) choose sectors that capture the key characteristics of the Irish manufacturing sector. This is useful both in highlighting the ability of the econometric modelling framework adopted to detect these differences and in providing a microcosmic snapshot of the diversity of the Irish manufacturing sector.

The key characteristics of the Irish manufacturing sector are well-documented (Baker (1988), Bradley *et al.* (1993)). The rise of the foreign-owned, export-oriented industries (variously referred to as the "high-tech" or "modern" sector) coincided with the decline in many indigenously-owned "traditional" industries. To capture these changes we classify the sectors into three stylised groups based on their output growth performance over the period. Our central division is between expanding ("medium-growth") sectors and contracting ("declining") sectors, however we also identify a third category of "high-growth" sectors which are largely foreign-owned and export-oriented with an exceptionally rapid growth performance over the period. From these groups we then select three sectors for individual study:

1. **Metal Articles** (NACE 31): indigenously-owned, export-oriented sector with cyclical growth pattern. This sector was selected as representative of the stable core of medium-growth manufacturing sectors over the period. It had the modal growth rate in output of the thirty-one sectors, averaging 2% per annum. It accounted for approximately 6% of total manufacturing employment over the period, and was the second largest employer in 1990 (Electrical Engineering, NACE 34, was the largest).

2. **Pharmaceuticals** (NACE 257): foreign-owned, highly export oriented, high growth sector. Five of the thirty-one sectors had very rapid growth rates (averaging more than 7% per annum). Of these the Pharmaceuticals sector had the highest percentage of foreign-owned firms in 1990 (65%).

3. **Wool Industry** (NACE 431) indigenously-owned, export-oriented sector in secular decline. Ten of the thirty-one sectors contracted in output terms during the period 1973-1990. From this group of "declining" sectors we selected the Wool industry, a traditional industry in Irish manufacturing, for further study.

Table 3.1 summarises some of the key indicators for these three sectors.

Sector:	Metal Articles	Pharma-ceuticals	Wool Industry	All Manuf'ing
Stylised Type:	*Stable*	*High Growth*	*Declining*	
Output Growth				
Annual Average 1973-90	2.0%	14.5%	-3.7%	5.8%
Rank out of 31	16^{th}	2^{nd}	29^{th}	-
Employment Growth				
Annual Average 1973-90	0.1%	7.6%	-6.4%	-0.7%
Rank out of 31	10^{th}	2^{nd}	30^{th}	
Ownership Profile and Export Orientation				
% Foreign firms	10%	65%	28%	17%
% Exporting firms	63%	99%	86%	64%
% Output Exported	42%	97%	74%	62%

Table 3.1: Selected Indicators on Ownership, Output, Exports and Employment for Selected High-Growth, Medium Growth and Declining Sectors

3.3 Preliminary Analysis of the Data

3.3.1 Univariate Tests: Unit Roots and Seasonal Factors

Unit root tests for the order of integration of the model variables for the three sectors were performed using Augmented Dickey Fuller tests[3]. These are reported in Section 3.10.1. All variables were found to be either $I(1)$ or $I(0)$. These results tentatively suggest that any VAR model framework can be framed as an $I(1)$ system.

For two sectors (Metal Articles and Wool) the labour share variable was found to be $I(0)$. This would confirm an *a priori* expectation that the labour share in value added should be relatively stable over a more than twenty year period (since it is a bounded variable). The fact that in the Pharmaceuticals sector the labour share variable has failed to reject the $I(1)$ hypothesis may be due to non-stationarities arising from structural change. An examination of the graphs of this variable indicates evidence of structural change in the late 1980s.

In our specification of the VAR in Chapter 2, seasonality is modelled as deterministic (with centred seasonal dummies used to avoid the unwitting introduction of a trend in the system) so the seasonal pattern of the data is assumed to remain constant over time. Crucially this does not affect the estimated *long-run* cointegrating matrix, it only alters the

[3]All of the analysis reported in this chapter was done using PcGive 9.0 (Hendry and Doornik (1997)) and PcFiml 9.0 (Doornik and Hendry (1997)) except where otherwise stated.

dynamics of the VAR process (Hendry, 1993, p. 562).

With a changing seasonal pattern (as exhibited in some of the data series) it would clearly be preferable to model seasonality within a stochastic framework. Harvey and Scott (1993) develop a model for this: it alters the VAR specification by introducing an MA process into the error term. This highlights the presence of a restriction in our VAR specification (namely that there is no MA component in the error process) which, if invalid, will introduce dynamic misspecification.

To allow for changing seasonal patterns we also estimate the initial UVAR using deseasonalised series (estimated with the SEATS programme as described in Section 3.10.2) and omitting seasonal dummies, where data series display significant and *changing* seasonality. We then compare the congruency properties of this "deseasonalised" UVAR with the UVAR estimated using the raw data.

Section 3.10.2 below shows estimated seasonal factors for these variables. There is strong evidence of seasonality in volume output and value added in all sectors. Furthermore, the seasonal pattern in the value-added variable appears to change in both the Metal articles sector and the Pharmaceuticals sector over time. This suggests the following variables for inclusion in the initial UVAR for each of the three sectors:

1. Metal Articles: $\{l, q, y, p_l, p_k, D_{cs}\}$ or $\{l, q^s, y^s, p_l, p_k\}$

2. Pharmaceuticals: $\{l, q, y, p_l, p_k, D_{cs}\}$ or $\{l, q^s, y^s, p_l, p_k\}$

3. Wool Industry: $\{l, q, y, p_l, p_k, D_{cs}\}$

The superscript s indicates a seasonally adjusted variable and D_{cs} denotes centred seasonal dummies. The initial UVAR also includes a trend and a constant term.

3.3.2 Behavioural Restrictions: Price Homogeneity and Factor Substitution

An important criterion in initial evaluation of the UVAR estimates is to check whether the restrictions implied by cost minimisation behaviour are satisfied. The first of these is price homogeneity, which simply implies that firms do not suffer from money illusion. If all factor prices increase in the same proportion firms will not alter their factor mix. The second is convexity of the cost function, which simply implies that firms will always seek to switch away from relatively expensive factors towards relatively cheap factors in the production process.

	α_l	γ_{lk}	γ_{lq}	γ_{lt}	ε_{ll}	σ_{lk}	R^2	D.W.
Metal Articles	0.86**	0.06**	−0.05	−.0001	-0.50	1.24	0.52	0.77
Pharmaceuticals	0.73**	0.004	−0.12**	.004**	-0.92	1.04	0.76	1.37
Wool	1.82**	−0.06	−0.24**	−.0008	-0.28	0.75	0.51	0.74

Table 3.2: Single Equation Estimates of the Demand for Labour

We use these behavioural restrictions to assess our estimated coefficients. The coefficient γ_{lk}, having imposed the price homogeneity restriction $\gamma_{lk} = -\gamma_{ll}$, is used to compute the elasticity of substitution σ_{lk}. In a two factor framework this elasticity is bounded from below by zero: $\sigma_{lk} \geq 0$. This implies the following:

$$\begin{aligned}\gamma_{lk} &= 0 \Rightarrow \sigma_{lk} = 1\\ \gamma_{lk} &> 0 \Rightarrow \sigma_{lk} > 1\\ \gamma_{lk} &= -S_l \cdot S_k \Rightarrow \sigma_{lk} = 0\\ \gamma_{lk} &< -S_l \cdot S_k \Rightarrow \sigma_{lk} < 0\end{aligned}$$

This relationship provides a ready rule-of-thumb in initial evaluation of coefficient estimates. The value of $-S_l \cdot S_k$ for the three sectors[4] provides a lower bound for the estimated coefficient $\widehat{\gamma_{lk}}$ in each sector:

	Metal Articles	Pharmaceuticals	Wool Industry
S_l	0.60	0.11	0.62
$-S_l \cdot S_k$	-0.24	-0.10	-0.24

3.3.3 Single Equation Estimates of the Long Run Demand for Labour Equation

Before proceeding to the systems estimation we first look at static single equation estimates of equation (2.27). The single equation results for each sector are reported in Table 3.2. ** denotes significance at the 1% level, * at the 5% level. Each regression included a trend and centred seasonal dummies. Price homogeneity was imposed. This restriction was rejected for the Metal Articles sector.

The estimated elasticities have the correct sign, however the coefficient on factor prices is only significant in the Metal Articles sector, suggesting that the other two sectors could be

[4]These are evaluated at the sample means of S_l and S_k.

approximated by a Cobb-Douglas technology. The estimated demand for labour is relatively inelastic in all sectors and close to zero in the Wool sector. There is evidence of strong scale effects in the Pharmaceuticals and Wool sectors while the coefficient on time is significant only in the Pharmaceuticals sector.

These results are included for illustrative purposes only. There are several problems with this approach. Firstly with a single equation specification, the cost of labour variable on the right hand side, P_l, has a definitional simultaneity with the dependent variable ($S_l = \frac{L \cdot P_l}{YV}$) and therefore should not be treated *ex ante* as an exogenous variable. Secondly P_l has a behavioural simultaneity with the dependent variable, since employment and wages are jointly determined in the labour market. Thirdly the specification omits any dynamics. All of these restrictions are relaxed in systems estimation.

3.3.4 Log Approximation

Finally note that we used a log approximation of the labour share to compute the coefficients of the translog equation, as described in Section 2.3.1 in Chapter 2. The accuracy of this approximation improves the smaller is the deviation of labour share from its mean. Figure 3.1 plots this deviation for each of the three sectors. In each case the deviation is within one half of one percentage point of the mean.

3.4 Estimation Results for Medium Growth Sector: Metal Articles

The metal articles sector is an interesting example of a relatively stable sector with modest average growth rates. The sector experiénced a prolonged single cycle over the period 1973-90 (see Figure 3.2). Throughout the 1970s employment and output rose to a peak in 1980, when its share in total manufacturing output also peaked. From that point employment fell steadily until 1986 and at 1990 was at approximately the same level as in 1973. Since 1993 employment has recovered, and in 1997 had returned to mid-1970s levels, still below its previous 1980 peak.

Labour's share of value added averaged approximately 60% throughout the period 1973-1997. In the 1980s it fell from a high of 65% in 1983 to a low of 54% in 1988 before recovering to an average of 59% in the 1990s. Note that these numbers are higher than those reported in Table 3.11 in Section 3.8. In that table, and heretofore in this thesis, labour share is measured as the wage bill share of value added. Hereafter labour share is defined as total labour costs, including non-wage labour costs, as a share of value added. This is the

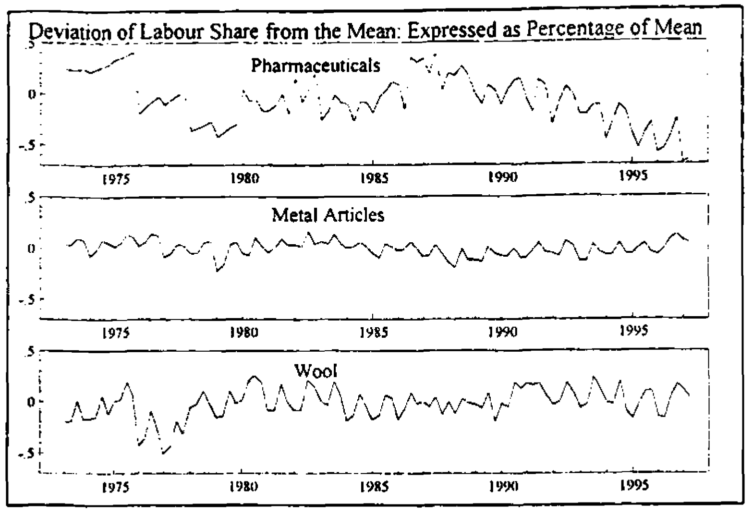

Figure 3.1: Deviation of Labour Share from The Mean In Percentage Terms in the Pharmaceuticals, Metal Articles and Wool Sectors: 1973Q1-1997Q2

dependent variable used in modelling the demand for labour.

The metal articles sector was 90% indigenously owned in 1990 with 42% of its total output exported. Over 50% of total exports in 1990 were to the UK. Approximately 50% of total production in 1990 was 'Finished Metal Articles' (e.g. metallic furniture, radiators, implements and tools), 30% 'Manufacture of Structural Metal Products', other products include 'Boilermaking, manufacture of tanks, 8%, 'Secondary transformation, treatment and coating of metals',8%, 'Foundries',4%, and 'Forging, pressing and stamping of metals', 1%.

3.4.1 The Unrestricted VAR

The initial UVAR estimated was an unrestricted fifth-order system including the five model variables $\{l, p_l, q, y, p_k - p_l\}$ together with a trend term and centred seasonal dummies. Evidence of instability in the system from examining the estimated residuals and Chow test diagnostics suggested the inclusion of two regime shift dummy variables, both of which are linked to regime changes within the European Union:

1. *EMS Dummy:* $S79q4 = 1$ from 1979Q4-1997Q2, 0 otherwise. This captures the shift in Ireland's exchange rate regime from a fixed link with sterling to membership of the EMS in 1979. The immediate impact of this regime shift on the bilateral IR£-Sterling

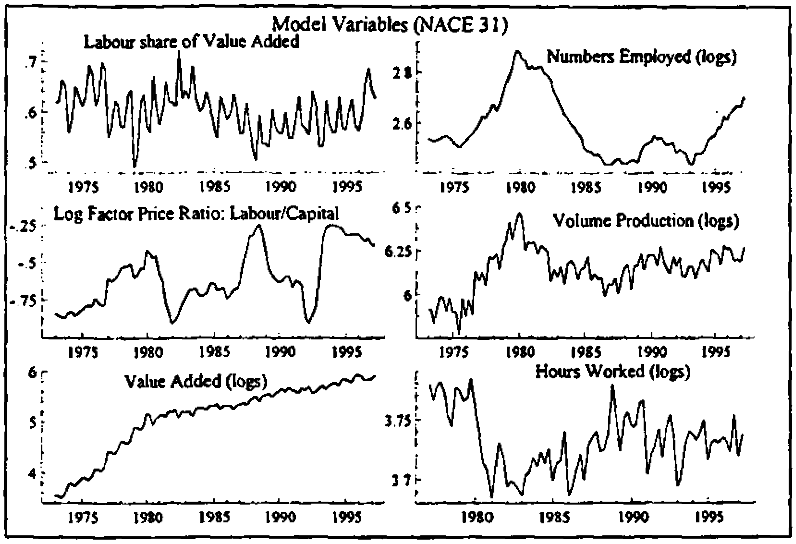

Figure 3.2: Metal Articles Sector: Model Variables

exchange rate can be seen clearly in Figure 3.3. Since the Metal Articles sector has substantial trade links with the UK (50% of all exports in 1990 were to the UK), and since the UK and Irish labour markets also have strong linkages, the move away from a fixed link with sterling in 1979 can plausibly be expected to impact on the demand for labour in this sector.

2. *Single Market Dummy:* $S93q1 = 1$ from 1993Q1-1997Q2, 0 otherwise. This dummy variable captures a second regime shift following the completion of the single market in 1992. Studies of the effects of the single market in Ireland identify it as a key factor in improving the competitiveness of the Irish manufacturing sector (Barry et al. (1997)).

Dropping the fifth lag was not rejected ($F(25, 213) = 1.29$) so the preferred specification included four lags. Section 3.10.3 contains tables of estimation results. Table 3.16 reports the diagnostic tests and Figure 3.4 plots the scaled residuals, together with the actual and fitted variables, for each of the five estimated equations. The equations in the UVAR (and graphs) are ordered $\{l, p_l, q, y, p_k - p_l\}$.

The diagnostics for the four-dimensional UVAR are good. The single equation tests indicate evidence of residual autocorrelation in the cost of labour equation and non-normality in the relative factor prices equation, however the systems tests for autocorrelation, normality

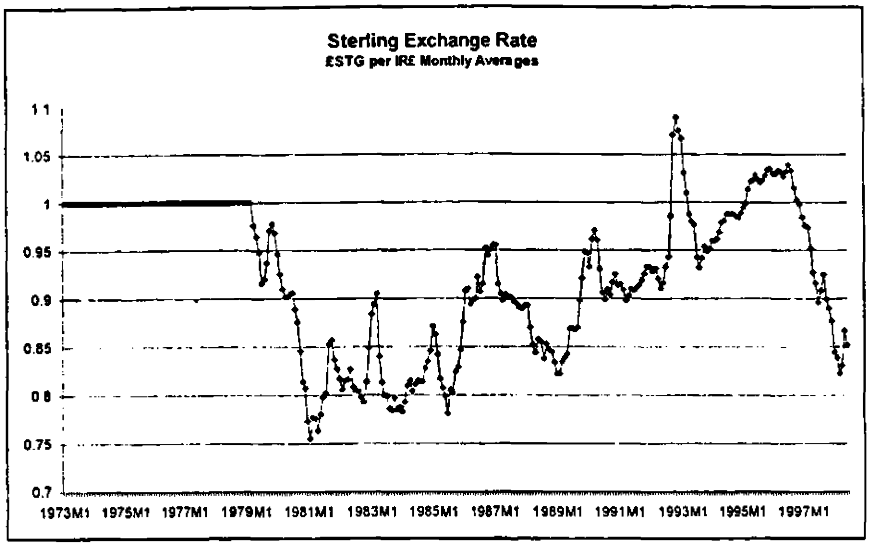

Figure 3.3: IR£-Sterling Exchange Rate

and heteroscedasticity are all clean. The one-step Chow tests suggest some evidence of parameter instability in individual equations. However the breakpoint and forecast Chow tests for parameter stability (Figure 3.5) suggest that the only equation with evidence of instability at the 5% level is the value added equation.

Estimation of this UVAR using the seasonally adjusted series for q and y indicated severe problems of non-normality in the estimated residuals. Further extensive specification testing indicated that this non-normality persisted. Therefore we did no further modelling using the seasonally adjusted data.

In the preferred UVAR system the trend term is insignificant at the 10% level ($F(5,62) = 1.89$). However omission of the trend term led to congruency problems in the diagnostic tests ($vecAR(125,191) =^{*} 1.35, vecN(10) =^{**} 23.78$). Therefore we proceed with the trend term included in our preferred UVAR.

The Cointegration Space

In initial estimation of the rank of the cointegrating space we restricted the trend term to lie within the cointegration space. However this specification led to a rejection of the key behavioural restrictions of price homogeneity and factor substitution for the first cointegrating vector, specifically it implied a negative elasticity of substitution. Therefore we omitted

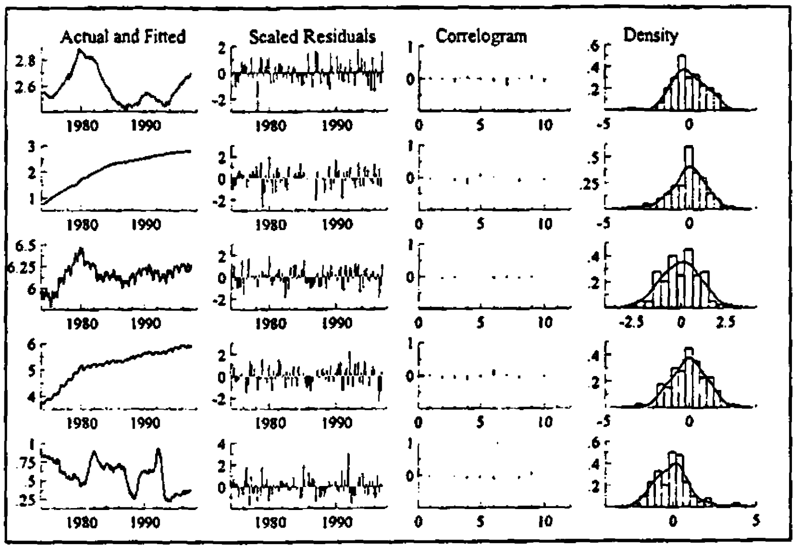

Figure 3.4: Metal Articles Sector UVAR Diagnostics: Actual and Fitted Values

the trend term from the cointegrating space. Instead, in our final specification we restricted both dummy variables to lie within the cointegration space. These imply permanent changes in the intercept of any estimated long-run relationship in 1979 and 1993.

We test for the rank of the cointegration space using the *Trace* and *Max*(imum eigenvalue) tests described in Chapter 2. These tests are also reported using a small-sample correction replacing T with $T - np$[5]. Table 3.17 also includes the value of each estimated eigenvalue, λ_r. Figure 3.6 plots the estimated eigenvectors (with the short-run dynamics partialled out) and the recursively estimated eigenvalues.

The *Max* and *Trace* small-sample tests both indicate a rank of two, suggesting the presence of two linearly independent long-run relations among the variables. The unadjusted *Max* test also suggests a rank of two while the unadjusted *Trace* test indicates marginal evidence of a rank of three. Given our prior preference for a rank of two as discussed in Chapter 2 and the clustering of these test results around a rank of two rather than three, we proceed on the basis of a rank of two. Table 3.18 shows the reduced form estimates of α and β with a rank of two.

[5]Doornik, Hendry and Nielsen (1998), in a study of the performance of tests of cointegration rank, recommend the use of the trace test and found that small-sample corrections often over-correct.

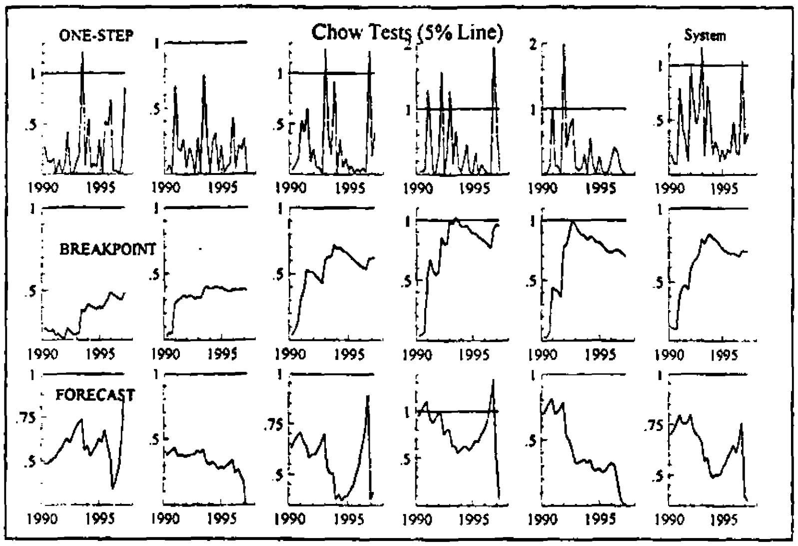

Figure 3.5: Metal Articles Sector: UVAR Chow Tests

Identification of β

Table 3.19 reports the results of hypotheses tests on the two reduced form β vectors as follows:

- H_1 Translog Technology and Price Homogeneity: *Accepted*

  This key hypothesis imposes the basic translog labour demand equation. Labour's share in value added in logs, $(l + p - y)$, is expressed as a function of relative factor prices $(p_k - p_l)$, with price homogeneity also imposed.

- H_2: Homotheticity & H_1: *Accepted*

  This hypothesis tests for homotheticity by omission of q from the basic translog labour demand equation. Rejection of homotheticity can also signal rejection of the weak separability assumption underlying the value added specification.

- H_3: Drop EMS dummy & H_2: *Rejected*

  This hypothesis tests for omission of the 1979 EMS intercept dummy variable from the homothetic translog labour demand equation.

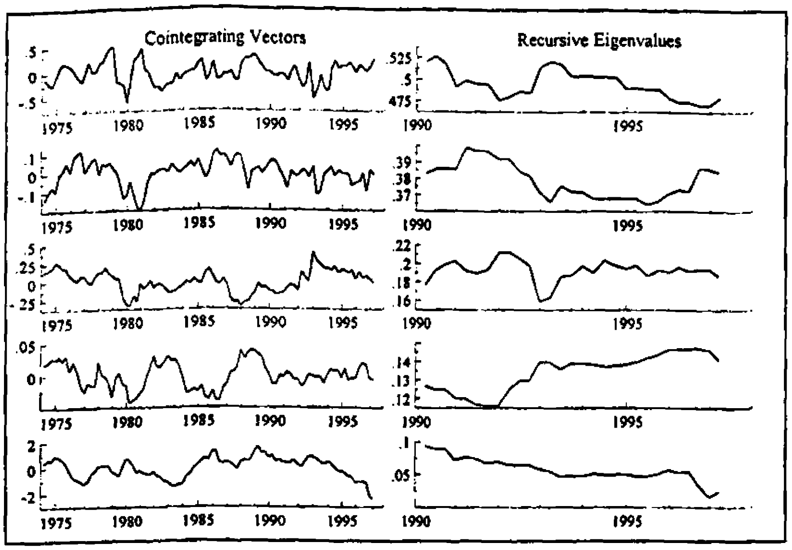

Figure 3.6: Metal Articles Sector: Estimated Cointegrating Vectors and Recursive Eigenvalues

- H_4: Drop Single Market dummy & H_2: *Rejected*

  This hypothesis tests for omission of the single market intercept dummy variable from the homothetic translog labour demand equation.

- H_5: Cobb-Douglas Technology : *Rejected*

  This hypothesis tests for a Cobb-Douglas technology, dropping the relative price term $(p_k - p_l)$, which implies a constant elasticity of substitution of one and a constant labour share of value added.

Based on this set of hypothesis tests, we identify the first cointegrating vector as a homothetic translog labour demand equation including both the EMS and Single Market dummies, namely H_2. Following on from this, the second cointegrating vector is identified as a reduced form wage equation as follows:

- H_6: Reduced Form Wage Equation & H_2: *Accepted*

  This hypothesis specifies a reduced form wage equation, dropping the relative factor price term and expressing the wage as a function of labour productivity $(q - l)$. Further testing indicated that the Single Market dummy was insignificant (as indicated by the reduced form estimates of β_2 reported in Table 3.18). The specification also includes value-added, (y) (further testing rejected the exclusion of value-added from the wage equation).

The estimated elasticity of demand under H_6 is very high, greater than 4. This lies well outside the limits suggested by Hamermesh's stylised facts that the elasticity of demand lies above 0 and below 1. The next set of restrictions test for a unit elasticity of demand:

- H_7: Unit Elasticity of Demand ($\beta_{15} = -0.60$) & H_6: *Marginally Rejected*

  This hypothesis tests for an elasticity of demand equal to one in the translog labour demand equation. This is equivalent to testing that the coefficient on relative prices in the first cointegrating vector is equal to -0.60.

- H_8: Unit Elasticity of Demand ($\beta_{15} = -0.60$), Equal Coefficients on Dummies ($\beta_{16} = \beta_{17}$) & H_6: *Accepted*

  While H_7 was rejected, it was only marginally so. Further identification testing suggested that, by equating the coefficients on the shift dummies in the labour demand vector, an elasticity of demand of -1 is not rejected.

Under H_8 reported in Table 3.19 we get the following two cointegrating relations:

$$\begin{aligned} l + p_l - y &= 0.6(p_k - p_l) + \underset{(0.03)}{0.20}(S1979q4 + S1993q1) \\ p_l &= \underset{(0.17)}{0.58}(q - l) + \underset{(0.07)}{0.42}\,y + \underset{(0.06)}{0.21}\,S79q4 \end{aligned} \tag{3.1}$$

Figure 3.7 plots these two relations. This graph plots the fitted values as functions of the cointegrating coefficients only with the short run dynamics partialled out. The fit of the two estimated relations is good.

Weak Exogeneity

Using these two identified cointegrating relations, we performed the following series of exogeneity tests on the α coefficients, testing weak exogeneity of each of the endogenous variables in turn. The results are reported in Table 3.20:

1. H_9 : Labour (l) w.e. (weakly exogenous) for β_1 and β_2 & H_8; *Rejected*
2. H_{10} : Labour Costs (p_l) w.e. for β_1 and β_2 & H_8; *Rejected*

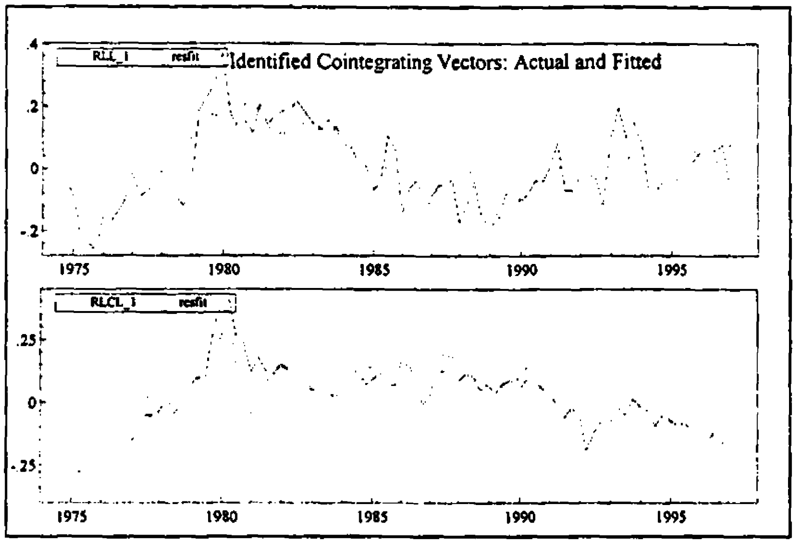

Figure 3.7: Metal Articles Sector: Two Identified Cointegrating Vectors

3. H_{11} : Volume Ouput (q) w.e. for β_1 and β_2 & H_8; *Rejected*

4. H_{12} : Value Added (y) w.e. for β_1 and β_2 & H_8; *Accepted*

5. H_{13} : Relative Factor Prices ($p_k - p_l$) w.e. for β_1 and β_2 & H_8; *Rejected*

6. H_{14} : Labour and Relative Factor Prices w.e. for β_2 and Volume Output w.e. for β_1 & H_{12}; *Accepted*

Only one variable in the system, value added, fails to reject the hypothesis of weak exogeneity. In addition, as suggested by the reduced form estimates of α, the hypotheses that labour is weakly exogenous in the wage equation β_2 and that output is weakly exogenous in the labour share relation β_1 are not rejected.

3.4.2 Encompassing the VAR

The Parsimonious VAR

We now formulate the PVAR including the two identified cointegrating relations as identities in a first-differenced version of our original UVAR system. Table 3.21 gives the system

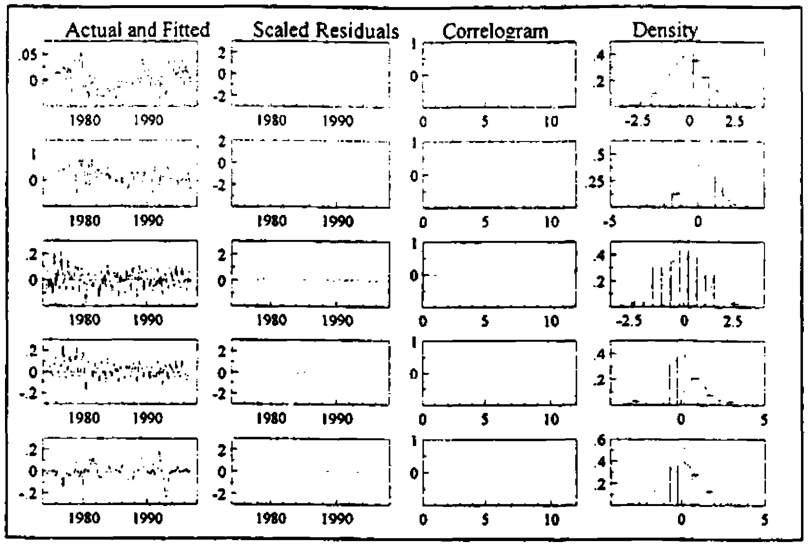

Figure 3.8: Metal Articles: PVAR Diagnostics Actual and Fitted Values

diagnostics for this PVAR. There is marginal evidence of non-normality in the systems tests and autocorrelation in the value added equation, and strong evidence of non-normality in the labour costs equation. However the diagnostics suggest the residuals are still reasonably clean, as can be seen in Figure 3.8.

We are now in $I(0)$ space and can test reductions of the general system using likelihood ratio tests. The first tests attempt to replicate the weak exogeneity findings from the tests on α in the UVAR. In all cases these results were confirmed by testing restrictions on the PVAR as shown in Table 3.22.

We also tested for a D(ifferenced) VAR specification, H_{20}. A DVAR excludes the long-run cointegrating relations from the system, implying a VAR in first differences. This hypothesis of weak exogeneity of all variables is rejected by the data. This is to be expected since the tests on the rank of the cointegrating space, reported earlier, indicated a rank greater than zero.

The Structural Econometric Model

The exogeneity tests on the UVAR and PVAR suggest that value added is weakly exogenous. Therefore we condition on value added in moving to a specific SEM. In addition we impose the exogeneity restrictions implied by H_{14}, namely we drop the cointegrating labour demand vector ($cvecS_l$) in the output equation and we drop the cointegrating wage vector ($cvecP_l$) in the labour and relative factor prices equations. Table 3.23 gives the system diagnostics for this SEM, these are similar to the PVAR indicating there has been no deterioration in moving from the PVAR to the SEM. Furthermore, the restrictions implied in moving from the PVAR to the SEM were not rejected by a Likelihood Ratio test of over-identifying restrictions ($\chi^2(3)$=3.13[0.37]). In this sense, the SEM can be said to encompass the PVAR.

The full set of estimated dynamic equations, with standard errors, is shown in Section 3.10.3. Because we are only interested in the long run, we do not proceed further with tests to reduce the dimensions of the SEM. As pointed out by Johansen (1995), and cited earlier, estimation of the long-run parameters in a data-congruent system can proceed independently of estimation of the short-run parameters. Since the estimated SEM has been found to be congruent with the data, as confirmed by the diagnostic tests, we can focus on the estimated long-run results without imposing further structure on the short-run dynamics of the system.

Equation:	$cvecS_l$	$cvecP_l$
Δl	0.09 (0.03)	
Δp_l	−0.15 (0.04)	−0.13 (0.04)
Δq		0.30 (0.06)
$\Delta(p_k - p_l)$	0.36 (0.07)	

Table 3.3: Metal Articles Sector: Estimated Adjustment Coefficients in SEM

The estimated adjustment coefficients on the cointegrating vectors in the SEM are shown in Table 3.3. These are quite large, indicating relatively rapid adjustment to the long-run.

3.4.3 Discussion of The Estimation Results

The First Cointegrating Vector: A Long Run Demand For Labour Function

The first cointegrating vector can be transformed into a labour share equation, as described in Section 2.3.3. Given $S_l = \ln S_l \cdot \overline{S_l} = (l + p_l - y) \cdot 0.60$ where $\overline{S_l} = 0.60$, then:

$$S_l = 0.36(p_k - p_l) + 0.12(S79q4 + S93q1) \tag{3.2}$$

This is a homothetic translog labour share equation. The estimated elasticity of substitution is 2.5 and the elasticity of demand is -1. The non-rejection of homotheticity is important in increasing confidence in the robustness of the results since it suggests that the assumption of weak separability is not rejected by the data.

The results reject a Cobb-Douglas technology despite the fact that labour share in the Metal Articles sector has been broadly stable over the period 1973-1997 (Figure 3.2), a seemingly contradictory result. This can be interpreted as follows. The estimated elasticity of substitution implies an underlying production technology with high rates of substitution between labour and capital. The long-run factor price ratio between labour and capital increased steadily from 1973 until 1993, although there were large swings in this ratio due to interest rate hikes in the period of the second oil price shock and the tightening of monetary policy in the late 1980s. The estimated elasticity implies that this increase in the relative cost of labour led to significant substitution away from labour towards capital in the production process, driving down labour's share in value added and reducing employment in the long run.

Offsetting this substitution away from labour are the two regime shift dummy variables, which both imply a long-run upward shift in labour's share of value added. The observed constancy of the labour share, and the close fit of the estimated cointegrating relation (Figure 3.7) implies that these served to offset its downward trend due to the long-run rise in the cost of labour relative to capital. These two dummy variables suggest that changes in the exchange rate regime in 1979 and in the competitive regime in 1992 both coincided with permanent capital-augmenting changes in the factor mix in the Metal Articles sector. One plausible explanation for such changes would be an increase in the human capital embodied in labour employed, Part II looks in detail at this issue.

Figure 3.9 shows estimates of employment implied by movements in relative factor prices alone. The predicted value of employment in 1997Q2, due to changes in relative factor prices between 1973Q2 and 1997Q2, is 7,800, just 52% of the actual level in 1997Q2 of 14,900. These estimates are based on constant-output elasticities. The overall responsiveness of the demand for labour to changes in its price also depends on the demand for output. In the Metal Articles sector output grew strongly between 1973 and 1980, driving the growth in employment in that period. In the period 1982 to 1997, output stagnated and employment fell to pre-1973 levels before picking up again in 1993. The empirical results suggest that this fall in employment in the 1980s, a period when output was constant, is in part explained by the substitution of relatively cheaper capital for labour in production.

The Second Cointegrating Vector: A Reduced Form Wage Equation

The second cointegrating relation is a reduced form wage equation:

$$p_l = 0.58(q - l) + 0.42y + 0.21S79q4 \tag{3.3}$$

This suggests that there is significantly less than full pass through of productivity to nominal wages, with pass-through in the long run averaging 58%. However in addition to

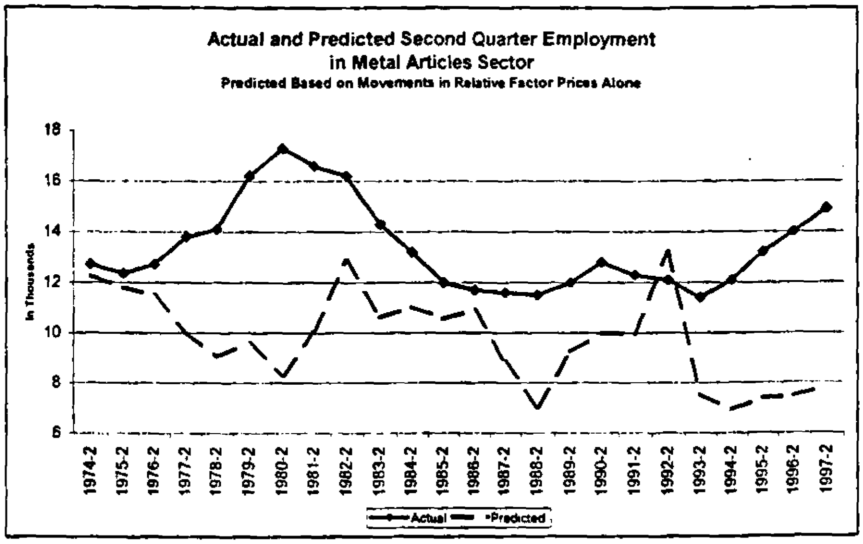

Figure 3.9: Estimated Effect of Relative Factor Prices on Employment in Metal Articles Sector

this, there is a indirect link between nominal wages and profitability through a 40% pass-through of value added to the nominal wage. Finally, membership of the EMS led to a long-run increase in the nominal wage in the sector.

3.5 Estimation Results for High Growth Sector: Pharmaceuticals

The pharmaceuticals sector is a very dynamic and rapidly expanding sector, which increased its share of total manufacturing output from below 2% in 1973 to approximately 7% in 1990. As can be seen in Figure 3.10, labour's share of value added averages about 11% which is very low, and this has fallen further in the 1990s. This indicates a high degree of capital-intensity but it is also due to a distortion in the reported profit figures due to transfer pricing agreements as the sector is dominated by foreign-owned firms. In 1990 73 of the 74 firms in the pharmaceuticals sector were grant-aided and 48 were foreign-owned (22 US, 20 EC, 6 Other). Foreign-owned firms accounted for approximately 95% of 1990 gross output (75% by US firms).

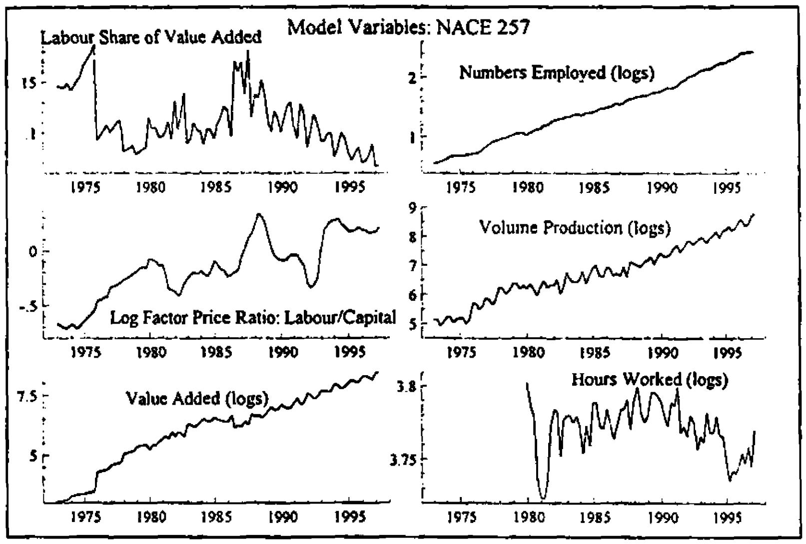

Figure 3.10: Pharmaceuticals Sector: Model Variables

The sector is highly export-oriented (96% of gross output was exported in 1990) and is high in value-added - value added was 76% of gross output in 1990 - although this may also reflect some distortion due to transfer pricing.

Its main products in 1990 were 'Bulk Unfinished Pharmaceuticals' (over 50% of total output in 1990) and 'Drugs, medicines and medicinal preparations for human use'(over 20% of total output in 1990).

3.5.1 The Unrestricted VAR

The initial UVAR estimated was an unrestricted fifth-order system including the five model variables $\{l, p_l, q, y, p_k - p_l\}$, in that equation order, together with a trend term and centred seasonal dummies. Evidence of instability in the system from examining the estimated residuals and Chow test diagnostics suggested the inclusion of three dummy variables:

1. $I76_1$ This is an impulse dummy in 1976Q1 when there was a discrete upward jump in value added.

2. $I80_1$ This is an impulse dummy in 1980Q1 when there was a once-off sharp decrease in average hours worked (Figure 3.10). This coincides with the period of the second

oil price shock combined with the immediate impact of EMS membership.

3. $I92_1$ This is an impulse dummy in 1992Q1 which captures the sharp upward increase in the cost of capital following the currency crisis at the end of 1992, when nominal interest rates reached record highs before the Irish pound devalued in February 1993. Because the interest rate is included as a forward moving average in the cost of capital equation, the dummy is three quarters prior to the currency crisis at the end of 1992.

Attempts to estimate a long run demand for labour equation with this data-congruent UVAR specification led to implausible results, in particular a failure to accept price homogeneity which is a fundamental behavioural restriction under cost-minimisation. Re-estimation using seasonally adjusted data also failed to accept this restriction.

Closer examination of the underlying data in the model, shown in Figure 3.10, highlighted the presence of a persistent downward trend in the labour share in this sector after 1986. The failure to reject the hypothesis of a unit root for this labour share variable, described in Section 3.3.1 above, may also be attributable to this mid-sample structural change.

This reflects a phenomenon that has drawn much comment in recent years, namely a near ten percentage points shift from labour to capital in Ireland since 1987 (Lane, 1998). Most of this downward shift in labour's share of GDP has been driven by a decline in labour share in the high-technology, modern manufacturing sector, which includes the Pharmaceuticals sector (Duffy et al. (1999)).

To capture this mid-sample change in trend, we included a further variable in the UVAR, $T86_3$, defined as $T86_3 = Trend$ from 1986Q3-1997Q2, 0 otherwise.

The diagnostics tests from this preferred fourth-order UVAR - dropping the fifth lag was not rejected (F(25, 205) = 1.14 [0.30]) - are reported in Table 3.24 in Section 3.10.3. Figures 3.11 and 3.12 plot the residuals and Chow tests for each of the five equations. The diagnostics are good, although there is some evidence of non-normality in the value added equation, otherwise all diagnostic tests are clean and the Chow tests do not indicate any evidence of parameter instability.

The Cointegration Space

In estimating the rank of the cointegrating space, we initially restricted the trend term to lie within the cointegrating space as a proxy for slowly changing technical progress. However this formulation indicated a very high rank (between 3 and 4) which would make identification of unique cointegrating vectors extremely difficult. Further testing indicated that including the $T86_3$ variable, a proxy for a mid-sample structural change in the sector as discussed above, and omitting the full-sample trend term, reduced the estimated rank to 2, a more tractable

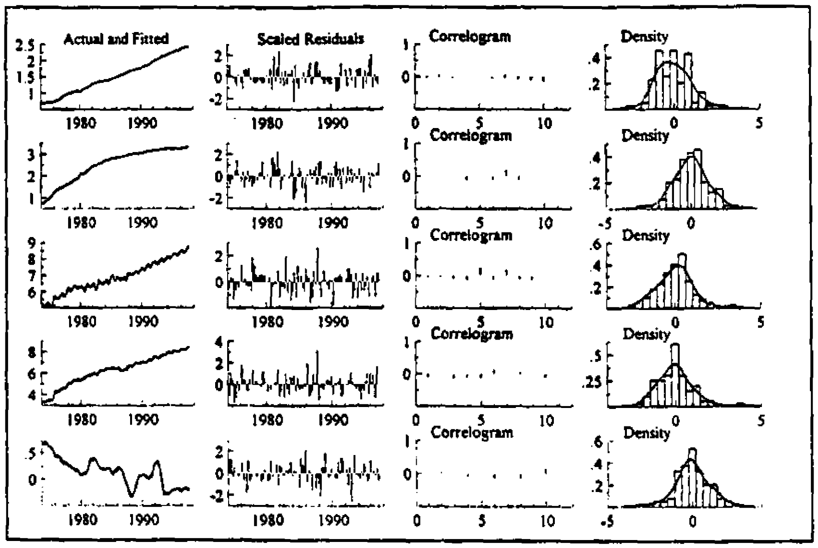

Figure 3.11: Pharmaceuticals Sector UVAR Diagnostics: Actual and Fitted Values

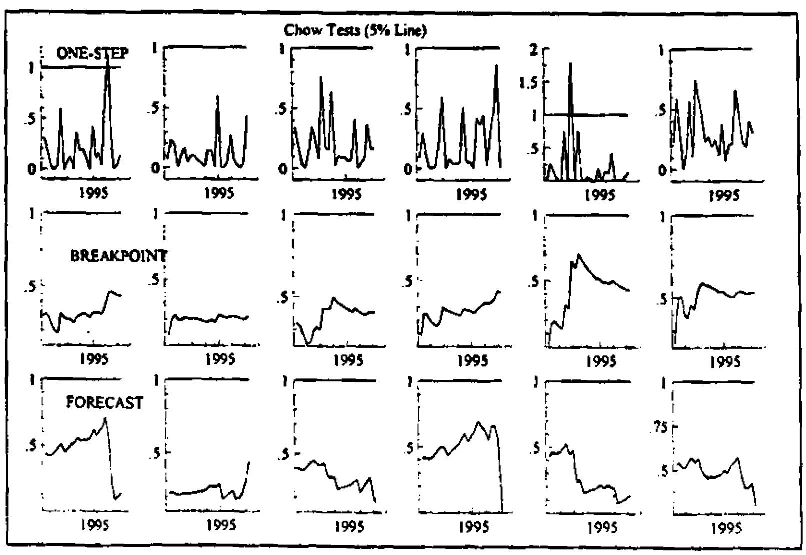

Figure 3.12: Pharmaceuticals Sector: UVAR Chow Tests

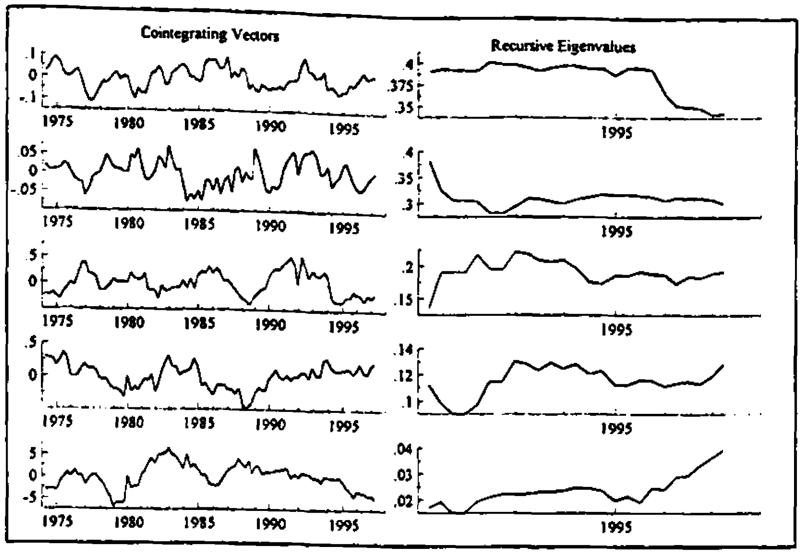

Figure 3.13: Pharmaceuticals Sector: Estimated Cointegrating Vectors and Recursive Eigenvalues

reduced form with which to identify unique relations. In all cases the impulse dummies were excluded from the cointegrating space.

The results of tests for the rank of the cointegrating space are reported in Table 3.25. Both the unadjusted *Max* test and the adjusted *Trace* test suggest a rank of two, with marginal evidence of a rank of three from the unadjusted *Trace* test while the adjusted *Max* test suggests a rank of zero. From this, we proceed on the basis of a rank of two given our preference for identifying at most two linearly independent relations. Figure 3.13 plots the five estimated eigenvectors (with the short-run dynamics partialled out) and the recursively estimated eigenvalues while Table 3.26 shows the reduced form estimates of α and β with a rank of two. There appears to be a significant change in the recursively estimated eigenvalue for the first cointegrating vector in the final two years of the sample, which is worrying since it suggests misspecification.

Identification of β

Table 3.27 reports the results of identification tests on the two reduced form β vectors. The first cointegrating vector is identified as a labour demand equation. Hypothesis tests on the labour demand equation are built up as follows:

- H_1: Translog Technology and Price Homogeneity: *Accepted*

  This key hypothesis imposes the basic translog labour demand equation. Labour's share in value added in logs, $(l + p - y)$, is expressed as a function of relative factor prices $(p_k - p_l)$, with price homogeneity also imposed.

- H_2: H_1 & No Structural Change in 1986: *Rejected*

  This hypothesis tests for omission of $T86_3$ from the basic translog labour demand equation.

- H_3: Homotheticity & H_1: *Rejected*

  This hypothesis tests for homotheticity (and also weak separability) by omission of q from the basic translog labour demand equation.

- H_4: Cobb-Douglas Technology : *Rejected*

  This hypothesis tests for a Cobb-Douglas technology.

- H_5: $H_2 \cap H_3 \cap H_4$: *Rejected*

  This hypothesis tests for a Cobb-Douglas technology with homotheticity and no structural change.

Based on this set of hypothesis tests, we identify the first cointegrating vector as a non-homothetic translog labour demand equation with evidence of structural change in the period since 1986, namely H_1. Following on from this, the second cointegrating vector is identified as a wage equation. Our hypotheses are built up as follows:

- H_6: H_1 & Reduced Form Wage Equation: *Accepted*

  This hypothesis combines the identified first cointegrating vector with a simple wage equation, omitting relative factor prices. The wage is expressed as a function of labour, output, value added and $T86_3$.

- H_7: H_6 & Modified Wage Equation: *Accepted*

  This hypothesis tests for the omission of labour (l) from the basic wage equation. This was suggested by the low value of the coefficient on l. In so doing, this precludes a direct relationship between wages and labour productivity $(q - l)$.

- H_8: H_7 & Restricted Wage Equation: *Accepted*

  This hypothesis tests that the coefficients on q and y are of equal and opposite sign. (Again this was suggested by the values of the estimated coefficients. The reduced form estimates for β_2, reported in Table 3.26, also suggest this parameterisation.) With some manipulation, as shown below, this introduces the share of value added in gross output as an explanatory variable in the wage equation.

Further tests on the second cointegrating vector, to omit the $T86_3$ structural change variable, were rejected. We therefore identify the two cointegrating vectors under H_8 as :

$$l + p_l - y = \underset{(0.14)}{-0.63}\,(p_k - p_l) - \underset{(0.14)}{1.42}\,q + \underset{(0.003)}{0.006}\,T86_3$$

and

$$p_l = \underset{(0.04)}{0.40}\,(y - q) - \underset{(0.002)}{0.03}\,T86_3$$

Figure 3.14 plots these identified cointegrating vectors. This graph plots the fitted values as functions of the cointegrating coefficients only with the short run dynamics partialled out. The fit for the translog labour demand equation is very poor, while the fit for the wage equation is good.

Weak Exogeneity

Using these two identified cointegrating relations we then test for weak exogeneity of each of the endogenous variables in turn. The results are reported in Table 3.28.

1. H_9 : Labour (l) w.e. (weakly exogenous) for β_1 and β_2 & H_8; *Rejected*
2. H_{10} : Labour Costs (p_l) w.e. for β_1 and β_2 & H_8; *Accepted*
3. H_{11} : Volume Ouput (q) w.e. for β_1 and β_2 & H_8; *Rejected*
4. H_{12} : Value Added (y) w.e. for β_1 and β_2 & H_8; *Rejected*
5. H_{13} : Relative Factor Prices ($p_k - p_l$) w.e. for β_1 and β_2 & H_8; *Rejected*

Only one variable in the system, labour costs, failed to reject the hypothesis of weak exogeneity.

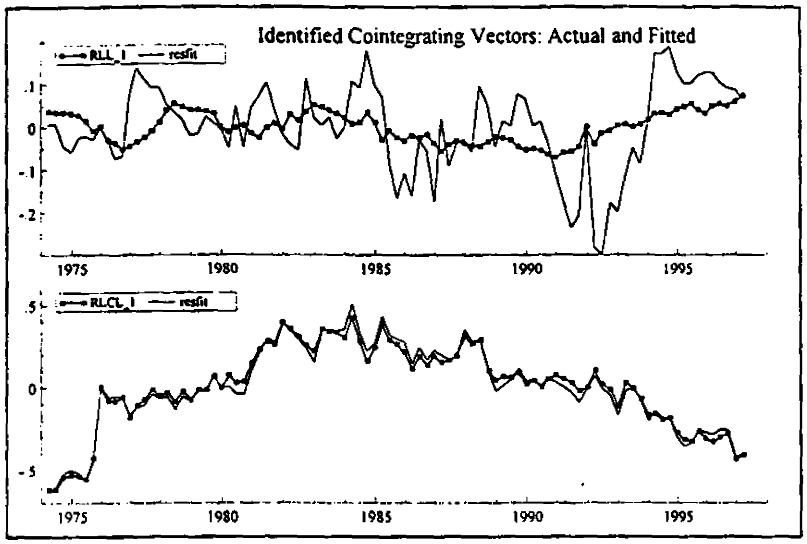

Figure 3.14: Pharmaceuticals Sector: Two Identified Cointegrating Vectors

3.5.2 Encompassing the VAR

The Parsimonious VAR

We now formulate the PVAR including the two identified cointegrating relations as identities in a first-differenced version of the original UVAR system. Table 3.29 gives the system diagnostics for this PVAR, estimated using FIML. There is evidence of autocorrelation in the single-equation tests for the volume output equation, otherwise the diagnostics are clean.

We are now in $I(0)$ space and can test reductions of the PVAR using likelihood ratio tests. The first tests were on the weak exogeneity findings from the tests on α. Weak exogeneity of labour costs is rejected here, contradicting the results from testing the unrestricted UVAR. Rather, the PVAR tests suggest that labour and value added are weakly exogenous. Furthermore, testing for weak exogeneity of both labour and value added simultaneously fails to reject (H_{21} in Table 3.30).

We also tested for a D(ifferenced) VAR specification, H_{20}. This hypothesis of weak exogeneity of all variables is rejected by the data.

These results confirm earlier evidence on misspecification of the first cointegrating vector. Weak exogeneity of labour suggests that we have not succeeded in identifying a long-run demand for labour equation, which is consistent with the poor fit of the first identified

Equation:	$cvecS_l$	$cvecP_l$
Δp_l	-0.002 (0.02)	-0.014 (0.03)
Δq	-0.42 (0.12)	0.46 (0.13)
$\Delta(p_k - p_l)$	-0.17 (0.05)	0.19 (0.05)

Table 3.4: Pharmaceuticals Sector: Adjustment Coefficients for SEM

cointegrating vector.

The Structural Econometric Model

The exogeneity tests on the PVAR suggest an SEM using three endogenous variables - labour costs, volume output and relative factor prices. The diagnostic test results for this SEM are shown in Table 3.31. The diagnostics are still good, there is now evidence of serious autocorrelation in the volume output equation, but the single equation diagnostics are otherwise clean and all of the system diagnostics are clean.

The adjustment coefficients for the SEM are shown in Table 3.4:

1. The adjustment coefficients in the labour costs equation are negligibly small and not significant, however tests to omit the two cointegrating vectors from the Δp_l equation were rejected ($\chi^2(2)$=12.26[0.00]**).
2. The rate of adjustment of volume output to changes in the long-run demand for labour and the long-run wage equation is very rapid.
3. The dynamic equation for relative factor prices suggests rapid adjustment to the long-run demand for labour with negligible adjustment to the long-run wage equation.

3.5.3 Discussion of The Estimation Results

The First Cointegrating Vector: A Long Run Labour Demand Function

The estimated translog labour demand equation, with $\overline{S_l} = 0.11$, is

$$S_l = -0.07(p_k - p_l) - 0.16\, q + 0.0006\, T86_3 \qquad (3.4)$$

The estimated elasticity of demand is very low at -0.26 which is close to approximating a Leontief technology.

Homotheticity is rejected (the equation includes q). There is a large, negative scale effect in the translog equation, driving the decline in labour share in this sector. This result must be interpreted with caution, as the non-homotheticity result may in fact be capturing a rejection of the weak separability assumption underlying the two-factor production specification.

There is evidence of capital augmenting technical progress from 1986 onwards, with a positive coefficient on the mid-sample trend term.

No reliance can be placed on these results however given the evidence of misspecification and the very poor fit of the cointegrating vector.

The Second Cointegrating Vector: A Reduced Form Wage Equation

The second cointegrating vector is specified as a wage equation. Since gross output is equal to volume times price, namely $QV = P_Q.Q$, and converting to logarithms, we can re-write it as follows:

$$p_l = 0.40\ (y - qv) + 0.4\ p_q - 0.03\ T86_3 \qquad (3.5)$$

The first term on the right hand side, $y - qv$, measures the share of value added in gross output which, as mentioned earlier, is relatively high and rising in this sector. In this specification there is no direct relationship between the nominal wage and productivity. Instead the nominal wage is positively related to the value added intensity of output, which can be interpreted as a proxy for total factor productivity or profitability in the sector.

There is less than full indexation of wages, at 40%, to output prices. From 1986 onwards there is a downward trend in the nominal wage, this corresponds to the period when profitability began rising in the sector and there was a progressive shift in value added away from labour towards capital.

Evidence of Misspecification

The estimation results indicated instability in the first cointegrating vector which were confirmed by the very poor fit of the estimated labour demand equation, together with conflicting test results from the *Max* and *Trace* statistics in testing for the rank of the cointegrating space. Furthermore, evidence of non-homotheticity may be signalling a rejection of the two-factor specification. In addition, the move from the UVAR to the PVAR led to contradictory results in tests of weak exogeneity. The estimated adjustment coefficients suggested implausibly rapid adjustment to the long run in the output equation. All of these results point to evidence of misspecification in the model. For this reason we did not proceed further in testing for an SEM to encompass the VAR. We conclude that we have failed to identify a long run demand for labour equation for this sector.

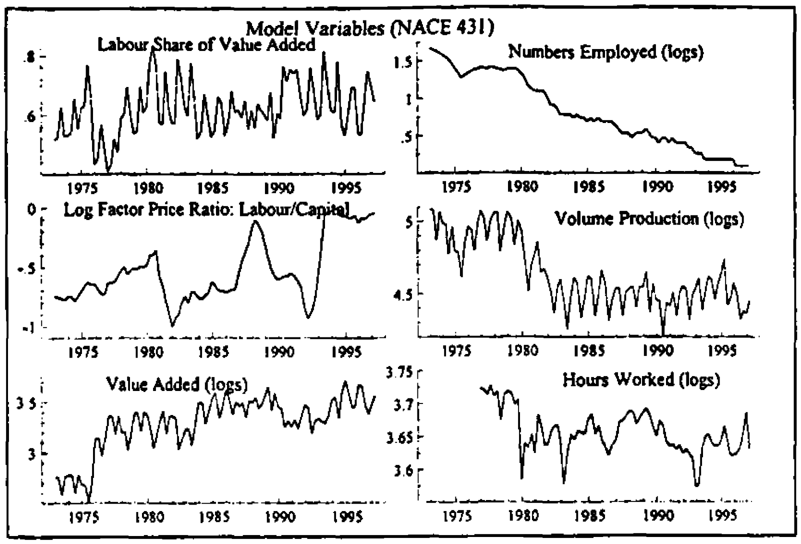

Figure 3.15: Wool Industry: Model Variables

3.6 Estimation Results for Declining Sector: Wool Industry

The wool sector is a good example of a traditional industry in secular decline. Output and employment fell continuously throughout the 1970s and 1980s, by an annual average of -3.7% and -6.4% respectively between 1973 and 1990. The wool sector has traditionally exported to the UK. Since 1990 volume production has remained broadly static while employment has continued to fall (Figure 3.15).

The wool industry is predominantly Irish-owned (21 out of a total 29 firms in 1990), nonetheless the 8 foreign firms accounted for over 60% of 1990 gross output. It is highly export-oriented (75% of gross output was exported in 1990 of which 87% were exported to EC countries) but low in value-added - value added was 33.5% of gross output in 1990. Of the 29 firms in the sector in 1990, 21 were grant-aided by the state.

Its main products in 1990 were 'Woolen and Worsted' (over 10% of total output), 'Yarns sold or added to stock' (over 60%) and 'Other products including blankets, sheep and lamb skins and wool' (just under 25%).

3.6.1 The Unrestricted VAR

We estimated an initial VAR with five lags which included the five model variables $\{l, p_l, q, y, p_k - p_l\}$ together with a trend term and centred seasonal dummies. Examination of the estimated residuals and Chow tests for parameter stability suggested the inclusion of the following three impulse dummy variables, which capture discrete once-off shifts in the cost of capital and cost of labour variables:

1. $I81_1$ This is an impulse dummy in 1981Q1 when there was a once-off decrease in the cost of labour variable.

2. $I92_1$ This is an impulse dummy in 1992Q1, three quarters prior to the currency crisis at the end of 1992 when nominal interest rates reached record highs before the Irish pound devalued in February 1993. Because the interest rate is included as a forward moving average in the cost of capital equation, there is a discrete jump in the cost of capital in the beginning of 1992.

3. $I93_3$ This is an impulse dummy in 1993 Q3 when there was a large once-off increase in the cost of labour.

Dropping the fifth lag was not rejected (F(25, 209) = 0.93 [0.56]). Table 3.32 in Section 3.10.5 reports the system diagnostic tests for the preferred fourth-order UVAR.

There is evidence of non-normality and heteroscedasticity in the residuals of the value added equation, otherwise the diagnostics are clean. The one-step and breakpoint Chow tests suggest some parameter instability in the latter period of the sample, while the forecast Chow tests are clean. Extensive further testing for an initial UVAR specification indicated that this specification came closest to satisfying the requirements of data-congruency.

The Cointegration Space

In our specification of the cointegration space the trend term was restricted to lie within the cointegration space. Both the adjusted and unadjusted *Max* and *Trace* tests suggest a rank of two with marginal evidence of a rank of three from the unadjusted *Trace* test (Table 3.33). We proceed on the basis of a rank of two.

Table 3.34 reports the reduced form estimates for the two cointegrating vectors and the estimated adjustment coefficients while Figure 3.18 plots the estimated cointegrating vectors and recursive eigenvalues.

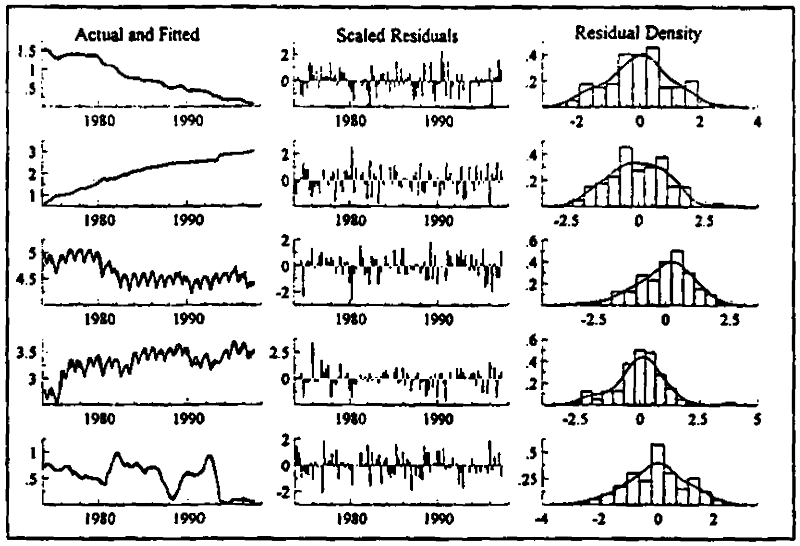

Figure 3.16: Wool Sector UVAR Diagnostics: Actual and Fitted Values

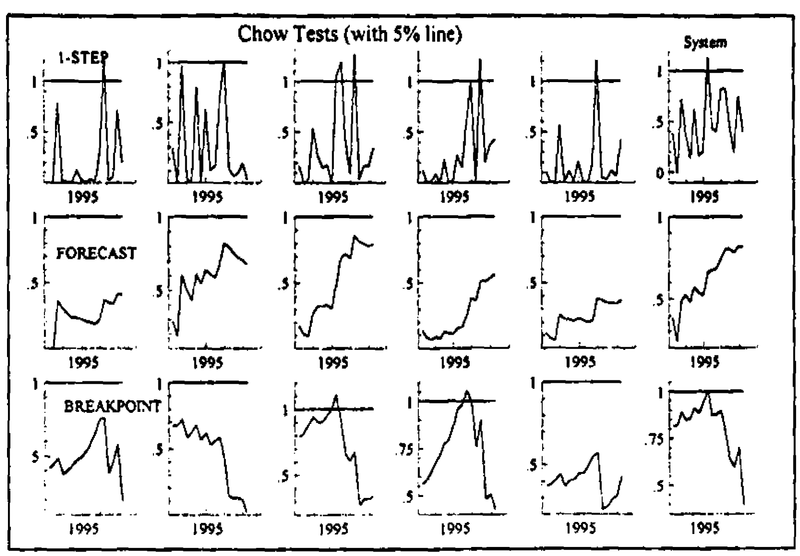

Figure 3.17: Wool Industry: UVAR Chow Tests

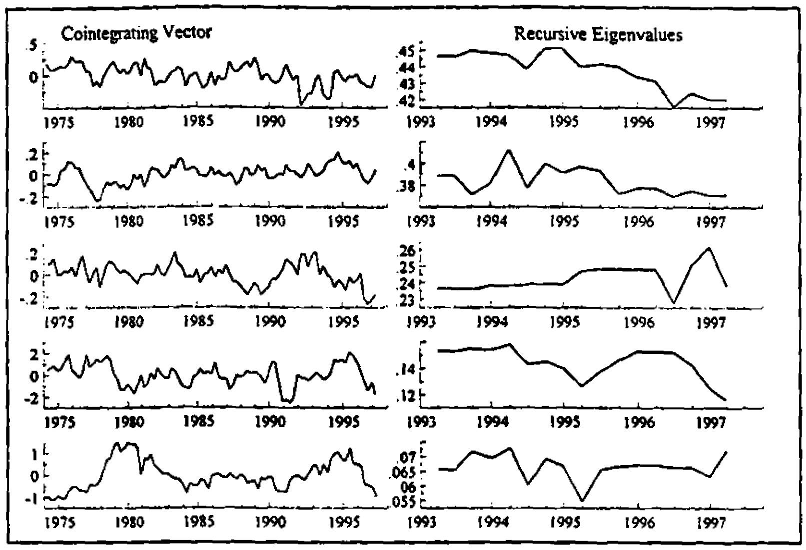

Figure 3.18: Wool Industry: Estimated Cointegrating Vectors and Recursive Eigenvalues

Identification of β

Table 3.35 describes the series of hypothesis tests used to identify the two cointegrating vectors. We identify the first cointegrating vector as a labour demand relation as follows:

- H_1: Translog Technology and Price Homogeneity: *Accepted*

  This key hypothesis imposes the basic translog labour demand equation. Labour's share in value added in logs, $(l + p - y)$, is expressed as a function of relative factor prices $(p_k - p_l)$, with price homogeneity also imposed.

- H_2: H_1 & No Technical Change: *Rejected*

  This hypothesis tests for omission of the trend term from the basic translog labour demand equation.

- H_3: Homotheticity & H_1: *Accepted*

  This hypothesis tests for homotheticity by omission of q from the basic translog labour demand equation.

- H_4: Cobb-Douglas Technology & H_1 : *Rejected*

This hypothesis tests for a Cobb-Douglas technology, dropping the relative price term $(p_k - p_l)$, which implies a constant elasticity of substitution of one.

- H_5: $H_2 \cap H_3$:Homotheticity, No Technical Change & H_1: *Rejected*

Based on this set of hypothesis tests, we identify the first cointegrating vector as a homothetic translog labour demand equation with evidence of technical change, namely H_3.

Under this identification, the parameter values for the second cointegrating vector indicate the rejection of a wage equation specification:

- H_6: Reduced Form Wage Equation & H_3: *Accepted*

  This hypothesis combines the identified first cointegrating vector with a simple wage equation, omitting relative factor prices and the trend term. The wage is expressed as a function of labour, output and value added. However with this normalisation on the wage, the coefficients on each of the other variables were implausibly high, indicating that with an alternative normalisation the coefficient on the wage is very low. Further testing indicated that dropping the wage was not rejected.

- H_7: Output as a Function of Labour & H_6: *Accepted*

  Testing alternative specifications of the second cointegrating vector indicated that only the coefficients on labour and volume output were significant. This gives a specification of output as a function of labour.

The two cointegrating vectors are:

$$l + p_l - y = \underset{(0.08)}{0.47}\,(p_k - p_l) + \underset{(0.002)}{0.02}\,T$$

$$q = \underset{(2.19)}{15}\,l \tag{3.6}$$

Figure 3.19 plots the two restricted cointegrating vectors. This graph plots the fitted values as functions of the cointegrating coefficients only with the short run dynamics partialled out. The fit of the second cointegrating vector is unacceptably poor, however further extensive testing failed to uncover a theoretically and empirically more satisfactory identification.

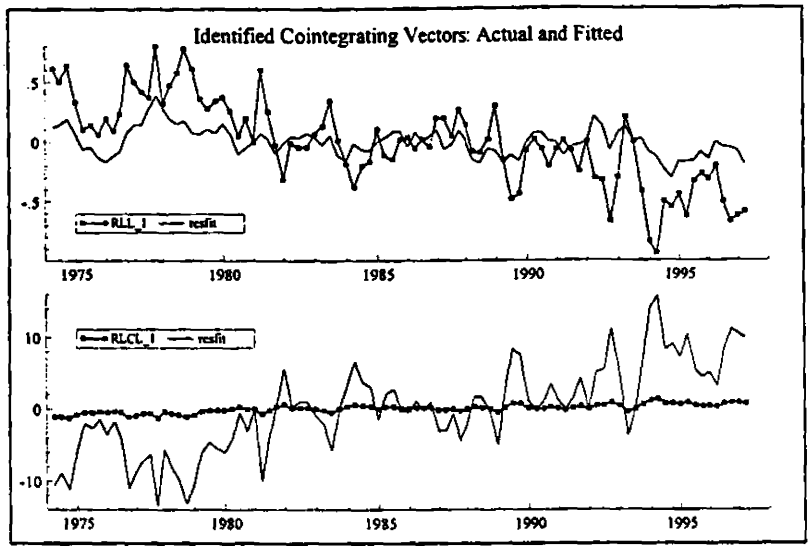

Figure 3.19: Wool Industry: Two Identified Cointegrating Vectors

Weak Exogeneity

Table 3.36 reports the results of testing for weak exogeneity of each of the system variables in turn:

1. H_8: Labour (l) w.e. for β_1 and β_2 & H_7; *Accepted*
2. H_9: Labour Costs (p_l) w.e. for β_1 and β_2 & H_7; *Rejected*
3. H_{10}: Volume Ouput (q) w.e. for β_1 and β_2 & H_7; *Accepted*
4. H_{11}: Value Added (y) w.e. for β_1 and β_2 & H_7; *Rejected*
5. H_{12}: Relative Factor Prices ($p_k - p_l$) w.e. for β_1 and β_2 & H_7; *Rejected*
6. H_{13}: Labour (l) and Volume Output (q) w.e. for β_1 and β_2 & H_7: *Accepted*

The weak exogeneity tests suggest that both labour and output are weakly exogenous to the system.

Equation:	$cvecS_l$	$cvecQ$
Δp_l	-0.02 (0.03)	0.004 (0.002)
Δy	0.31 (0.08)	-0.014 (0.004)
$\Delta(p_k - p_l)$	0.18 (0.04)	-0.01 (0.002)

Table 3.5: Wool Sector: Adjustment Coefficients in SEM

3.6.2 Encompassing the VAR

The Parsimonious VAR

The weak exogeneity results are confirmed by weak exogeneity tests on the estimated PVAR, reported in Table 3.38. The diagnostics for the PVAR are reported in Table 3.37. There is evidence of non-normality and heteroscedasticity in the value added equation, and of autocorrelation in the relative factor prices equation.

The Structural Econometric Model

In formulating the SEM we condition on the labour and output variables as suggested by the exogeneity tests. Table 3.39 reports the diagnostic results from this SEM. The diagnostics suggests evidence of non-normality in the system residuals and in the value added equation.

The estimated adjustment coefficients are shown in Table 3.5. These suggest that only the first cointegrating vector, the long-run labour demand relation, has any significant pass-through in the system:

1. The adjustment coefficients in the labour costs equation are very small and, for the first cointegrating vector not significant.

2. The rate of adjustment of value added and relative factor prices to changes in the long-run demand for labour is very rapid.

3. The rate of adjustment of value added and relative factor prices to changes in the long-run labour productivity relation is negligible.

3.6.3 Discussion of The Estimation Results

The First Cointegrating Vector: A Long Run Labour Demand Function

The first identified cointegrating vector specifies a translog labour demand relation as follows ($\overline{S_l}$=0.62):

$$S_l = 0.29(p_k - p_l) + 0.011T \tag{3.7}$$

The estimated elasticity of substitution is high at 2.23, and the elasticity of demand is high though inelastic at -0.85. These results suggest an underlying production technology not dissimilar to that for the Metal Articles sector, discussed earlier. Technical progress is biased towards labour. The fit of this relation in the 1980s is reasonably close but is erratic at the beginning and end of the sample (Figure 3.19).

The Second Cointegrating Vector: Not Identified

The second identified cointegrating vector is specified as a rudimentary production function:

$$Q = L^{15}$$

This relationship is not plausible given the units of measurement for output and employment as can be seen from Figure 3.20 and produces astronomically large residuals with the exception of the period from the mid-1990s onwards.

Evidence of Misspecification

Weak exogeneity tests on the restricted cointegrating space and on the PVAR indicated that the PVAR could be encompassed by an SEM conditioning on labour and output. This suggests that identification of the first cointegrating vector as a labour demand relation is incorrect, if labour itself is exogenous to the system. Furthermore, given that identification, the second cointegrating vector is a very poorly defined relation between two exogenous variables, labour and output. We therefore conclude that due to misspecification problems we have failed to identify a long run labour demand relation. For this reason we did not proceed to further estimation of an SEM to encompass the VAR.

3.7 Conclusions

In this chapter we estimated long-run demand for labour equations for three sectors, representative of medium-growth, high-growth and declining sectors in Irish manufacturing. The

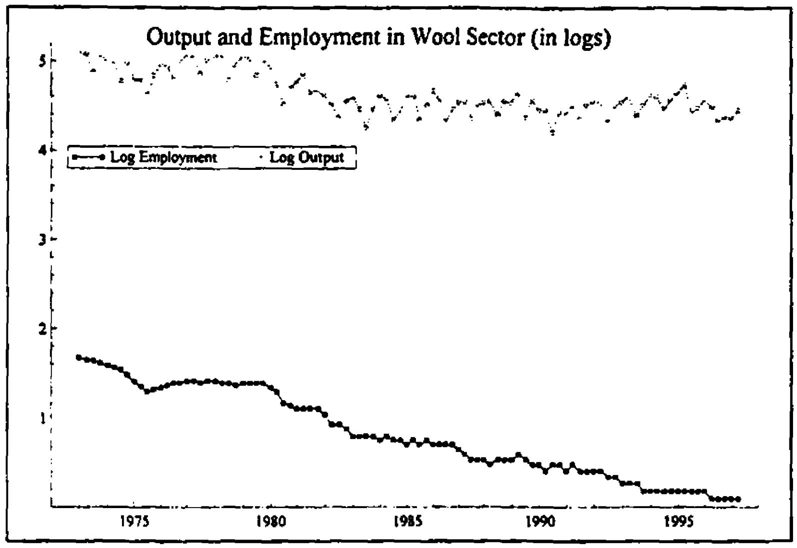

Figure 3.20: Ouput and Employment in the Wool Sector (in logs)

estimated results suggest that the underlying production technology in the medium-growth and declining sectors is similar, with high substitutability between labour and capital for a given level of output, while for the high-growth sector the estimated underlying production technology was very different, pointing to very low substitutability between labour and capital for a given level of output.

There was strong evidence of misspecification in the declining and high growth sector models. Therefore we conclude that we have failed to identify a long run demand for labour equation for these sectors.

Our results for the medium-growth sector suggest the following conclusions:

1. Movements in relative prices do matter in driving the demand for labour. Our results suggest that the decline in employment in this sector in the 1980s, a period when output was constant, is in part explained by the substitution of relatively cheaper capital for labour in production.

2. The two major events associated with EU membership since 1973, namely joining the EMS in 1979 (and thereby breaking the link with sterling) and the completion of the single market in 1992 had long run effects in increasing the demand for labour, possibly through human capital effects.

3. Disaggregation is critical in studies of labour demand in Ireland. The empirical results were only robust for Metal Articles, a sector which has undergone relatively little change over the estimation period.

3.8 Tables and Graphs for 31 Sectors

31 Manufacturing Sectors in Quarterly Data Set		
NACE Sector	**Mnemonic**	**Description**
24	24	Manufacture of Non-Metallic Mineral Products
22	22	Production and Preliminary Processing of Metals
31	31	Manufacture of metal articles
32	32	Mechanical engineering
33	33	Office and Data Processing
34	34	Electrical Engineering
35	35	Manuf and assembly of motor vehicles (incl. parts)
36	36	Manufacture of other means of transport
37	37	Instrument Engineering
251	251	Basic Industrial Chemicals
257	257	Pharmaceuticals
255-256, 258-260	255260	Chemicals, Remainder (incl. Man-made Fibres)
412	412	Slaughtering, preparing and preserving of meat
413	413	Manufacture of dairy products
416,422	416422	Grain Milling and Animal feeding Stuffs
419	419	Bread, biscuits and flour confectionery
420,421	420421	Sugar; Cocoa, Chocolate and Sugar Confectionery
411,414-415,417-418,423	41rem	Other Food
431	431	Wool Industry
436	436	Knitting industry
432-434, 437-439	43rem	Other Textiles
424-428	424428	Drink
429	429	Tobacco
44, 451	44451	Leather and Footwear
453-456	453456	Clothing (incl. Furs and Household Textiles)
481-482	481482	Manufacture of rubber products (incl. retreading c tyres)
483	483	Processing of plastics
49	49	Other manufacturing industries
46	46	Timber and Wooden Furniture Industries
471-472	471472	Paper and Paper Products
473-474	473474	Printing and Publishing

Table 3.6: The 31 NACE Manufacturing Sectors in the Data Set.

	Number of firms			Gross Output in 1990			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sector	Total	Percent Foreign	Percent Exporting	£m.	Proportion Exported	Proportion Exporting	(6)/(7)
24	306	13.73	43.14	884,903	0.46	0.72	0.64
22	45	17.78	88.89	189,257	0.68	0.97	0.70
31	597	10.05	62.98	662,038	0.42	0.78	0.54
32	278	19.78	68.35	493,989	0.69	0.89	0.78
33	56	55.36	100.00	2,075,937	0.97	1.00	0.97
34	291	43.99	81.44	1,911,718	0.90	0.97	0.93
35	82	10.98	41.46	140,901	0.33	0.44	0.74
36	38	15.79	65.79	235,079	0.59	0.85	0.69
37	81	58.02	83.95	544,686	0.98	0.99	0.98
251	34	26.47	50.00	454,016	0.47	0.79	0.60
257	74	64.86	98.65	1,471,189	0.97	1.00	0.97
255260	109	39.45	75.23	531,205	0.77	0.92	0.83
412	133	11.28	77.44	2,004,102	0.48	0.94	0.51
413	97	5.15	46.39	2,068,151	0.49	0.79	0.61
416422	118	0.00	35.59	555,558	0.06	0.25	0.26
419	227	0.00	11.45	215,306	0.04	0.24	0.17
420421	39	28.21	69.23	381,187	0.51	0.77	0.66
41rem	151	17.22	82.78	1,162,137	0.79	0.96	0.82
431	29	27.59	86.21	86,671	0.74	0.96	0.77
436	75	17.33	74.67	124,940	0.66	0.83	0.79
43rem	63	50.79	85.71	283,521	0.72	0.88	0.81
424429	70	45.71	70.00	910,850	0.39	0.88	0.44
44451	52	9.62	80.77	79,988	0.56	0.97	0.57
453456	319	11.29	74.61	319,513	0.46	0.84	0.54
481482	42	45.24	76.19	142,843	0.91	0.97	0.94
483	218	23.85	74.77	441,242	0.54	0.88	0.62
49	109	16.51	72.48	395,798	0.29	0.35	0.83
46	435	1.38	63.68	378,791	0.27	0.71	0.38
471472	87	18.39	65.52	287,709	0.20	0.68	0.30
473474	347	3.17	53.89	529,748	0.13	0.57	0.22
manuf	4602	17.32	64.25	19,962,972	0.62	0.85	0.73

Gross Output (QV) is measured at 1990 current prices.

Column (3) % of foreign owned firms in each sector.

Column (4) % of exporting firms in each sector.

Column (6) is the share of gross output which was exported.

Column (7) is the share of gross output produced by exporting firms.

Column (8) is the share of *exporting* firms gross output which was exported.

Table 3.7: Selected Indicators On Size, Ownership and Exports in 1990

NACE Sector	Share of Gross Output	Output Average Annual Growth Rates				Cumulative Percentage Change
	Average 1973-1990	*1973-81*	*1981-1990*	*Δ in Rate*	*1973-1990*	*1973-1990*
24	0.05	2.8	0.5	-2.3	1.5	29.8
22	0.01	-6.2	5.3	11.6	-0.3	-4.3
31	0.03	4.9	-0.6	-5.5	2.0	38.9
32	0.02	5.6	4.2	-1.4	4.9	124.9
33	0.06	44.5	20.6	-23.9	31.4	10213.0
34	0.05	5.5	15.9	10.4	10.9	477.3
35	0.02	-3.4	-10.6	-7.2	-7.3	-72.5
36	0.01	-0.7	0.0	0.7	-0.4	-5.9
37	0.02	6.6	9.1	2.5	7.9	266.3
251	0.02	5.2	5.8	0.6	5.5	148.8
257	0.04	17.3	12.2	-5.1	14.5	904.6
255260	0.02	8.3	3.9	-4.4	5.7	157.0
412	0.10	3.1	6.4	3.3	4.8	122.5
413	0.11	5.3	2.9	-2.3	4.0	95.5
416422	0.04	4.9	1.6	-3.3	2.9	62.0
419	0.02	0.3	-3.2	-3.5	-1.6	-23.8
420421	0.03	-1.2	2.0	3.2	0.3	5.19
41rem	0.04	7.3	9.3	2.0	8.0	272.9
431	0.01	-3.5	-3.8	-0.4	-3.7	-46.9
436	0.01	-4.4	2.9	7.3	-0.6	-10.4
43rem	0.02	6.7	-2.2	-8.9	1.5	29.7
424428	0.03	3.1	3.1	-0.1	3.1	68.0
429	0.02	0.9	-2.6	-3.5	-0.9	-14.9
44451	0.01	-5.5	-4.0	1.5	-4.9	-57.7
453456	0.02	-1.7	0.6	2.3	-0.6	-9.7
481482	0.01	2.4	1.4	-0.9	1.9	37.2
483	0.02	5.5	7.2	1.7	6.4	185.6
49	0.01	12.1	0.5	-11.5	5.8	161.0
46	0.02	0.0	0.3	0.2	0.2	2.9
471472	0.02	-1.6	1.3	2.9	-0.1	-1.1
473474	0.02	1.8	5.1	3.3	3.5	79.7
manuf	0.92	4.5	6.9	2.4	5.8	159.5

Volume Gross Output (Q) is measured at 1985 constant prices

Table 3.8: Volume Output Growth Rates by Sector

NACE Sector	Share of Total Employment	Employment Average of Annual Growth Rates				Cumulative Percentage Change
	Average 1973-1990	*1973-81*	*1981-1990*	Δ *in Rate*	*1973-1990*	*1973-1990*
24	0.06	1.8	-3.7	-5.5	-1.1	-17.7
22	0.01	-7.1	-3.4	3.7	-5.2	-59.4
31	0.06	3.7	-3.0	-6.7	0.1	0.9
32	0.03	4.7	0.3	-4.4	2.4	48.5
33	0.02	22.3	4.5	-17.8	12.5	642.3
34	0.07	4.4	3.7	-0.7	4.0	95.4
35	0.02	-3.4	-6.8	-3.4	-5.2	-59.8
36	0.02	-0.9	-2.5	-1.5	-1.7	-25.6
37	0.03	13.1	2.4	-10.7	7.3	229.3
251	0.01	0.9	-2.0	-2.9	-0.6	-10.1
257	0.02	8.0	7.2	-0.7	7.6	245.6
255260	0.02	1.7	-2.2	-3.9	-0.4	-6.6
412	0.05	0.2	0.2	0.0	0.2	2.9
413	0.04	0.4	-2.8	-3.2	-1.3	-20.4
416422	0.02	-1.5	-5.3	-3.9	-3.5	-45.6
419	0.04	-0.5	-5.9	-5.4	-3.4	-44.3
420421	0.03	-2.8	-4.4	-1.6	-3.6	-46.6
41rem	0.03	-0.5	0.7	1.2	0.2	2.6
431	0.01	-6.6	-6.3	0.3	-6.4	-67.7
436	0.02	-6.6	-0.2	6.3	-3.3	-43.1
43rem	0.03	-0.7	-6.3	-5.5	-3.7	-47.2
424428	0.03	0.5	-6.0	-6.5	-3.0	-40.7
429	0.01	-0.3	-6.0	-5.6	-3.3	-44.0
44451	0.02	-5.3	-13.4	-8.1	-9.7	-82.4
453456	0.06	-3.0	-2.3	0.7	-2.6	-36.0
481482	0.01	-0.8	-2.3	-1.5	-1.6	-24.4
483	0.02	4.6	3.9	-0.7	4.2	101.5
49	0.01	3.5	-0.4	-3.9	1.5	27.8
46	0.04	-0.8	-3.1	-2.3	-2.0	-29.2
471472	0.02	-3.0	-3.2	-0.2	-3.1	-41.2
473474	0.5	0.6	-0.5	-1.1	0.0	0.4
manuf	0.89	0.3	-1.5	-1.9	-0.7	-10.7

Table 3.9: Employment Growth Rates by Sector

NACE Sector	Output per head Index 1985=100	Output per head Average Annual Growth Rates				Cumulative Percentage Change
	Average 1973-90	*1973-81*	*1981-1990*	Δ *in Rate*	*1973-1990*	*1973-1990*
24	93.88	0.9	4.3	3.4	2.7	57.6
22	79.40	1.0	9.1	8.1	5.2	135.9
31	88.39	1.2	2.5	1.3	1.9	37.8
32	96.88	0.9	3.9	3.0	2.5	51.4
33	76.28	18.3	15.4	-2.9	16.8	1295.2
34	88.56	1.0	11.8	10.7	6.6	195.5
35	106.98	0.0	-4.1	-4.1	-2.2	-31.7
36	76.23	0.2	2.5	2.3	1.4	26.5
37	95.88	-5.7	6.6	12.3	0.6	11.3
251	73.27	4.2	7.9	3.7	6.2	176.6
257	79.60	8.6	4.6	-4.0	6.5	190.7
255260	80.09	6.1	6.1	0.0	6.1	175.3
412	83.68	2.9	6.2	3.3	4.6	116.3
413	75.96	4.8	5.9	1.1	5.4	145.4
416422	83.78	6.2	7.0	0.8	6.6	197.7
419	93.22	0.8	2.8	2.0	1.9	37.0
420421	83.78	1.4	6.5	5.1	4.1	97.1
41rem	88.61	7.5	8.2	0.7	7.9	263.3
431	89.81	3.4	2.6	-0.7	3.0	64.3
436	91.66	2.3	3.1	0.9	2.7	57.6
43rem	78.8	7.0	4.0	-3.0	5.4	145.8
424428	85.76	2.7	9.7	7.0	6.3	183.3
429	98.73	1.3	3.6	2.3	2.5	51.9
44451	79.19	-0.3	10.5	10.8	5.3	139.7
453456	94.96	1.2	2.8	1.6	2.0	41.1
481482	85.03	3.2	3.9	0.6	3.6	81.5
483	87.1	0.9	3.2	2.3	2.1	41.9
49	92.29	8.2	0.9	-7.3	4.3	104.3
46	93.13	0.8	3.5	2.6	2.2	45.3
471472	88.22	1.4	4.7	3.2	3.1	68.3
473474	96.9	1.2	5.6	4.3	3.5	79.1
manuf	82.69	4.2	8.6	4.4	6.5	190.5

Output per head = Q/L = Volume Gross Output / Total Employment

Table 3.10: Labour Productivity: Growth Rates by Sector

	Labour Share of Value Added			
	Average	*Percentage Point Changes*		
Sector	*1973-1990*	*1973-1981*	*1981-1990*	*1973-1990*
24	0.43	-1.1	-6.2	-7.3
22	0.52	15.2	-31.9	-16.7
31	0.53	-1.4	-5.1	-6.4
32	0.44	-5.1	-2.6	-7.8
33	0.16	-21.1	-5.1	-26.2
34	0.36	-2.0	-20.5	-22.4
35	0.74	20.7	-15.9	4.8
36	0.72	4.1	-20.8	-16.7
37	0.29	13.1	-9.4	3.7
251	0.45	1.2	7.2	8.4
257	0.10	-4.6	1.6	-3.0
255260	0.34	0.8	-7.8	-7.0
412	0.42	5.5	-10.4	-4.9
413	0.41	4.8	-15.2	-10.4
416422	0.36	-6.0	-5.6	-11.6
419	0.59	6.8	-10.5	-3.7
420421	0.50	5.7	-18.1	-12.3
41rem	0.20	-29.4	-9.4	-38.9
431	0.52	7.2	5.1	12.3
436	0.63	12.2	-3.3	8.9
43rem	0.52	-3.7	-1.2	-4.9
424428	0.31	5.3	-15.9	-10.7
429	0.32	0.6	-9.3	-8.7
44451	0.58	5.1	-10.4	-5.2
453456	0.60	7.2	-0.8	6.4
481482	0.53	7.8	-15.2	-7.4
483	0.44	5.7	-6.3	-0.6
49	0.44	-24.7	0.9	-23.8
46	0.52	-1.0	-6.2	-7.2
471472	0.49	10.8	-14.3	-3.5
473474	0.55	1.3	-8.1	-6.8
manuf	0.38	-5.2	-13.7	-18.9

Labour Share of Value-Added = YW/YV, Wage Bill/Net Output

Table 3.11: Changes in Labour Share of Value Added by Sector

	Value Added/Gross Output			
	Average	*Percentage Point Changes*		
Sector	*1973-90*	*1973-81*	*1981-1990*	*1973-1990*
24	0.48	-4.5	3.4	-1.1
22	0.35	-8.4	2.8	-5.6
31	0.45	-2.2	-2.5	-4.8
32	0.48	-2.2	-0.6	-2.8
33	0.43	-3.4	9.5	6.1
34	0.50	1.2	12.0	13.2
35	0.32	-3.6	13.9	10.3
36	0.50	1.3	7.6	8.9
37	0.60	-5.8	13.6	7.8
251	0.30	-11.4	-5.2	-16.6
257	0.71	9.2	2.1	11.3
255260	0.46	-11.0	6.0	-4.9
412	0.15	-1.0	-0.3	-1.3
413	0.16	-1.2	2.0	0.9
416422	0.18	-2.1	2.9	0.8
419	0.43	-6.4	2.7	-3.8
420421	0.32	-2.0	7.5	5.6
41rem	0.54	19.7	18.1	37.8
431	0.35	-1.9	-1.0	-2.8
436	0.48	-2.1	-1.8	-4.0
43rem	0.35	-6.1	6.3	0.1
424428	0.60	-13.6	5.1	-8.5
429	0.49	44.1	10.8	54.9
44451	0.35	3.2	-12.2	-9.0
453456	0.47	0.0	-2.4	-2.4
481482	0.47	-10.3	7.5	-2.8
483	0.42	-1.1	3.1	2.1
49	0.48	-0.3	3.8	3.5
46	0.42	-1.0	-2.4	-3.4
471472	0.38	-6.3	3.2	-3.1
473474	0.65	-4.1	-0.5	-4.6
manuf	0.38	1.4	7.3	8.7

Value Added/Gross Output = YV/QV in current prices

Table 3.12: Changes in Value Added as a Proportion of Gross Output

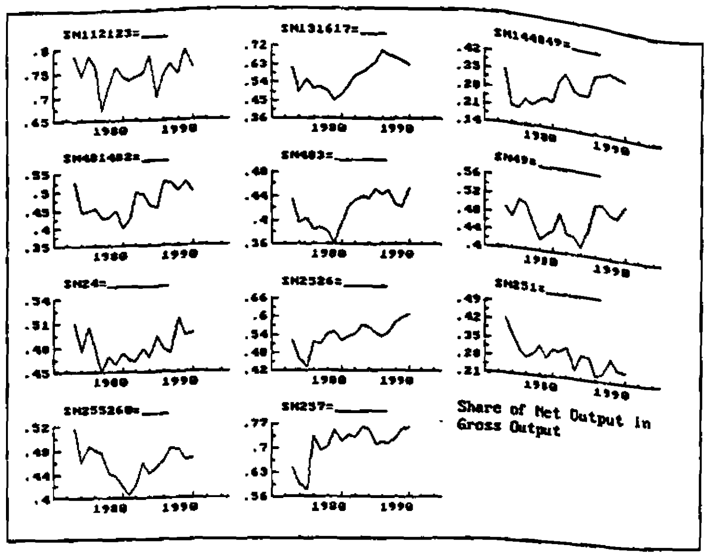

Figure 3.21: Share of Value Added in Gross Output 1973-1990 in Selected Sectors I

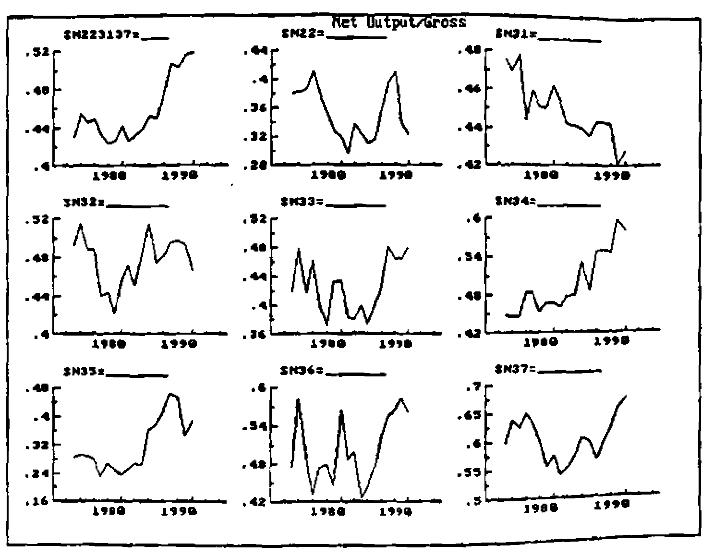

Figure 3.22: Share of Value Added in Gross Output 1973-90 in Selected Sectors II

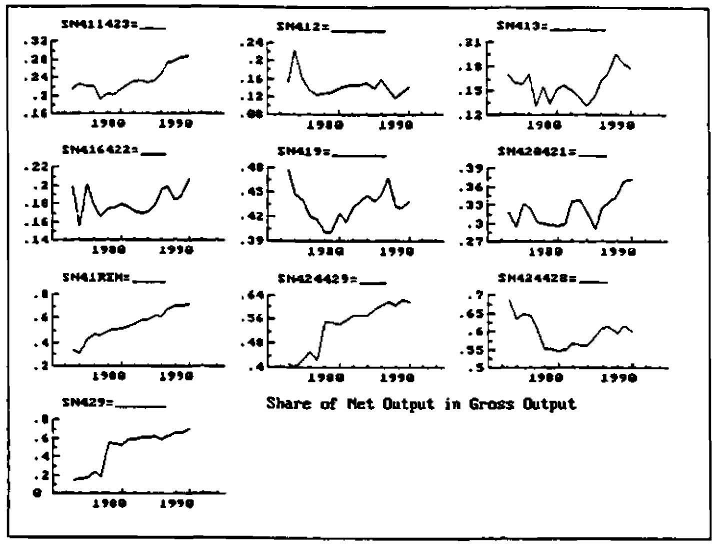

Figure 3.23: Share of Value Added in Gross Output 1973-90 in Selected Sectors III

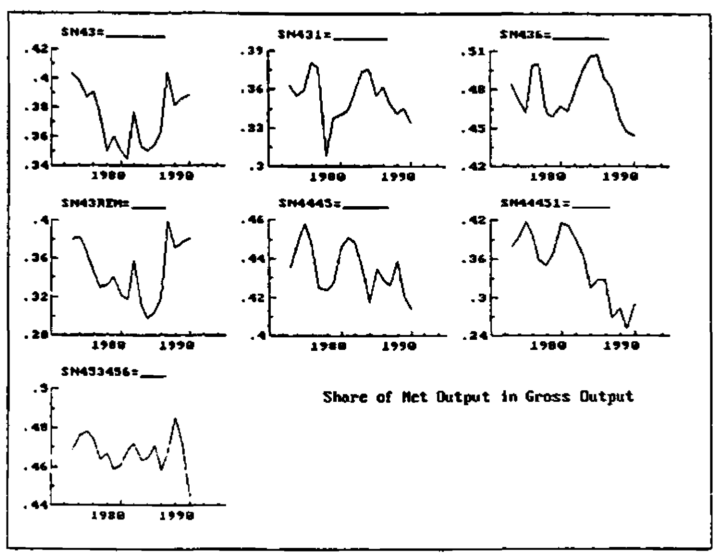

Figure 3.24: Share of Value Added in Gross Output 1973-90 in Selected Sectors IV

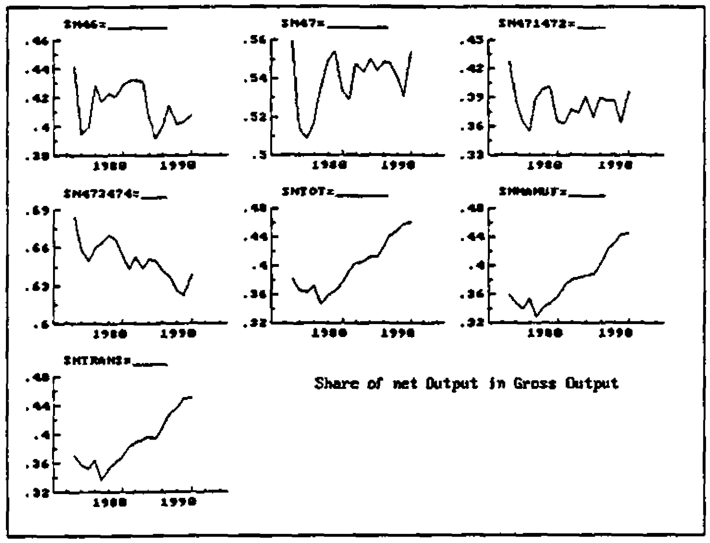

Figure 3.25: Share of Value Added in Gross Output 1973-90 in Selected Sectors V

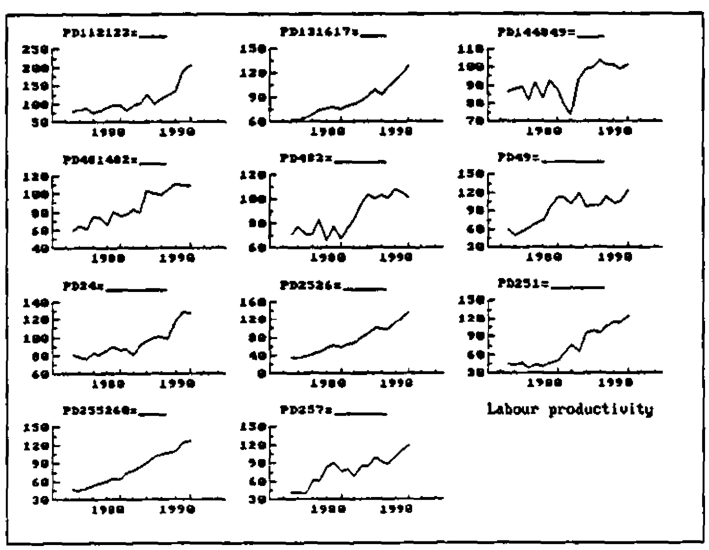

Figure 3.26: Average Labour Productivity in Selected Sectors I

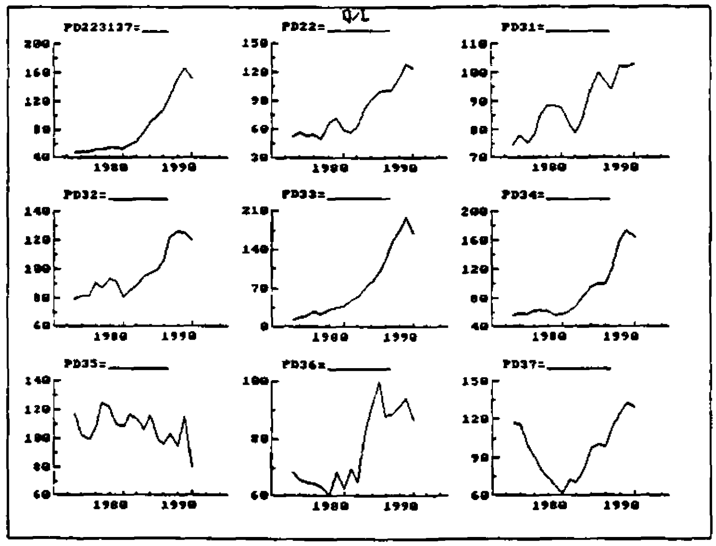

Figure 3.27: Average Labour Productivity in Selected Sectors 1973-90 II

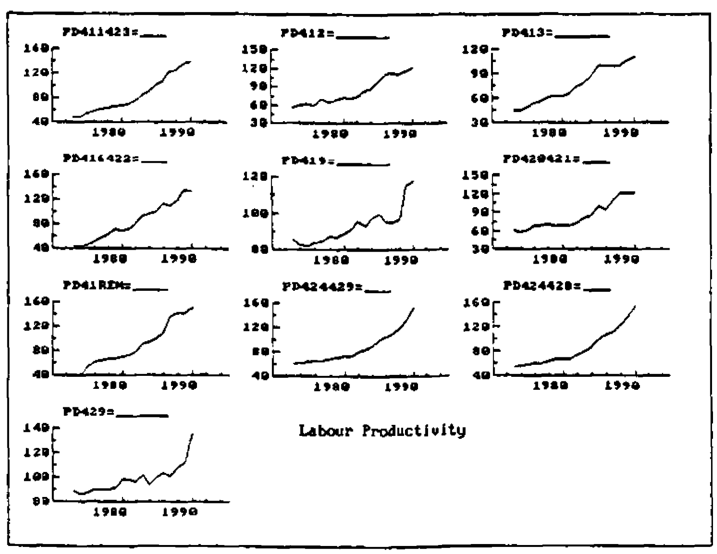

Figure 3.28: Average Labour Productivity in Selected Sectors III

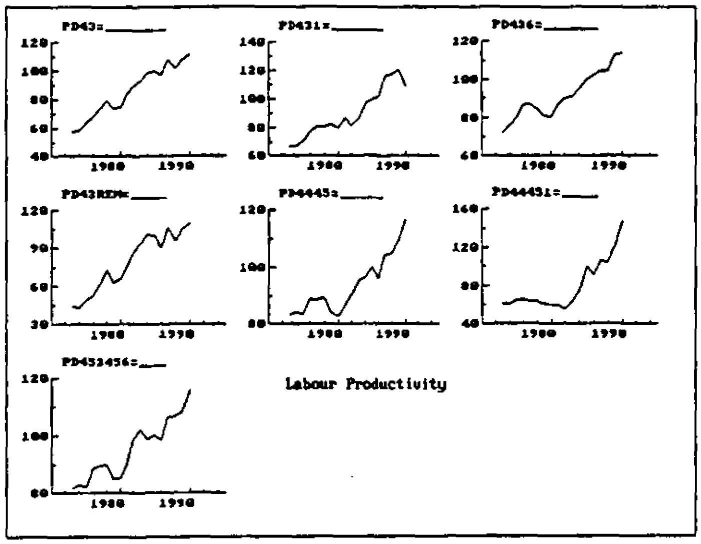

Figure 3.29: Average Labour Productivity in Selected Sectors 1973-90 IV

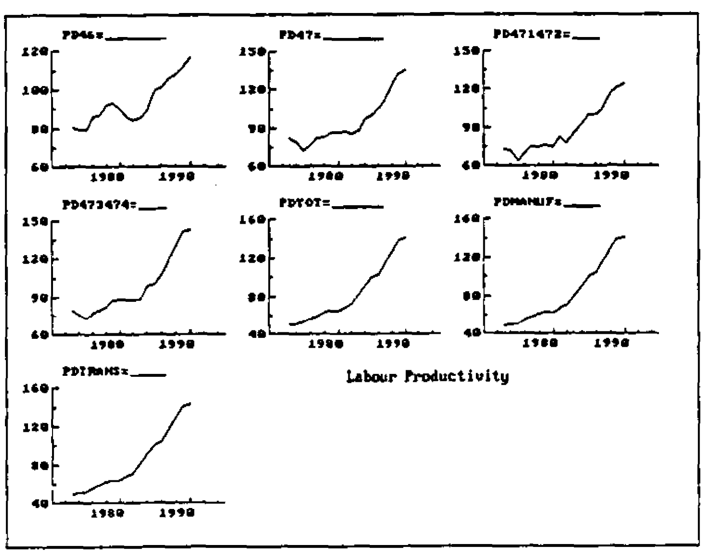

Figure 3.30: Average Labour Productivity in Selected Sectors 1973-90 V

3.9 The Quarterly Dataset of Variables

This section describes the quarterly time series databank of variables used in modelling the long-run demand for labour in individual sectors in Part I. The key source of data is the annual Census of Industrial Production which is available 1973-90. Any econometric study using these data would be severely restricted by the small number of observations available. Therefore additional short-term indicators are used to extend the number of observations available for each variable. This is not purely an exercise in increasing degrees of freedom, these indicators contain important new information about the behaviour of these variables within a given year. Because the short-term indicators for employment and wages are quarterly series, all the monthly databank series are aggregated or averaged to quarterly seasons. The series in the databank (including some missing observations) cover the period 1973Q1-1997Q2, 98 observations. They cover all manufacturing activity disaggregated into 31 individual sectors. Appendix B.1.5 describes the quarterly dataset in some detail.

3.9.1 Factor Demand Estimation: The Data Requirements

Given X as an $N \times 1$ vector of factor inputs, P_X as an $N \times 1$ vector of factor prices, Q as total production and C as total cost we can write the cost function of the firm as $C(P_X, Q)$. This states that the total cost which the firm faces depends on the prices of all the factors used in production and on the level of output produced. The N conditional factor demand functions $X_i(P_X, Q)$ can be derived from the cost function using first order conditions for cost minimisation and Shephard's Lemma. The demand for factor X_i depends on the prices of all other factors used in production and on the level of output. The assumption that the cost function is convex means that the Hessian matrix of second-order derivatives of the cost function is negative semi-definite. This leads to a set of symmetry and adding-up restrictions on the parameters of the factor demand equations. In practice these restrictions mean that it is only necessary to estimate $N - 1$ equations.

Value-Added Framework: If only two factors, labour (L) and capital (K), are included in the factor demand system, the total cost for these two factors sums to the value-added (YV) in the production process. This is only a partial factor demand system since it ignores the demand for intermediate inputs (MV). Value-added is defined as

$$YV = Y.P_Y = L.P_l + K.P_k \tag{3.8}$$

The demand for labour is $L(P_l, P_k, Y)$. Because $N = 2$ we only need to estimate the demand for one factor.

Gross Output Framework: If all factors are included in the factor demand system then total cost equals gross output (QV). Gross Output is defined as

$$QV = Q.P_Q = M.P_m + L.P_l + K.P_k \tag{3.9}$$

The demand for labour is $L(P_l, P_k, P_m, Q)$. To estimate the full factor demand system ($N = 3$) it is necessary to also estimate either the demand for materials $M(P_l, P_k, P_m, Q)$ or the demand for capital services $K(P_l, P_k, P_m, Q)$.

Each of the factors M, L, and K could be further disaggregated, this would increase N and the number of factor demand equations to be estimated.

3.9.2 The Data Constraint: A Value-Added Framework

1. *Annual Data Set*: From the annual CIP we can construct the following set of identities:

QV	=	MV	+	YV	{=	LV	+	KV}
Gross Output		Intermediate Inputs		Value Added		Wages Salaries		Capital Expenditure

   The data constraint arises because of a lack of data on prices P_m and P_k. Given total employment (L) we can derive an implied price for labour (P_l). Volume index numbers supplied by the CSO (Q) allow for calculation of an output price deflator. This gives the following breakdown:

$$QV = Q.P_Q = MV + YV (= LV (= P_l.L) + KV)$$

2. *Quarterly Data Set*: The following short-term indices are available:

I_{QV}	I_Q	I_{P_Q}	L	I_{P_l}	I_{W_H}	H
Turnover Index	Production Index	Producer Prices Index	Employment	Weekly Wages Index	Hourly Wages Index	Hours Worked per week

   There are no quarterly indicators for M, MV, K, KV or YV.

Value Added Framework

1. The quarterly and annual data can be combined directly for QV, Q, P_Q, P_l, L. This gives combined quarterly and annual data on

$$QV = Q.P_Q = P_l.L + \underbrace{\text{Residual}}_{\{=MV+KV\}}$$

2. A quarterly proxy for value added, YV^E can be estimated using the quarterly turnover index I_{QV}. This gives

$$QV = Q.P_Q = MV^R + YV^E\{= P_l.L + KV^R\}$$

where R indicates a residual.

3. A quarterly cost of capital index $I^E_{P_K}$ can be estimated from extraneous data sources (see Appendix B.3). This gives

$$QV = Q.P_Q = MV^R + YV^E\{= P_l.L + KV^R\{= K^R.I^E_{P_K}\}\}$$

Using these data the following demand for labour function can be estimated with quarterly data within a "quasi"[6] value-added framework:

$$L(P_l, I^E_{P_k}, Q) \tag{3.10}$$

It is also possible to estimate a cost of materials index $I^E_{P_M}$ from extraneous data sources. This would permit estimation of a demand for labour function in a gross output framework

$$L(P_l, I^E_{P_k}, I^E_{P_m}, Q) \tag{3.11}$$

with quarterly data. In this case for full systems estimation it would be necessary to also estimate the demand for capital services $K^E(.)$ or for intermediate inputs $M^E(.)$. There are no independent sources of quarterly data on either of these at a sectoral level but they could be proxied as $K^R = \frac{KV^R}{I^E_{P_k}}$ and $M^R = \frac{MV^R}{I^E_{P_m}}$. The value-added specification was preferred because the variables M^R and K^R are constructed by combining estimation residuals (KV^R and MV^R) with estimated price indices ($I^E_{P_k}$ and $I^E_{P_m}$) so that they have a doubling of estimation error.

3.9.3 Definitions of the Quarterly Databank Variables

1. **Employment L**

   This variable measures the numbers employed (excluding outside piece workers) in each sector in the middle week of the last month of each quarter.

[6]Quasi because in this formulation we include Q volume production rather that Y volume value added since we have no estimate of P_Y and therefore no estimate of Y.

2. **Cost of Labour P_l**

   The variable W measures the annual wage bill per worker. This measure excludes a wide range of non-wage labour costs which should properly be included as a part of the cost of labour to the firm. In Appendix B.1.5 the variable F_l is defined, this measures the ratio of non-wage costs to wage costs for the 33 sectors at annual intervals. This ratio was used to scale up the annual wage bill data, linking it to the quarterly data. We define the quarterly variable P_l as that which includes non-wage labour costs in its *level*. The within-year quarterly growth rate of P_l is based on an indicator of the growth in weekly gross earnings per worker as measured in the middle week of the last month of each quarter. Therefore the variable P_l moves at discrete annual intervals to reflect changes in non-wage labour costs (in earlier years, 1973-78, at three year intervals.)

3. **Value Added YV**

   The variable YV is measured using annual *net* output at quarterly intervals. The within-year growth rate of YV is a proxy measure since it is based on the growth rate of *turnover*. Using this measure assumes that net output is a constant proportion of gross output within any given year, an assumption which was unavoidable in the absence of quarterly data on net output. The variable YV is used as a proxy for value-added, however the net output measure includes certain items (advertising and marketing) which do not figure in a true definition of value-added. This means that the residual measure of capital expenditure $KV^R = YV^E - LV$ is over estimated and the share of labour in value-added - $S_L = \frac{LV}{YV^E}$ is underestimated.

4. **Volume Production Q**

   The variable Q measures annual gross output at constant 1985 prices at quarterly intervals.

5. **Cost of Capital P_K**

   We define the *pre-tax cost of capital* as

$$P_{kt} = p_{It}\frac{(1-g_t)}{(1-\tau_t)}(i_t - \gamma_t + \delta) \tag{3.12}$$

   where p_I is the price of investment goods, γ is the rate of change of investment goods prices, δ is the rate of economic depreciation, i is the nominal rate of interest, g is an average measure of the present value of tax allowances and investment grants and τ is the rate of corporation tax. Appendix B.3 contains a full discussion of the definition and measurement of this variable.

3.10 Tables and Graphs for Three Selected Sectors

3.10.1 Unit Root Tests on Model Variables

Unit root tests statistics are based on the Augmented Dickey-Fuller test including a trend, seasonal dummies and a maximum lag length of 5:

$$\Delta Y_t = \alpha + \mu t + \beta Y_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta Y_{t-i} + u_t$$

The t-statistic on β tests the hypothesis that the variable Y is I(1) against I(0). The other statistics reported in the table give the estimated value of β, the equation standard error σ, the lag length, t-value and the significance level on the longest lag included, and the significance level of an F-test on the lags dropped. Insignificant lags (up to a maximum of 5) were dropped if insignificant at the 5% level.

S_l is the share of labour in value added, l is employment, p_l is the cost of labour, p_k is the cost of capital, y is value added, q is volume production and h is hours worked. Lower case letters denote that the variables are in logs.

	t_β	β	σ	lag	$t_{\Delta Y_i}$	$t-prob$	$F-prob$
S_l	-3.58*	0.66	0.03	0			0.29
l	-0.76	0.98	0.02	2	2.13	0.04	0.21
p_l	-2.08	0.94	0.02	4	-3.00	0.00	0.94
p_k	-3.17	0.93	0.04	1	8.90	0.00	0.07
y	-4.49**	0.67	0.04	4	2.26	0.03	0.79
q	-1.94	0.89	0.04	0			0.67
h	-3.06	0.76	0.01	0			0.53
ΔS_l	-8.63**	-0.68	0.03	1	2.12	0.03	0.44
Δl	-3.51*	0.54	0.02	1	-2.01	0.05	0.49
Δp_l	-6.62**	-0.94	0.02	3	2.79	0.00	0.96
Δp_k	-5.06**	0.43	0.04	3	2.07	0.04	0.39
Δy	-10.01**	-0.20	0.05	0			0.11
Δq	-8.49**	-0.04	0.04	0			0.68
Δh	-8.07**	-0.36	0.02	1	2.26	0.03	0.35

Table 3.13: Metal Articles Sector (NACE 31): Descriptive Unit Root Test Statistics for Model Variables

	t_β	β	σ	lag	$t_{\Delta Y_i}$	$t-prob$	$F-prob$
S_l	-2.02	0.80	0.01	1	-4.15	0.00	0.77
l	-2.14	0.90	0.02	0			0.79
p_l	-3.46	0.87	0.02	0			0.16
p_k	-3.71*	0.87	0.04	1	8.62	0.00	0.10
y	-1.77	0.82	0.12	1	-4.04	0.00	0.86
q	-1.68	0.75	0.11	4	-2.47	0.02	0.54
h	-4.89**	0.49	0.01	0			0.21
ΔS_l	-14.76**	-0.58	0.02	0			0.71
Δl	-9.77**	-0.06	0.02	0			0.91
Δp_l	-7.76**	-0.05	0.02	0			0.87
Δp_k	-5.01**	0.42	0.04	3	2.23	0.03	0.23
Δy	-14.49**	-0.57	0.12	0			0.79
Δq	-7.24**	-1.97	0.11	3	2.99	0.00	0.24
Δh	-7.06**	-1.38	0.01	3	2.71	0.01	0.16

Table 3.14: Pharmaceuticals Sector (NACE 257): Descriptive Unit Root Test Statistics for Model Variables

	t_β	β	σ	lag	$t_{\Delta Y_i}$	$t-prob$	$F-prob$
S_l	-4.62**	0.53	0.05	0			0.91
l	-2.05	0.89	0.04	0			0.37
p_l	-3.07	0.83	0.05	0			0.75
p_k	-2.50	0.95	0.04	2	-2.08	0.04	0.08
y	-3.30	0.74	0.08	0			0.99
q	-2.68	0.83	0.07	0			0.66
h	-4.22**	0.59	0.02	0			0.47
ΔS_l	-7.96**	-0.45	0.06	1	1.95	0.06	0.11
Δl	-10.02**	-0.18	0.04	0			0.40
Δp_l	-10.34**	-0.20	0.05	0			0.85
Δp_k	-4.40**	0.62	0.05	0			0.00
Δy	-9.26**	-0.12	0.08	0			0.60
Δq	-6.68**	-0.50	0.07	2	2.02	0.05	0.93
Δh	-6.34**	-1.39	0.02	4	2.62	0.01	0.19

Table 3.15: Wool Sector (NACE 431): Descriptive Unit Root Test Statistics for Model Variables

3.10.2 Seasonal Factors of Model Variables

Estimation of the seasonal factors of the series was performed using the SEATS (Signal Extraction in ARIMA Time Series) programme (Maravall and Gomez (1994). This estimates a univariate ARIMA model for each series, decomposing the series into a trend, seasonal, cyclical and irregular component. The programme SEATS offers a model-based approach, however the authors state that "SEATS can efficiently be used as a fixed-type filter for routine applications to many series" (p5). We apply the programme's default "airline model", originally analysed by Box and Jenkins (1970):

$$\nabla\nabla_4 Y_t = (1+\theta_1 B)(1+\theta_4)B^4)a_t + c$$

where $\nabla = (1-B)$ and $\nabla_4 = (1-B^4)$, B is the lag operator, a_t is an innovation error and c is a constant. In all cases the variable Y was in logs. The estimated seasonal factors from this model are shown in the graphs below.

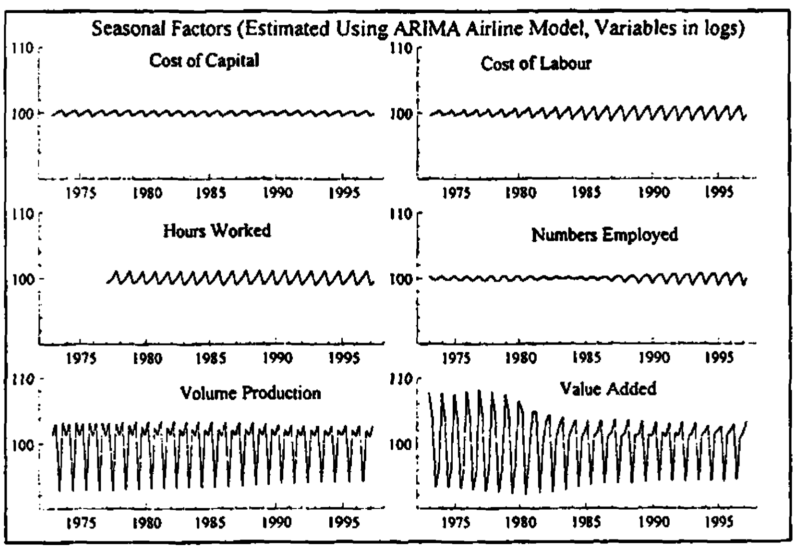

Figure 3.31: Model Variables for Metal Articles Sector (NACE 31): Seasonal Factors Estimated from ARIMA Model

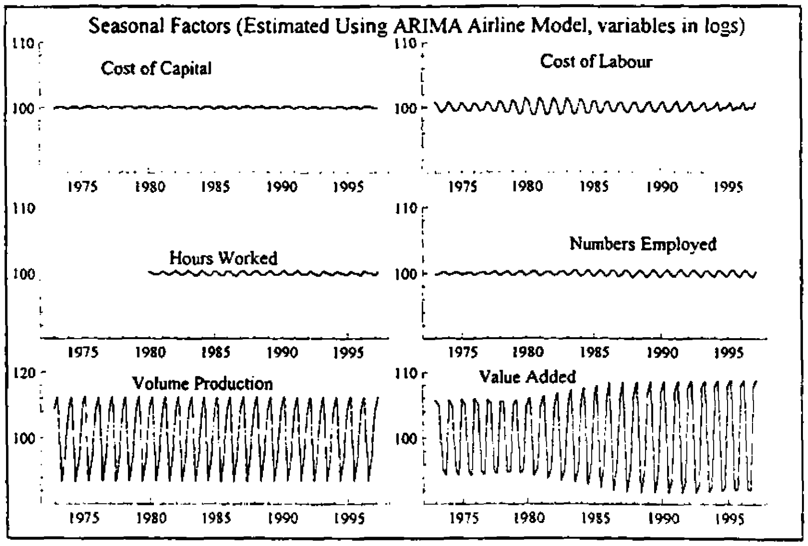

Figure 3.32: Model Variables for Pharmaceuticals Sector (NACE 257): Seasonal Factors Estimated from ARIMA Model

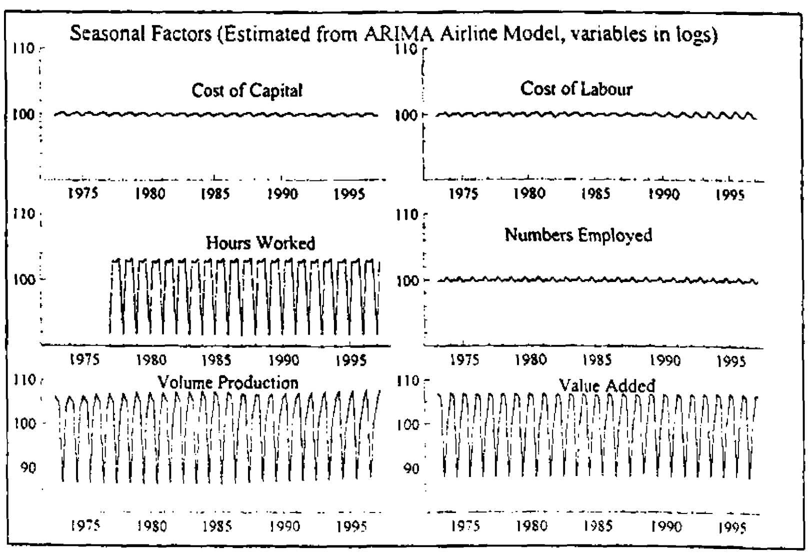

Figure 3.33: Model Variables for Wool Sector (NACE 431): Seasonal Factors Estimated from ARIMA Model

3.10.3 Estimation Results for Metal Articles Sector

	l	p_l	q	y	$(p_k - p_l)$	*vector residuals*	
Diagnostic Statistics							
$\hat{\sigma}$	0.02	0.02	0.04	0.04	0.04		
$Corr(x, \hat{x})$	0.99	1.00	0.96	1.00	0.98		
$AR(5,61)$	1.11	**3.52	0.46	2.02	1.26	$AR(125,187)$	1.23
$ARCH(4,58)$	0.25	1.32	0.07	0.14	0.57		
$N(2)$	2.57	4.22	0.21	0.21	*6.35	$N(10)$	16.98
$H(47,18)$	0.37	0.60	0.37	0.56	0.34	$H(705,127)$	0.29
Residual Correlations							
p_l	-0.04						
q	0.30	0.10					
y	0.35	0.19	0.62				
$(p_k - p_l)$	0.06	-0.30	-0.004	-0.14			

$\hat{\sigma}$ is the equation standard deviation; $Corr(x,\hat{x})$ is correlation between actual and fitted values;
See Section 2.3.2 for definition of other reported statistics.Estimated 1974 Q2 - 1997 Q2

Table 3.16: Metal Articles Sector: UVAR System Diagnostics

rank r =	1	2	3	4	5
λ_r	0.48	0.38	0.18	0.14	0.02
Max	**60.67	**45.04	19.12	14.11	2.27
$Max^{(adj.)}$	**47.62	*35.35	15.01	11.08	1.78
Trace	**141.2	**80.54	*35.51	16.38	2.27
$Trace^{(adj.)}$	**110.8	**63.22	27.87	12.86	1.78

Table 3.17: Metal Articles Sector - Tests for Rank of Cointegrating Space

Standardised Cointegrating Vectors β_i		
$\beta_1 : l =$	$-2.77p_l - 2.07\ q + 3.04\ y + 2.08\ (p_k - p_l)$	$+0.51\ S79q4 + 0.39\ S93q1$
$\beta_2 : p_l =$	$-0.43l + 0.55\ q + 0.36y - 0.06\ (p_k - p_l)$	$+0.21\ S79q4 - 0.01\ S93q1$
Equation:	Standardised Adjustment Coefficients α_{ij}	
Δl	$\alpha_{11} = 0.03\ (0.01)$	$\alpha_{12} = -0.02(0.03)$
Δp_l	$\alpha_{21} = -0.05(0.01)$	$\alpha_{22} = -0.13(0.03)$
Δq	$\alpha_{31} = 0.01(0.02)$	$\alpha_{32} = 0.23(0.06)$
Δy	$\alpha_{41} = 0.01(0.02)$	$\alpha_{42} = 0.005(0.06)$
$\Delta(p_k - p_l)$	$\alpha_{51} = 0.12(0.02)$	$\alpha_{52} = -0.03(0.06)$

Table 3.18: Metal Articles Sector: Reduced Form β and α for Rank=2

	β_1: 1st CVector							β_2: 2nd CVector					
	β_{11}	β_{12}	β_{13}	β_{14}	β_{15}	β_{16}	β_{17}	β_{21}	β_{23}	β_{25}	β_{27}	$\chi^2(dof)$	p-
	l	p_l	q	y	$p_k - p_l$	$S79q4$	$S93q1$	l	q	$p_k - p_l$	$S93q1$		
H_1 :	1	1		-1								3.10(1)	[0.
H_2 :	1	1	0	-1								3.11(2)	[0.
H_3 :	1	1	0	-1		0						20.84(3)	[0.
H_4 :	1	1	0	-1			0					8.04(3)	[0.
H_5 :	1	1	0	-1	0							24.18(3)	[0.
H_6 :	1	1	0	-1				1	-1	0	0	3.12(4)	[0.
H_7 :	1	1	0	-1	-0.60			1	-1	0	0	11.51(5)	[0.
H_8 :	1	1	0	-1	-0.60		$= \beta_{16}$	1	-1	0	0	11.75(6)	[0.

Table 3.19: Metal Articles Sector: Hypotheses Tests on Cointegrating Relations

	Restrictions on α	$\chi^2(dof)$	p-value
H_9 :	$H_8 \cap \{\alpha_{11} = 0, \alpha_{12} = 0\}$	26.3(8)	[0.00]**
H_{10} :	$H_8 \cap \{\alpha_{21} = 0, \alpha_{22} = 0\}$	36.4(8)	[0.00]**
H_{11} :	$H_8 \cap \{\alpha_{31} = 0, \alpha_{32} = 0\}$	28.9(8)	[0.00]**
H_{12} :	$H_8 \cap \{\alpha_{41} = 0, \alpha_{42} = 0\}$	12.3(8)	[0.14]
H_{13} :	$H_8 \cap \{\alpha_{51} = 0, \alpha_{52} = 0\}$	49.4(8)	[0.00]**
H_{14} :	$H_{12} \cap \{\alpha_{12} = 0, \alpha_{31} = 0, \alpha_{52} = 0\}$	17.5(11)	[0.09]

Table 3.20: Metal Articles Sector: Tests of Weak Exogeneity

	Δl	Δp_l	Δq	Δy	$\Delta(p_k - p_l)$	vector residuals	
Diagnostic Statistics							
$\hat{\sigma}$	0.02	0.02	0.04	0.04	0.04		
$AR(5,64)$	1.00	1.79	1.56	*2.83	0.41	$AR(125,196)$	1.26
$ARCH(4,61)$	0.52	0.55	0.14	0.28	0.28		
$N(2)$	0.163	**10.46	0.26	0.58	3.64	$N(10)$	*21.68
$H(41,26)$	0.55	0.78	0.66	0.63	0.40	$H(615,236)$	0.46
Residual Correlations							
p_l	-0.08						
q	0.30	0.17					
y	0.36	0.18	0.59				
$(p_k - p_l)$	0.00	-0.36	-0.00	-0.13			

SeeTable 3.16 for definition of reported statistics. Estimated 1974 Q3 - 1997 Q2

Table 3.21: Metal Articles Sector: PVAR System Diagnostics

	Restrictions on α	$\chi^2(dof)$	p-value
H_{15}	l weakly exogenous in PVAR	10.4(2)	[0.00]**
H_{16}	p_l weakly exogenous in PVAR	25.83(2)	[0.00]**
H_{17}	q weakly exogenous in PVAR	14.6(2)	[0.00]**
H_{18}	y weakly exogenous in PVAR	1.04(2)	[0.00]
H_{19}	$p_k - p_l$ weakly exogenous in PVAR	28.2(2)	[0.00]**
H_{20}	DVAR: All weakly exogenous	86.49(10)	[0.00]**
H_{21}	$H_{18} \cap l$ and $p_k - p_l$ w.e. for $cvec2$ and q w.e. for $cvec1$	3.41(5)	[0.64]

Table 3.22: Metal Articles Sector: Tests of Weak Exogeneity in PVAR

	Δl	Δp_l	Δq	$\Delta(p_k - p_l)$	*vector residuals*	
Diagnostic Statistics						
$\hat{\sigma}$	0.02	0.02	0.03	0.04		
$AR(5,62)$	*2.54	1.74	0.79	0.77	$AR(125,206)$	1.18
$ARCH(4,59)$	0.71	0.31	1.43	0.17		
$N(2)$	0.18	**13.63	2.32	2.74	$N(8)$	*20
$H(43,23)$	0.28	0.82	0.63	0.39	$H(430,176)$	0.46
Residual Correlations						
p_l	-0.15					
q	0.11	0.08				
$(p_k - p_l)$	0.07	-0.35	0.09			

SeeTable 3.16 for definition of reported statistics. Estimated 1974 Q3 - 1997 Q2

Table 3.23: Metal Articles Sector: SEM System Diagnostics

The SEM: A Four Equation System Conditioning on Value Added[7]:

$\underline{Dynamic\ Equation\ for\ Labour}:\Delta l =$

$$\underset{(0.12)}{-0.15}\,\Delta l_{-1} \underset{(0.12)}{-0.02}\,\Delta l_{-2} \underset{(0.11)}{+0.16}\,\Delta l_{-3} \underset{(0.09)}{-0.12}\,\Delta P_{l-1} \underset{(0.09)}{-0.21}\,\Delta P_{l-2} \underset{(0.10)}{-0.13}\,\Delta P_{l-3}$$
$$\underset{(0.06)}{+0.03}\,\Delta q_{-1} \underset{(0.06)}{+0.05}\,\Delta q_{-2} \underset{(0.06)}{-0.11}\,\Delta q_{-3} \underset{(0.05)}{+0.17}\,\Delta y \underset{(0.07)}{+0.13}\,\Delta y_{-1} \underset{(0.07)}{+0.09}\,\Delta y_{-2} \underset{(0.07)}{+0.15}\,\Delta y_{-3}$$
$$\underset{(0.05)}{+0.07}\,\Delta(p_k - p_l)_{-1} \underset{(0.06)}{-0.04}\,\Delta(p_k - p_l)_{-2} \underset{(0.05)}{+0.08}\,\Delta(p_k - p_l)_{-3} \underset{(0.03)}{+0.09}\,cvecS_{l-1}$$
$$\underset{(0.03)}{+0.07}\underset{(0.01)}{+0.001}\,D_{CS} \underset{(0.01)}{+0.0003}\,D_{CS-1} \underset{(0.01)}{+0.03}\,D_{CS-2}$$
$$\underset{(0.02)}{+0.01}\,\Delta D_{79q4} \underset{(0.02)}{-0.03}\,\Delta D_{93q1} \underset{(0.0002)}{+0.0004}\,T$$

$\underline{Dynamic\ Equation\ for\ Labour\ Costs}:\Delta P_l =$

$$\underset{(0.16)}{+0.29}\,\Delta l_{-1} \underset{(0.16)}{+0.10}\,\Delta l_{-2} \underset{(0.16)}{+0.22}\,\Delta l_{-3} \underset{(0.12)}{-0.17}\,\Delta P_{l-1} \underset{(0.13)}{-0.09}\,\Delta P_{l-2} \underset{(0.14)}{-0.17}\,\Delta P_{l-3}$$
$$\underset{(0.07)}{-0.01}\,\Delta q_{-1} \underset{(0.08)}{+0.05}\,\Delta q_{-2} \underset{(0.08)}{+0.08}\,\Delta q_{-3} \underset{(0.07)}{+0.10}\,\Delta y \underset{(0.09)}{-0.19}\,\Delta y_{-1} \underset{(0.10)}{-0.19}\,\Delta y_{-2} \underset{(0.08)}{-0.19}\,\Delta y_{-3}$$
$$\underset{(0.06)}{-0.04}\,\Delta(p_k - p_l)_{-1} \underset{(0.08)}{+0.03}\,\Delta(p_k - p_l)_{-2} \underset{(0.07)}{-0.18}\,\Delta(p_k - p_l)_{-3} \underset{(0.04)}{-0.15}\,cvecS_{l-1} \underset{(0.04)}{-0.13}\,cvecP_{l-1}$$
$$\underset{(0.11)}{-0.41}\underset{(0.02)}{-0.03}\,D_{CS} \underset{(0.02)}{-0.01}\,D_{CS-1} \underset{(0.02)}{+0.01}\,D_{CS-2}$$
$$\underset{(0.03)}{+0.03}\,\Delta D_{79q4} \underset{(0.03)}{-0.01}\,\Delta D_{93q1} \underset{(0.0004)}{-0.0002}\,T$$

$\underline{Dynamic\ Equation\ for\ Output}:\Delta q =$

$$\underset{(0.22)}{+0.04}\,\Delta l_{-1} \underset{(0.22)}{+0.35}\,\Delta l_{-2} \underset{(0.22)}{+0.37}\,\Delta l_{-3} \underset{(0.16)}{-0.05}\,\Delta P_{l-1} \underset{(0.18)}{-0.26}\,\Delta P_{l-2} \underset{(0.20)}{-0.06}\,\Delta P_{l-3}$$
$$\underset{(0.11)}{-0.56}\,\Delta q_{-1} \underset{(0.12)}{-0.23}\,\Delta q_{-2} \underset{(0.11)}{-0.44}\,\Delta q_{-3} \underset{(0.10)}{+0.62}\,\Delta y \underset{(0.13)}{+0.59}\,\Delta y_{-1} \underset{(0.14)}{+0.31}\,\Delta y_{-2} \underset{(0.12)}{+0.35}\,\Delta y_{-3}$$
$$\underset{(0.09)}{+0.28}\,\Delta(p_k - p_l)_{-1} \underset{(0.12)}{-0.13}\,\Delta(p_k - p_l)_{-2} \underset{(0.10)}{-0.10}\,\Delta(p_k - p_l)_{-3} \underset{(0.06)}{+0.30}\,cvecP_{l-1}$$
$$\underset{(0.16)}{+0.78}\underset{(0.02)}{-0.03}\,D_{CS} \underset{(0.02)}{-0.04}\,D_{CS-1} \underset{(0.02)}{-0.04}\,D_{CS-2}$$
$$\underset{(0.04)}{-0.005}\,\Delta D_{79q4} \underset{(0.04)}{+0.03}\,\Delta D_{93q1} \underset{(0.0006)}{-0.002}\,T$$

[7] D_{CS} are centred seasonal dummies. D_{93q1} is a shift dummy variable in 1993Q1. D_{79q4} is a shift dummy variable in 1979Q4.

$\underline{Dynamic\ Equation\ for\ Relative\ Factor\ Prices}: \Delta(p_k - p_l) =$

$$\underset{(0.27)}{-0.70}\,\Delta l_{-1} \underset{(0.28)}{-0.41}\,\Delta l_{-2} \underset{(0.26)}{-0.71}\,\Delta l_{-3} \underset{(0.20)}{+0.80}\,\Delta P_{l-1} \underset{(0.22)}{-0.22}\,\Delta P_{l-2} \underset{(0.24)}{+0.09}\,\Delta P_{l-3}$$
$$\underset{(0.13)}{-0.36}\,\Delta q_{-1} \underset{(0.14)}{-0.13}\,\Delta q_{-2} \underset{(0.13)}{-0.24}\,\Delta q_{-3} \underset{(0.12)}{-0.12}\,\Delta y \underset{(0.16)}{+0.65}\,\Delta y_{-1} \underset{(0.17)}{+0.46}\,\Delta y_{-2} \underset{(0.15)}{+0.25}\,\Delta y_{-3}$$
$$\underset{(0.10)}{+0.81}\,\Delta(p_k - p_l)_{-1} \underset{(0.15)}{-0.09}\,\Delta(p_k - p_l)_{-2} \underset{(0.12)}{+0.17}\,\Delta(p_k - p_l)_{-3} \underset{(0.07)}{+0.36}\,cvecS_{l-1}$$
$$\underset{(0.07)}{+0.231}\underset{(0.03)}{+0.06}\,D_{CS} \underset{(0.03)}{-0.02}\,D_{CS-1} \underset{(0.03)}{-0.003}\,D_{CS-2}$$
$$\underset{(0.05)}{+0.019}\,\Delta D_{79q4} \underset{(0.05)}{-0.14}\,\Delta D_{93q1} \underset{(0.0004)}{+0.002}\,T$$

<u>Identities:</u>

$$cvecS_l = \Delta l + \Delta p_l - \Delta y - 0.6(\Delta p_k - \Delta p_l) - 0.20(\Delta D_{79q4} + \Delta D_{93q1}) + cvecS_{l-1}$$
$$cvecP_l = 0.58\Delta l + \Delta p_l - 0.58\Delta q - 0.42\Delta y - 0.21\Delta D_{79q4} + cvecP_{l-1}$$

3.10.4 Estimation Results for Pharmaceuticals Sector

	l	p_l	q	y	$(p_k - p_l)$	*vector residuals*	
			Diagnostic Statistics				
$\hat{\sigma}$	0.02	0.0	0.11	0.10	0.04		
$Corr(x,\hat{x})$	1.00	1.00	0.99	1.00	0.99		
$AR(5,59)$	0.48	0.39	2.03	2.19	0.52	$AR(125,177)$	1.29
$ARCH(4,56)$	1.36	0.13	0.43	0.28	0.40		
$N(2)$	2.44	2.26	2.49	*7.63	4.57	$N(10)$	12.25
$H(50,13)$	0.29	0.32	0.55	0.26	0.34	$H(750,57)$	0.11
			Residual Correlations				
p_l	0.04						
q	-0.19	-0.03					
y	-0.07	0.01	0.60				
$(p_k - p_l)$	0.01	-0.45	-0.02	-0.10			

$\hat{\sigma}$ is the equation standard deviation; $Corr(x,\hat{x})$ is correlation between actual and fitted values;
See Section 2.3.2 for definition of other reported statistics.Estimated 1974 Q2 - 1997 Q2

Table 3.24: Pharmaceuticals Sector: UVAR System Diagnostics

rank r =	1	2	3	4	5
λ_r	0.34	0.30	0.19	0.13	0.04
Max	**39.01	**33.35	19.87	12.77	3.73
$Max^{(adj.)}$	30.62	26.18	15.60	10.03	2.93
Trace	**108.7	**69.72	*36.37	16.50	3.73
$Trace^{(adj.)}$	*85.35	*54.73	28.5	12.95	2.93

Table 3.25: Pharmaceuticals Sector - Tests for Rank of Cointegrating Space

Standardised Cointegrating Vectors β_i		
$\beta_1 : l =$	$0.44\ p_l - 0.23\ q\ + 0.12y\ - 0.25(p_k - p_l)$	$+0.03T86_3$
$\beta_2 : p_l =$	$-0.67l - 0.53q + 0.53\ y - 0.06(p_k - p_l)$	$-0.02T86_3$
Equation:	Standardised Adjustment Coefficients α_{ii}	
Δl	$\alpha_{11} = -0.10(0.04)$	$\alpha_{12} = 0.05(0.05)$
Δp_l	$\alpha_{21} = 0.02(0.05)$	$\alpha_{22} = -0.06(0.06)$
Δq	$\alpha_{31} = -0.69(0.24)$	$\alpha_{32} = -0.47(0.32)$
Δy	$\alpha_{41} = -0.60(0.23)$	$\alpha_{42} = 0.92(0.31)$
$\Delta(p_k - p_l)$	$\alpha_{51} = -0.29(0.09)$	$\alpha_{52} = -0.10(0.13)$

Table 3.26: Pharmaceuticals Sector: Reduced Form β and α for Rank=2

	β_1: 1[st] CVector						β_2: 2[nd] CVector						
	β_{11}	β_{12}	β_{13}	β_{14}	β_{15}	β_{16}	β_{21}	β_{22}	β_{23}	β_{24}	β_{25}	β_{26}	$\chi^2(dof)$
	l	p_l	q	y	$p_k - p_l$	$T86_3$	l	p_l	q	y	$p_k - p_l$	$T86_3$	
H_1 :	1	1		-1									3.51(1)
H_2 :	1	1		-1		0							6.50(2)
H_3 :	1	1	0	-1									14.16(2)
H_4 :	1	1		-1	0								11.24(2)
H_5 :	1	1	0	-1	0	0							31.11(4)
H_6 :	1	1		-1				1			0		3.51(1)
H_7 :	1	1		-1			0	1			0		3.51(2)
H_8 :	1	1		-1			0	1		$-\beta_{23}$	0		3.53(3)

Table 3.27: Pharmaceuticals Sector:Hypotheses Tests on Cointegrating Relations

	Restrictions on α	$\chi^2(dof)$	p-value
H_9 :	$H_8 \cap \{\alpha_{11} = 0, \alpha_{12} = 0\}$	13.16(5)	[0.02]*
H_{10} :	$H_8 \cap \{\alpha_{21} = 0, \alpha_{22} = 0\}$	4.96(5)	[0.42]
H_{11} :	$H_8 \cap \{\alpha_{31} = 0, \alpha_{32} = 0\}$	14.95(5)	[0.01]*
H_{12} :	$H_8 \cap \{\alpha_{41} = 0, \alpha_{42} = 0\}$	20.04(5)	[0.00]**
H_{13} :	$H_8 \cap \{\alpha_{51} = 0, \alpha_{52} = 0\}$	12.95(5)	[0.02]*

Table 3.28: Pharmaceuticals Sector: Tests of Weak Exogeneity

	Δl	Δp_l	Δq	Δy	$\Delta(p_k - p_l)$	*vector residuals*	
			Diagnostic Statistics				
$\hat{\sigma}$	0.02	0.02	0.10	0.11	0.04		
$AR(5,63)$	0.97	0.29	*2.57	0.62	1.03	$AR(125,196)$	1.15
$ARCH(4,60)$	0.17	0.12	0.42	0.91	0.32		
$N(2)$	2.40	1.19	3.10	5.14	5.76	$N(10)$	9.91
$H(41,26)$	0.55	0.56	0.82	0.42	0.53	$H(615,236)$	0.44
			Residual Correlations				
p_l	-0.008						
q	-0.159	0.007					
y	-0.006	0.006	0.52				
$(p_k - p_l)$	0.017	-0.475	-0.071	-0.134			

SeeTable 3.16 for definition of reported statistics.Estimated 1974 Q3 - 1997 Q2

Table 3.29: Pharmaceuticals Sector: PVAR System Diagnostics

	Restrictions on α	$\chi^2(dof)$	p-value
H_{15}	l weakly exogenous in PVAR	1.45(2)	[0.48]
H_{16}	p_l weakly exogenous in PVAR	12.27(2)	[0.00]**
H_{17}	q weakly exogenous in PVAR	14.93(2)	[0.00]**
H_{18}	y weakly exogenous in PVAR	5.00(2)	[0.08]
H_{19}	$p_k - p_l$ weakly exogenous in PVAR	15.89(2)	[0.00]**
H_{20}	DVAR: All weakly exogenous	48.13(10)	[0.00]**
H_{21}	l and y weakly exogenous in PVAR	6.40(4)	[0.17]

Table 3.30: Pharmaceuticals Sector: Tests of Weak Exogeneity in PVAR

	Δp_l	Δq	$\Delta(p_k - p_l)$	*vector residuals*	
		Diagnostic Statistics			
$\hat{\sigma}$	0.02	0.11	0.04		.
$AR(5,61)$	0.29	**6.47	1.19	$AR(45,152)$	1.16
$ARCH(4,58)$	0.12	0.41	0.31		
$N(2)$	1.19	3.10	5.76	$N(6)$	9.11
$H(45,20)$	0.55	0.82	0.47	$H(270,110)$	0.56
		Residual Correlations			
q	0.01				
$(p_k - p_l)$	-0.47	-0.07			

SeeTable 3.16 for definition of reported statistics.Estimated 1974 Q3 - 1997 Q2

Table 3.31: Pharmaceuticals Sector: SEM System Diagnostics

3.10.5 Estimation Results for Wool Sector

	l	p_l	q	y	$(p_k - p_l)$	vector residuals	
Diagnostic Statistics							
$\hat{\sigma}$	0.04	0.03	0.07	0.08	0.04		
$Corr(x, \hat{x})$	1.00	1.00	0.97	0.96	0.99		
$AR(5,60)$	1.68	1.71	0.89	0.97	1.95	$AR(125,182)$	0.93
$ARCH(4,57)$	1.05	1.62	2.17	*3.05	0.82		
$N(2)$	0.07	0.96	3.57	*6.20	0.27	$N(10)$	11.09
$H(42,22)$	0.38	0.86	0.55	1.03	0.68	$H(630,181)$	0.31
Residual Correlations							
p_l	-0.22						
q	0.36	-0.18					
y	0.26	-0.22	0.54				
$(p_k - p_l)$	0.27	-0.46	0.08	0.08			

$\hat{\sigma}$ is the equation standard deviation; $Corr(x,\hat{x})$ is correlation between actual and fitted values;
See Section 2.3.2 for definition of other reported statistics. Estimated 1974 Q2 - 1997 Q2

Table 3.32: Wool Sector: UVAR System Diagnostics

rank $r =$	1	2	3	4	5
λ_r	0.42	0.37	0.24	0.11	0.07
Max	**50.66	**43.15	25.27	11.45	6.99
$Max^{(adj.)}$	**39.76	*33.87	19.83	8.99	5.49
$Trace$	**137.5	**86.86	*43.71	18.44	6.99
$Trace^{(adj.)}$	**107.9	*68.18	34.31	14.47	5.49

Table 3.33: Wool Sector - Tests for Rank of Cointegrating Space

Standardised Cointegrating Vectors β_i		
$\beta_1 : l =$	$-0.92p_l + 0.65\ q\ + 1.07y\ + 0.80(p_k - p_l)$	$-0.01T$
$\beta_2 : p_l =$	$0.58l - 0.80q + 0.93\ y - 0.04(p_k - p_l)$	$+0.02T$
Equation:	Standardised Adjustment Coefficients α_{ij}	
Δl	$\alpha_{11} = 0.03(0.02)$	$\alpha_{12} = 0.02(0.05)$
Δp_l	$\alpha_{21} = 0.05(0.02)$	$\alpha_{22} = -0.19(0.03)$
Δq	$\alpha_{31} = 0.07(0.04)$	$\alpha_{32} = 0.16(0.08)$
Δy	$\alpha_{41} = 0.21(0.05)$	$\alpha_{42} = 0.35(0.10)$
$\Delta(p_k - p_l)$	$\alpha_{51} = 0.07(0.03)$	$\alpha_{52} = 0.15(0.05)$

Table 3.34: Wool Sector: Reduced Form β and α for Rank=2

	β_1: 1^{st} CVector						β_2: 2^{nd} CVector							
	β_{11} l	β_{12} p_l	β_{13} q	β_{14} y	β_{15} $p_k - p_l$	β_{16} T	β_{21} l	β_{22} p_l	β_{23} q	β_{24} y	β_{25} $p_k - p_l$	β_{26} T	$\chi^2(dof)$	p-va
H_1 :	1	1		-1									0.59(1)	[0.44
H_2 :	1	1		-1		0							9.58(2)	[0.00
H_3 :	1	1	0	-1									2.82(2)	[0.24
H_4 :	1	1		-1	0								7.48(2)	[0.02
H_5 :	1	1	0	-1		0							17.11(3)	[0.00
H_6 :	1	1	0	-1				1			0	0	6.56(3)	[0.09
H_7 :	1	1	0	-1				0	1	0	0	0	7.06(5)	[0.22

Table 3.35: Wool Sector: Hypotheses Tests on Cointegrating Relations

	Restrictions on α	$\chi^2(dof)$	p-value
H_8 :	$H_7 \cap \{\alpha_{11} = 0, \alpha_{12} = 0\}$	8.60(7)	[0.28]
H_9 :	$H_7 \cap \{\alpha_{21} = 0, \alpha_{22} = 0\}$	40.68(7)	[0.00]**
H_{10} :	$H_7 \cap \{\alpha_{31} = 0, \alpha_{32} = 0\}$	11.77(7)	[0.11]
H_{11} :	$H_7 \cap \{\alpha_{41} = 0, \alpha_{42} = 0\}$	22.86(7)	[0.00]**
H_{12} :	$H_7 \cap \{\alpha_{51} = 0, \alpha_{52} = 0\}$	23.65(7)	[0.00]**
H_{13} :	$H_8 \cap H_{10}$	12.52(9)	[0.18]

Table 3.36: Wool Sector: Tests of Weak Exogeneity

	Δl	Δp_l	Δq	Δy	$\Delta(p_k - p_l)$	*vector residuals*	
Diagnostic Statistics							
$\hat{\sigma}$	0.04	0.03	0.07	0.08	0.04		
$AR(5,63)$	1.00	1.74	0.51	0.14	*2.56	$AR(125,196)$	1.00
$ARCH(4,60)$	1.09	0.36	1.24	*3.33	0.63		
$N(2)$	0.02	0.37	4.95	**11.55	0.10	$N(10)$	15.21
$H(40,27)$	0.71	0.54	0.52	0.84	0.60	$H(585,276)$	0.45
Residual Correlations							
p_l	-0.21						
q	0.32	-0.21					
y	0.21	-0.29	0.55				
$(p_k - p_l)$	0.30	-0.36	0.02	-0.005			

SeeTable 3.16 for definition of reported statistics. Estimated 1974 Q3 - 1997 Q2

Table 3.37: Wool Sector: PVAR System Diagnostics

	Restrictions on α	$\chi^2(dof)$	p-value
H_{14}	l weakly exogenous in PVAR	1.96(2)	[0.37]
H_{15}	p_l weakly exogenous in PVAR	35.27(2)	[0.00]**
H_{16}	q weakly exogenous in PVAR	5.79(2)	[0.05]
H_{17}	y weakly exogenous in PVAR	25.90(2)	[0.00]**
H_{18}	$p_k - p_l$ weakly exogenous in PVAR	28.54(2)	[0.00]**
H_{19}	All weakly exogenous	88.35(10)	[0.00]**
H_{20}	l and q weakly exogenous in PVAR	6.20(4)	[0.18]

Table 3.38: Wool Sector: Tests of Weak Exogeneity in PVAR

	Δp_l	Δy	$\Delta(p_k - p_l)$	*vector residuals*	
Diagnostic Statistics					
$\hat{\sigma}$	0.03	0.07	0.04		
$AR(5,61)$	1.92	1.22	2.03	$AR(45,126)$	0.92
$ARCH(4,58)$	0.87	0.46	0.89		
$N(2)$	2.86	**9.22	0.80	$N(6)$	*15.48
$H(44,21)$	0.52	0.39	0.41	$H(264,104)$	0.48
Residual Correlations					
y	-0.21				
$(p_k - p_l)$	-0.34	-0.03			

SeeTable 3.16 for definition of reported statistics. Estimated 1974 Q3 - 1997 Q2

Table 3.39: Wool Sector: SEM System Diagnostics

Part II

Modelling The Long Run Demand for Skilled Labour

Chapter 4

Changes in Composition of Labour 1979-1990

4.1 Introduction

This chapter describes the aggregate and sectoral changes in the composition of employment in Irish manufacturing which occurred in the 1980s. We use data on employment, wages and output for 72 sectors from the annual *Census of Industrial Production* covering the period 1979-1990.

Throughout the 1980s the Irish manufacturing sector, both in terms of output and employment, underwent a radical structural transformation. Together with a dramatic increase in the importance of foreign-owned, high-technology, export-oriented industries there has been a marked shift in the composition of employment towards more so-called "skilled" labour. This is consistent with trends in skilled manufacturing employment in most developed economies (Berman, Bound and Machin (1998)). Widespread public investment in education in Ireland only began in the late 1960s, so that a large cohort of more highly educated workers came on stream in the 1980s, and during that decade average education levels of Irish workers continued to rise.[1]

During this period unemployment and emigration rose strongly and the proportion of long-term unemployed, especially among the more "unskilled", increased[2]. These long-term unemployed were concentrated in older age groups and groups with low educational

[1]From 1981 to 1991 the percentage of all workers who left full-time education at the age of 14 or less fell from 27% to 17% while the percentage who were still in full-time education at the age of 19 or more increased from 15% to 20% (see Table 4.10).

[2]From an estimated 34% in 1983 to 63% in 1990 (Sexton and O'Connell (1996, Table 3.4).

qualifications[3].

The chapter is structured as follows. Section 4.2 looks at the debate surrounding the causes of the shift towards skilled labour in developed economies. Section 4.3 looks at movements in the composition of employment and wages in the aggregate manufacturing sector. In Section 4.4 we formulate stylised categories of skilled and unskilled labour from these data. Clerical workers are separately identified as a third category of labour. Section 4.5 looks in more detail at the sectoral data on employment, wages and output. In this section we identify three broad groups of sectors which exhibit diverse output and employment growth patterns over the period. These correspond to a 'high-growth' group of sectors which has more than doubled in importance both in output and employment terms over the period, a 'medium-growth' group of sectors and a 'declining' group of sectors which has shrunk in size over the period. Section 4.6 decomposes the change in both employment and wages for these three groups of sectors into the relative importance of within and between group shifts in skilled labour over the period.

4.2 What causes Shifts in the Demand for Skilled Labour?

One key shared characteristic of developed economies has been the increase in the demand for skilled labour relative to unskilled labour (Berman, Bound and Machin, 1998). As an economy develops and disposable incomes rise, the demand for goods with a higher skill-intensity in production rises. These underlying changes in consumption patterns are changing the production mix (e.g. the long-term shift from agriculture towards services), and hence the relative demand for skilled labour.

The shift in demand towards skilled labour increases average productivity and the growth potential of an economy. "New growth" theory emphasises the key roles of technological progress and the stock of human capital to the growth of an economy[4]. These are intimately linked. Firstly there have been extraordinarily rapid developments in existing and new technologies which have transformed the structure of modern economies. As production processes and competition on goods markets get increasingly more complicated, firms, par-

[3]Strobl and Walsh (1996), in an analysis of long-term unemployment in Ireland, show that "the build up in the long term unemployment stock in the 1980s was primarily driven by flows of older, unskilled males entering unemployment from employment one year earlier." (p.27)

[4]In neoclassical growth models technology is the only factor which explains observed wide differences in income levels and growth rates between trading countries. By introducing human capital accumulation, which serves as an additional factor influencing productivity, growth models can generate permanent differentials in per capita incomes between countries which is a better characterisation of observed patterns of development (see Lucas (1988)).

ticularly multinationals, are investing heavily in research and development and require more highly skilled employees. Secondly there has been a large and broad-based increase in the level of public and private investment in education and training. This has led to substantial increases in the relative demand for and supply of so-called "skilled" labour.

This observed shift in employment towards more skilled labour in developed economies has spawned a large literature internationally. While there is a general consensus that these shifts have indeed occurred, there is much disagreement as to the likely causes of these shifts. This disagreement can be broadly characterised as distinguishing between two separate effects. Abstracting from general increases in skill levels in the workforce as a whole (which increase the relative supply of skilled labour) there are two competing demand-side explanations for why there has been a relative increase in the employment of skilled labour. One theory suggests that reductions in trade barriers and the globalisation of goods markets has caused production of low-skill intensive goods to shift to low-wage countries (Wood (1994)). This theory is centrally based on the factor-content theory of trade. Countries which are relatively skill-abundant will, given a reduction in trade barriers, shift towards producing more skill-intensive goods resulting in an expansion of production in skill-intensive sectors and a contraction in low-skill intensive sectors. As a first round effect this will increase the employment of skilled labour and reduce the relative wage of unskilled labour. The fall in the price of unskilled labour will in turn lead to an increase in the proportion of unskilled labour employed both in the expanding skill-intensive sectors and in the contracting labour-intensive sectors.

The second theory argues instead that skill-biased technological change[5] has increased the productivity of skilled labour more than unskilled thereby causing an outward shift in the relative demand curve for skilled labour (see Berman, Bound and Griliches (1994)). (Although the net effect of a skill-biased technology shock on the relative employment of skilled labour is ambiguous[6] it is generally assumed that positive output effects will outweigh negative substitution effects and shift the relative demand curve for skilled labour rightwards.) In this case we would observe an increase in the proportion of skilled labour employed in all sectors and an increase in the wage gap between skilled and unskilled labour or, in the presence of labour market rigidities, an increase in unemployment of unskilled labour.

A commonly used empirical technique to distinguish between these two effects is to

[5]Skill-biased technological change refers to changes in existing technologies or the introduction of new technologies with an unskilled-labour-saving bias. Typically it refers to the widespread introduction of microprocessor-based technologies in recent decades.

[6]The ambiguity arises as follows. A skill-biased technology shock increases the productivity of skilled workers. This has two separate effects. For an unchanged level of output it reduces the employment of skilled workers - the *substitution effect* of a technology shock. For an unchanged level of skilled employment it increases the level of output - the *output effect* of a technology shock.

decompose the increase in skilled employment into a) the proportion due to an increase *within* sectors which, it is argued, is evidence in favour of skill-biased technological change because it does not alter the type of goods produced but rather their production process, and b) the proportion due to shifts in relative employment *between* sectors, with a consequent change in the type of goods produced, which is taken as evidence of a trade effect. Empirical research has shown that the within sector effect dominates in the manufacturing sector for most developed countries (Bound, Berman and Machin (1998), OECD (1996)).

Of course these two effects are not mutually exclusive. Rather the debate focuses on which is relatively more important. In addition the *ceteris paribus* assumption is clearly unrealistic. Trade may cause technological advances, where firms faced with tougher international competition are forced into what is termed "defensive innovation". Technological progress, rather than being factor biased, may be sector biased in favour of skill-intensive sectors causing a shift between sectors. Alternatively firms may outsource the less skill-intensive parts of their production process e.g. moving assembly to a low-wage country, which would show up as a shift within sectors (Wood (1995)).

This analysis is further confounded by the fact that the general increase in skill levels has altered the relative supply of skilled labour. Whether this general increase in skill levels was driven by demand or supply factors is an open question, since increased education levels are clearly central to the improvements of existing and the development of new technologies. However the fact that both the relative demand and supply curves for skilled labour have shifted makes causality difficult to determine.

Regardless of whether the increased relative demand for skilled labour is largely attributable to a technology, trade or supply-side effect, it is clear that such an increase has indeed occurred in most developed countries. This has important implications for macroeconomic policy.

- The shift towards more skilled labour will raise average productivity and hence the long-run growth potential.

- The increase in the relative demand for skills can lead to higher aggregate unemployment and widening wage inequality:

  "There has been a substantial shift in demand away from unskilled workers toward skilled workers. This shift has outweighed supply shifts in the same direction. In countries where wages are flexible, such as the United States, this demand shift generates substantial declines in the relative wages of the unskilled. In countries where wage relativities are fixed, as in Europe, the consequence is a large rise in unemployment among the unskilled, which is enough to explain much of the overall rise in unemployment." Nickell and Bell (1996, p.302)

4.3 Aggregate Trends in Composition of Labour 1979-1990

This section describes the trends in the aggregate manufacturing sector's output and employment performance over the period 1979 to 1990. The *Census of Industrial Production* gathers data on the employment and wages of five different categories of employee. These data are described briefly in Section 4.3.1 and more fully in Section 4.11. Examination of these data, reported in Section 4.3.2, reveals that until 1987 aggregate employment in the manufacturing sector fell continuously, this was during a period of relatively low growth in output. In 1987 output growth picked up strongly and in 1988 employment began to rise. There has been a significant and persistent shift towards employing more administrative and technical workers over this period while relative wage increases for these workers have been modest. An interesting trend has been the increase in clerical employment and wages which, we argue, reflects an increase in the demand for computer skills in manufacturing.

Note that the aggregate manufacturing sector covers only 69 of the 72 sectors analysed later in the chapter. Specifically it excludes three utilities sectors, namely Electricity, Gas and Water. This accounts for differences with aggregate data reported later in the chapter and also with the data in Figure 1.5 of Chapter 1.

4.3.1 Data on the Composition of Manufacturing Employment

We use some unpublished data from the CSO[7] which, together with the data published in the *Census of Industrial Production* (CIP), provide a five-way disaggregation of employment and wages at the NACE 3-digit sector level for a total of 72 individual sectors. These data cover the period 1979-1990 and are as detailed as the original CIP questionnaire allows as shown in Section B.4. Further details on the data set are given in Section 4.11 in Chapter 5. This five-way disaggregation is as follows:

[7] I am grateful to Richard Maher of the CSO for providing me with these data.

Employee Category		Description
1	*Administrative and Technical Staff*	All managerial, technical and other salaried staff.
2	*Clerical Staff*	Clerical and other office staff, including clerical supervisors.
	Industrial Workers comprising:	
3	Supervisors	Manual supervisory staff, e.g. foremen and production supervisors.
4	Operatives	All manual workers with the exception of apprentices and outside piece workers.
5	Apprentices	All apprentices

There are two problems with the definitions of the wage bill and employment[8]. The first is that these data include both full-time and part-time workers. This means that the calculated wage rates per worker will be understated to the extent that numbers employed include part time workers. The correct denominator in calculating wage rates is full-time equivalent numbers employed. Unfortunately there is no way around this problem; as can be seen from the CIP questionnaire this information is not asked of the firms. However in Ireland the rates of part-time work (8% in 1990 for the workforce as a whole, 17% for women and 3% for men) are much lower that the EC average although they rose rapidly in the 1980s (from 58,000 in 1979 to 92,000 in 1990). It is estimated that three quarters of this employment (70,000) is in the services sector (Corcoran et al. (1992)). This would suggest that the importance of part-time work for manufacturing was relatively small over the 1980s [9] although there is evidence that it has been increasing since then.[10] In fact Drew (1990, p.22) points out that between 1983 and 1987 the proportion (and absolute number) of part time workers employed in industry actually declined.

The second problem with the definition of wages and employment is that the employment figures are measured in the second week of September in each year while all other data, including the wage bill data, are measured at the end of firms' financial year (which for over three quarters of all firms is the end of calendar year). Thus the numerator and the denominator of the calculated wage rates do not relate to the same time period. This problem will be more distortionary for sectors with high and changing seasonality in employment over the sample period. Quarterly total employment data, which could be used to get an annual

[8]I am grateful to John Micklewright for pointing these out to me.

[9]The 1990 Labour Force Survey data estimate that 7,500 workers (equivalent to 3% of all workers) in "Other Production Industries" (all production industries except for agriculture, forestry, fishing and building and construction) were in part-time jobs.

[10]The Forfas survey of manufacturing industries estimates that 13,000 (5.8%) workers were employed in the category "part-time, temporary and short-term employment" in 1990, this figure has risen to 24,000 (9.5%) by 1995 (Forfas (1996)).

average estimate of employment, are only collected for 34 "broad" manufacturing sectors so this is not possible for the 72 "detailed" sectors used here[11].

4.3.2 Trends in the Aggregate Manufacturing Sector Data

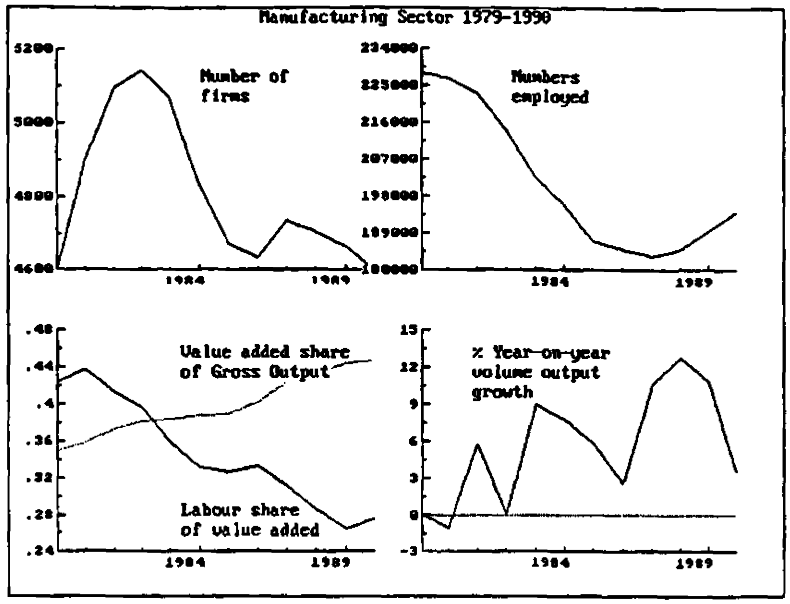

Figure 4.1: Output, Employment and Number of Firms in the Irish Manufacturing Sector 1979-1990

Figure 4.1 plots some key variables for the aggregate manufacturing sector. There are three distinct sub-periods in overall output growth performance: the three year period 1979-82 where growth was virtually stagnant, (annual average growth was 1.5%), the four year period 1982-86 when growth picked up (annual average growth was 6.3%), and the four year period 1986-90 when there was a rapid expansion in growth (annual average growth was 9.4%). This pattern is mirrored in the behaviour of aggregate employment, albeit with a one-year lag. Employment fell continuously at a rate of -2.7% per annum until 1987 (with the highest single year decrease recorded in 1983 at 5.5%), from then it increased at a rate of 1.9% per

[11]In addition, because the wage data measure average annual earnings rather than hourly wages they are influenced by hours worked. This may introduce a spurious positive correlation between wages and employment because hours are procyclical (see Nickell and Wadwhani, 1991).

annum. The overall decline in manufacturing employment from 1979 to 1990 was close to 34,000, almost 15% of the 1979 level.

Over this period the aggregate data indicate that there has been a marked change in the production of manufacturing output. The ratio of value added to gross output, that is the amount of value added embodied in each unit of output, rose from 35% to 45%. Abstracting from potential biases due to transfer pricing distortions[12], this is indicative of a significant improvement in productive efficiency. At the same time labour's share of value-added (as measured by the wage bill relative to net output) fell from 42% to 28%. Both of these trends are suggestive of structural and/or technological change in production in the manufacturing sector.

Finally Figure 4.1 plots the number of firms in the manufacturing sector over the period 1979-1990.[13] While the number of firms has fallen by only 3 between 1979 and 1990 it is clear from the graph that within the period there were substantial births and deaths of firms with a *net* increase of 538 firms (an increase of 11.7%) set up in the early 1980s, this peaked in 1982 after which the number of firms contracted until 1987 when there was another more modest increase of exactly 100 firms. From 1987 onwards firm closures dominated and the total number of firms in 1990 was 4602 as compared with 4605 in 1979.

Since employment did not rise in tandem with the increase in the number of firms in the early 1980s this would suggest that these were mainly small firms. This is in fact the case. In a longitudinal study of unpublished CIP firm-level data, Keating and Keane (1989) show that all of the increase in the number of firms between 1979 and 1982 was in firms employing less than 30 workers. In addition the rate of firm closure was highest for small firms.[14] Notably the average size of firms fell so that while in 1979 the average firm employed

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[12]The term 'transfer pricing' is used throughout this chapter in a rather loose sense to refer to the propensity of subsidiaries of foreign multinationals to overstate reported profits originating in Ireland, so-called "profit-switching transfer pricing" (see Stewart (1989) for a full discussion). The existence of zero-rated corporation tax on manufacturing exports until 1980 (and until 1990 for firms in place before Jan. 1 1980) and a reduced rate of 10% on all manufacturing profits from 1980 onwards means that branch plants located in Ireland have an incentive to engage in such profit-switching transfer pricing. That is, they artificially underprice their imported inputs (imported from other subsidiaries located outside of Ireland) and overprice their output prices to inflate reported profits earned in Ireland. The measured statistics are thereby distorted (see Murphy (1995)). A substantial portion of these profits are then repatriated to their home country. This is not an insignificant issue since profit outflows (including profits, dividends and royalties) rose from 2.8% of GDP in 1980 to 9.4% of GDP in 1990 (O'Malley and Scott (1994)).

[13]In these Census of Industrial Production data a firm is defined on an establishment basis where an establishment is defined as "a single economic activity conducted at a particular location." (CSO 1990, p9) In this chapter the term 'firm' refers to an establishment as defined on this basis.

[14]Between 1979 and 1985 59% of firms with less than 5 employees closed, 38% of those with 5-9 employees closed while the overall closure rate was 35% (Keating and Keane, p10).

50 workers, by 1990 this had fallen to 42 (see Tables 4.14 and 4.15). This is in line with international trends towards a fall in the average size of firms (Haskel (1996b, p.3)).

Part of the explanation for the high closure rate in the period 1982-1985 may lie in the fact that in 1979 the census was revised and updated and "includes some establishments which ... were included at an early stage of their development" (Keating and Keane (1989, p.11)). In addition, given that a lot of the firm turnover occurred in firms with 3-5 employees, it may be that firm 'closures' merely reflect a decline in firm size below the lower cut-off point of three or more persons engaged which is used in the census. In sum, the analysis in the paper by Keating and Keane highlights that the summary data on number of firms in each year mask considerable volatility in start-ups and closures in each year. This will be of crucial importance in modelling factor demands in the next chapter, since we do not have access to firm-level data.

	% Share of Total Employment						**Employment**		
	Male		*Female*		*Total*		*Male*	*Fem.*	*Total*
	1979	*1990*	*1979*	*1990*	*1979*	*1990*	*1990 as % of 1979*		
Supervisors	3.6	3.6	0.6	0.6	4.1	4.2	86.2	94.5	87.3
Operatives	52.1	47.1	21.3	23.2	73.4	70.2	77.3	93.1	81.9
Apprentices	2.5	1.7	0.7	0.3	3.2	2.0	56.7	38.3	52.8
Industrial	58.1	52.3	22.6	24.1	80.7	76.4	77.0	91.5	81.0
Clerical	3.4	4.5	5.6	6.4	9.0	10.8	113.1	96.6	102.8
Admin/Tech.	9.3	10.9	1.0	1.9	10.3	12.8	99.8	162.4	105.8
Total	70.8	67.7	29.2	32.4	100.0	100.0	81.7	94.9	85.6

Table 4.1: Manufacturing Employment Shares By Sex and Category of Worker

Table 4.1 gives details on the shares of each type of worker in total manufacturing employment in 1979 and 1990. It can be seen that Operatives are by far the largest group of workers represented, accounting for 73% of total manufacturing employment in 1979, this share dropped to 70% in 1990. Apprentices are the smallest group with a share of under 2% in 1990 and Supervisors are the next smallest group (approximately 4%). The share of Clerical Staff (CL) rose by almost 2 percentage points over the period while the share of Admin/Tech (AT) Staff rose by two and a half percentage points. These are the only two groups where the absolute number employed has risen, by almost 6% for AT workers and almost 3% for CL workers. By contrast the level of Industrial Workers (IW) employment in 1990 fell by 19% relative to 1979, the biggest percentage fall was in the employment of Apprentices which almost halved over the period. Figure 4.7 gives an overview of the relative share of CL, AT and IW workers in total manufacturing employment over the period.

This visually confirms that the decline in manufacturing employment was due to a dramatic decline in *IW* employment.

Interestingly the increase in employment in the *AT* category was exclusively due to an increase in female employment, while in all other categories, and indeed in absolute terms, the level of female employment fell marginally (dramatically in the case of Apprentices). Since the data do not distinguish between part-time and full-time employment, it is not possible to infer how much of this increase in female *AT* employment is in part-time work. General trends in female employment[15] over the period suggest it may account for some, but not all, of the increase.

Figure 4.8 shows the numbers of male and female workers employed for each of the years 1979 to 1990 for *AT*, *IW* and *CL* workers. Besides a sizeable fall of over 30,000 in male *IW* employment which, given the importance of this category, has led to an overall fall in manufacturing employment of almost 33,000 over the period, the other categories of employment are relatively stable. The growth in female *AT* employment is clearly from a very low base.

The increase in *CL* employment is interesting. Perhaps surprisingly the increase in clerical employment in manufacturing is due to an increase in male employment with a marginal fall in female clerical employment. By contrast a recent study by Canny et al.(1996) found that between 1981 and 1991 male clerical employment for the economy as a whole fell by 13% while female clerical employment rose by almost 7%. Within their detailed occupation groups, male clerical employment rose in three occupational groups, namely typists and key-punch operators, computer operators and clerical supervisors. The increase in employment of computer operators was approximately 280% (220% for females), while the biggest decline was the employment of telephone operators. This would suggest that the increase in *CL* male employment for manufacturing reflects a large increase in the employment of computer operators. Indeed if we look at the manufacturing sectors where male clerical employment increased by 200% or more over the period 1979-1990 they are Office and Data Processing (sector 33, 247%), Insulated wires and cables (sector 341, 243%), Equipment for telecommunications, electronic recording, etc. (sector 344, 460%) and Radio and television receivers[16], etc. (sector 345, 423%). These are all sectors where computer skills are likely to be important. Therefore we are assuming that the increase in *CL* male employment is due to a) advances in information technology increasing the demand for computer skills and

[15]Both female labour force participation rates and the proportion of part-time work in total female employment have risen between 1979 and 1990 in the economy as a whole (the former from 35.1% to 38.5%, the latter from 12.7% to 17.1%).

[16]Bizarrely this sector which is defined by the CSO as 'Radio and television receivers, sound reproducing and recording equipment' includes 'reproduction of computer media' and 'software consultancy and supply'.

b) the classification of computer operators as clerical staff by firms in answering the Census questionnaire.

	1979	1990	1990 as % of 1979
Supervisors	0.79	0.78	99.0
Apprentices	0.30	0.29	96.8
Operatives	0.57	0.54	94.9
Industrial Workers	0.57	0.54	96.0
Clerical	0.57	0.63	111.2
Admin/Tech	1.00	1.00	100.0

Table 4.2: Ratio of Wage Rates to Admin/Tech Wage Rates in Manufacturing Sector

Table 4.2 gives details of relative wages (where the wage rate for Admin/Tech Staff is the denominator) for each category of worker in the manufacturing sector. Unfortunately the wage data are not broken down by sex. Relative wages have fallen somewhat for Industrial Workers and risen strongly for Clerical Staff. (Arguably the AT wage data may be understated if the increase in female employment is mainly due to part time work and the CL wage data overstated if the increase in male employment has increased total full-time CL employment.) Interestingly Clerical relative wages start at the same level as Industrial wages but while there is no catchup in the IW/AT wage, Clerical wages move from 57% to 63% of AT wages over the period. The net effect is that from close to parity in 1979 Clerical wages had increased by 17% relative to Industrial wages by 1990. Supervisors wages are well above the IW (and indeed CL) average although there is no persistent evidence of catchup over the period.

These relative wage ratios indicate clearly that the level of AT wages is far above the others. In 1990 Apprentices on average earned just 29% of the average AT wage, Clerical workers 63%. Figure 4.9 shows labour costs per worker for the years 1979 to 1990. AT wage rates are higher than all other wages and the wage gap is sizeable and persistent.

The increase in Clerical relative wages, given an increase in CL relative employment, would suggest an outward shift in the demand curve for clerical workers. This could be due to an information technology shock raising the productivity of workers with computer skills.[17] Krueger(1993), in a micro study of US workers over the 1980s, found that workers who use computers at work earn on average 10 to 15% more than similar workers who do not

[17]Unfortunately there are no data for Irish manufacturing on computer usage however there is strong anecdotal evidence that there has been a dramatic increase in investment in information technology. (see Fitz Gerald and Breathnach, 1994)

use a computer at work. Both Machin (1994) and Haskel (1996a) found that the introduction of computers had a positive effect on "skilled" employment. Also Timothy Bresnahan, in commenting on Lawrence and Slaughter's (1993) paper, argued that the most important factor behind the shift in demand towards skilled labour in the US was the computerisation of white collar work. Note that in these studies, clerical workers are grouped within the aggregate "skilled" labour category.

4.4 Definition of Skilled and Unskilled Labour

This section describes how we map the Census of Industrial Production data on employment categories into stylised "skilled" and "unskilled" labour categories. We have chosen to distinguish three separate categories of employment, namely Administrative and Technical Staff as a stylised proxy for "skilled labour", Industrial Workers as a stylised proxy for "unskilled labour" and Clerical workers as a third category which is of separate interest due to the impact of computerisation on the demand for these workers.

4.4.1 Definition of Skilled and Unskilled Labour in International Studies

The burgeoning international literature on labour demand heterogeneity typically defines two broad categories of worker which are intended to approximate to a skilled/unskilled distinction and are measured variously as nonproduction/production, white-collar/blue-collar. salaried/waged etc. This distinction is then used to investigate observed shifts in the relative demand for skilled workers so defined. For example Bresson et al. (1992) disaggregate their employment variable into skilled and unskilled workers where the skilled workers category includes engineers, technicians, skilled production workers, administrative and commercial staff and the unskilled workers category includes unskilled production workers. Berman, Bound and Griliches (1994) disaggregate employment into production and non-production workers where "production workers are "workers (up through the working foreman level) engaged in fabricating, processing, assembling, inspecting and other manufacturing." Non-production workers are "personnel, including those engaged in supervision (above the working foreman level), installation and servicing of product, sales, delivery, professional, technological, administrative, etc." [U.S. Bureau of the Census 1986, p. D-16]"(p. 369) In the only Irish study of this type, Boyle and Sloane (1982) disaggregate employment into wage-earners and salaried-workers, (these correspond broadly to production and non-production workers) where the former includes clerical staff. There are numerous other examples of studies of this type; Hamermesh (1993, pp108- 118) documents a broad range of studies on the demand for heterogeneous labour, citing twenty one studies which use a blue-collar/white-collar disaggregation.

Hamermesh (1993, p.112) is very critical of the "production" and "non-production" proxies for skilled/unskilled which are used in many studies of labour demand. "Part of the problem is that studies using aggregate data on the nonproduction-production worker distinction are comparing groups whose skills overlap greatly. While there is on average less human capital embodied in production workers, the distinction between the two groups is not sharp,..." He argues that it would be more meaningful to disaggregate employment by age and experience because "the huge literature on human capital makes it clear that this is also an aggregation by skill."(p.66)

There are many potential inconsistencies with the production/nonproduction distinction.[18] For instance they abstract from changes in the skill composition of the workforce as a whole. This point is particularly relevant for Ireland where the introduction of free education in the late 1960s meant that there was a general increase in skill levels in the cohort of workers entering the labour force in the 1980s. A potentially more worrying definitional problem, raised by Davis and Topel (see Lawrence and Slaughter, 1993), is that relative skill levels within production/nonproduction categories may vary between firms, across manufacturing sectors and over time. If this were the case then examining underlying trends in different worker categories, however defined, would be meaningless.[19] In a different vein Caves and Krepps (1993) argue that much of the increase in white-collar workers employment reflects an increase in "fat" or bureaucracy within many companies rather than an increased demand for skilled workers.

Several recent studies have tried to address some of these definitional difficulties. Machin, Ryan and Van Reenan (1996) examined the correlation between education based definitions of skill and the production/nonproduction distinction for four countries, the UK, the US, Sweden and Denmark, and found that they were highly correlated. Similarly Berman, Bound and Griliches (1994) found that nonproduction workers and white-collar workers had consistently more years of education than production and blue-collar workers. Significantly they found that this was also true for clerical nonproduction workers.

Table 4.10 gives some details on education by broad occupational groups from the Irish *Census of Population* for those in employment. In 1991 more than 80% of professional workers had continued full-time education up to the age of 19 plus. This contrasts with less than 5% for labourers, and 5% for skilled production workers. The majority of those in clerical

[18]Robert Hall points out that the US definition of nonproduction workers includes airline pilots while production workers includes co-pilots (see Caves and Krepps, 1993).

[19]This issue is explored in relation to our dataset in Section 4.5.2.

occupations completed secondary education (ceased education at age 17-18) as compared with less than 30% of skilled production workers. More than three quarters of managers, professional workers, associate professional workers and clerical occupations continued in full-time education beyond the age of 16 compared with an overall average of 55% for all occupational groups, 38% for production operatives and 34% for skilled production workers. These data suggest that those in the administrative and technical staff category are likely to have more years education than the industrial workers category.

Despite their limitations the production/nonproduction categories are now widely used, mainly because they are identified in the annual census in most countries and are therefore available over time across a broad range of industries. Irish data are no exception to this, the data we have sourced are the closest time-series approximation to a skilled/unskilled distinction currently available in Irish data. In disaggregating the data we define Administrative and Technical Staff as "skilled labour" and Industrial Workers as "unskilled labour". It is important to remember that these categories are defined by the firms themselves in answering the questionnaire, the CSO do not provide a listing of occupational classifications to be used by firms beyond the broad definitions given in Section 4.3.1. The Admin/Tech Staff category is defined to include all "salaried staff" which would in general be a proxy for staff hired with some educational qualification. And the Industrial Workers category refers to "manual" workers which, arguably, would be more closely associated with lower levels of educational qualifications.

4.4.2 "Unskilled Labour" = Industrial Workers

The Industrial Worker category is an aggregation of three separate categories in the CIP questionnaire, namely Apprentices, Manual Workers (also defined as "Operatives") and Manual Supervisory Staff (also defined as "Supervisors"). Manual Supervisory Staff includes both foremen and production supervisors. In this it differs for the US Annual Survey of Manufactures which defines foremen as production workers and supervisors as non-production workers. This separation is not possible with the Irish data because they are not separated in the census questionnaire.

The two individual categories, Apprentices and Supervisors, are very small. Operatives account for 90.9% of IW manufacturing sector employment in 1979 and 91.9% in 1990. Supervisors for 5.1% in 1979 and 5.5% in 1990 and Apprentices for 4% in 1979 and 2.6% in 1990. The numbers for separate categories on "Supervisors" and "Apprentices" are very small and for some industry groupings are zero (esp. for "Apprentices"). At a sectoral level the domination of Operatives employment is also apparent, e.g. in the Wool sector (NACE 431) on average Operatives accounted for 93% of IW employment, in the Pharmaceuticals sector (NACE 257) the corresponding figure is 91%. The Operatives category, relating as it does to manual workers, is likely to cover most of the unskilled or lower-skilled employment in a given firm so that its dominance within the IW category does lend some credence to our IW = unskilled proxy.

4.4.3 "Skilled Labour" = Administrative and Technical Staff

The discussion of the aggregation to the Industrial Workers category raises a related point in the definition of Admin/Tech Staff, namely why we chose not to include Supervisors in the AT category. Essentially it is a moot point whether Supervisors should more properly be included with Administrative and Technical Staff. As mentioned above, in the CSO data Supervisors includes both foremen and production supervisors where in the US Survey of Manufactures foremen are defined as production workers and production supervisors as non-production workers so the appropriate classification of this Supervisors category as between production and nonproduction workers is unclear.

Manufacturing sector employment of Supervisors as a percentage of IW barely changed over the period 1979-1990 while the level of Supervisors employment fell by almost 13% over the period (IW fell by almost 19%) in contrast to the 6% increase in AT employment (Table 4.1). So in employment terms Supervisors would more naturally be grouped with IW workers. However Supervisors' wages are far higher than average Industrial Worker wages. On average AT wages are 25% higher than Supervisors' while IW wage rates are 28% lower, thus Supervisors wages are approximately half-way between IW wages at the lower end and AT wages at the upper end (see Figure 4.9). Furthermore Supervisors wages have risen relative to the IW average over the period. We finally opted to group Supervisors within Industrial Workers by recourse to the likely nature of the firms' classification in the questionnaire. This is because in the CSO questionnaire the question on Supervisors relates to "Manual supervisory staff", and the question on Administrative and Technical Staff relates to "Managerial, technical and *other salaried staff*". Therefore we suspect (of course one cannot be sure how such questions are treated by firms themselves without asking them) that firms would answer these questions with reference to salaried vs. waged staff, a distinction which exists in a lot of Irish firms. We would hazard that "waged" or "manual" staff within a firm are less likely to have high levels of education, assuming education is an indicator of skill levels. Thus we felt it better to leave Supervisors in the general unskilled category.

4.4.4 Clerical Workers: A Third Category

We keep the category Clerical Staff separate. It is a relatively large category, accounting for almost 11% of manufacturing employment in 1990, and along with *AT* it is the only other category where employment grew, albeit slowly, over the period. It is also the only category where wage rates, relative to *AT*, grew significantly over the period, by over 6 percentage points. However its wage levels are so far below *AT* levels, even in 1990, that we consider it should be kept separate from *AT*.

As mentioned above, clerical employment has undergone enormous change as rapid growth in the use of computer technology has swept across all manufacturing sectors. This was anticipated to herald major job losses for clerical workers. This does not appear to have happened in Irish manufacturing, instead wages relative to 'skilled' workers have risen[20] and (male) clerical employment has risen, two factors which taken together would suggest an outward shift in the demand for clerical workers.[21]

The fact that the nature of clerical employment is changing, with big shifts in occupations within the clerical employment category as documented in Canny et al. (1996) and referred to earlier, makes it a fundamentally different category of worker from the other two. In defining labour as "skilled" or "unskilled" the motivation is to identify two distinct but internally homogenous types of labour and to look at shifts which have taken place between the two groups. However the major changes in the clerical workers category seem to have occurred within the category with an increase in the skill-intensity of clerical work. Although such internal changes may have also occurred within the skilled and unskilled categories, the very evident idiosyncratic effect which computerisation has had on clerical occupations makes it impossible to ignore.

Finally a more prosaic reason why we separate out Clerical staff is that the *CL* wage data for certain sectors behave somewhat erratically. This is because in the CSO dataset we had to calculate the Clerical wage bill as a residual. (Section 4.11 in Chapter 5 gives more details on this.) For example in the Furs and fur goods sector (NACE 456) clerical wages as measured increased by 450% in 1988. This is the largest outlier in the *CL* wage data. Within this sector between 1987 to 1988 two firms closed down, clerical employment halved

[20] Entorf and Kramarz (1994), in a panel study of France labour force data over the period 1985-87, found that the higher the skill level of the employee the less the use of modern new technologies is compensated. "Managers, technicians, engineers are not compensated for their use of modern NT; it is part of the definition of their job" [p25].

[21] It is possible that the increase in male employment may have caused an increase in *full-time* clerical employment so that the observed increase in wages merely reflects a shift from part-time to full-time employment. However even if this were the case it still indicates that there has been a change in the demand for clerical workers.

and the actual level of clerical employment was very small (4 employees in 1988). So, in a small number of cases, the *CL* data are bedevilled by a small numbers problem coupled with the effect of discrete changes within small sectors. Also because the wage bill data are calculated as a residual, small numbers can be seriously distorted by rounding and revisions.

4.4.5 Comparison with International Definitions

How do these definitions of skilled and unskilled labour compare with those used in international studies? Table 4.3 contains data on the wage share and labour share of nonproduction workers in manufacturing for four countries, the UK, the US, Denmark and Sweden. These are compared with three alternative definitions of skilled labour from the Irish data, respectively AT, $AT + CL$ and $AT + CL + IW(Supervisors)$. The first of these is the narrowest definition of skilled labour, this is the definition which we use in this chapter. The second includes clerical workers in the definition of skilled labour. Clerical workers are typically included as skilled labour in international data despite the fact that clerical wages are substantially lower than average non-clerical skilled wages, at least for Ireland. The third definition includes manual supervisors.

	Wage Share			**Labour Share**		
	1973	1979	1989	1973	1979	1989
US	0.34	0.35	0.42	0.25	0.26	0.31
UK	0.32	0.35	0.41	0.26	0.29	0.33
Denmark	0.34	0.33	0.40	0.25	0.27	0.32
Sweden	0.36	0.39	0.40	0.27	0.29	0.30
Ireland:						
AT		0.17	0.20		0.10	0.13
$AT + CL$		0.25	0.32		0.19	0.24
$AT + CL + IW(Supervisors)$		0.31	0.37		0.23	0.28
International data on nonproduction workers in manufacturing taken from Machin, Ryan and Van Reenan (1996), Table 1 and Figure 4						

Table 4.3: Nonproduction Workers Share of Total Employment and Wage Bill In Four Countries: A Comparison With Different Measures of Irish Nonproduction Workers

Looking at the table it is clear that under even the widest definition of skilled labour, Irish employment and wage bill shares for skilled labour were lower in 1989 than the equivalent measures for any of the other four countries. This is not surprising since education levels in Ireland have only recently begun to catch up with those of the US and Europe. Nonetheless the Irish skilled labour and wage shares had the highest annual average growth rates of all the countries listed. Thus there is evidence that the skill composition of the Irish manufacturing sector's labour market is increasing in line with similar international trends in OECD economies and, given these higher growth rates, is catching up with international levels.

The second definition of Irish skilled labour is closest to that used internationally. However, as argued above, we feel it is useful to separate out clerical workers from other skilled labour. Under this definition Irish relative skilled/unskilled wages have risen over the period. However under all three definitions Irish relative wage rates have not changed by much. This is in contrast to the US and UK experience during the 1980s (see Figure 2 in Machin et al. (1996)) but similar to average European trends. Rapidly widening wage gaps in the US and UK between skilled and unskilled labour have fuelled much of the recent interest in analysing the composition of employment in those countries. By contrast in mainland European countries wage differentials have in some cases narrowed (Draper and Manders (1996) for the Netherlands). It is argued (Saint-Paul (1996)) that this is due to labour market institutional rigidities, which prevent relative unskilled wages from falling in many European countries thus causing a spill-over of this relatively expensive unskilled labour into unemployment. This means that given a fall in demand for unskilled labour, the net result for the UK and the US has been a widening wage gap[22] while the net result in Europe has been an increase in unemployment. The Irish experience, where there is also evidence of an increase in the demand for skilled labour relative to unskilled, seems to lie closer to the European experience. The large and persistent increase in long-term unemployment in Ireland in the early 1980s was mainly among those with relatively few educational qualifications (see Table 4.10).

4.5 Sectoral Trends in Composition of Labour 1979-1990

In this section we look at some statistical indicators for 72 individual sectors in order to piece together a picture of the structure of the manufacturing sector and its evolution over the period 1979-90. We look across the panel of 72 individual sectors over a period of 12 years. The data in general reveal the extent to which the manufacturing sector is an aggregation of many very different types of production activities. Finally in this section we group the sectoral data into three sectoral "types" based on their growth performance over the period.

[22]For an analysis of the UK skilled/unskilled wage premium see Haskel (1996b), he argues that more that 50% of the increase in the UK premium over the 1980s is due to the introduction of computers.

4.5.1 Correlations Between Variables in Panel

	LAT	LIW	LCL	CLAT	CLIW	CLCL	NO	Q
LAT	1.0							
LIW	0.74	1.0						
LCL	0.82	0.69	1.0					
CLAT	0.10	-0.08	0.13	1.0				
CLIW	0.13	-0.09	0.14	0.90	1.0			
CLCL	0.12	-0.06	0.14	0.86	0.84	1.0		
NO	0.54	0.70	0.41	-0.21	-0.17	-0.16	1.0	
Q	0.73	0.52	0.58	0.21	0.22	0.19	0.19	1.0

LAT is *AT* Employment, *LIW* is *IW*Employment, *LCL* is *CL* Employment
CLAT is *AT* Labour Costs per employee, *CLIW* is *IW* Labour Costs per employee
CLCL is *CL* Labour Costs per employee, *NO* is Number of firms, *Q* is Volume Output.

Table 4.4: Correlation matrix of sectoral variables

Table 4.4 summarises the population correlation coefficients[23] covering the period 1979-1990 between the employment levels, labour costs per employee (referred to here as 'wages'), number of firms and volume output. These are calculated for all 72 sectors. In addition Figures 4.10 and 4.11 in Section 4.10 plot these correlations computed recursively from 1979 to 1990.

The correlation between volume output and employment is highest for skilled (*LAT*) labour and weakest for unskilled (*LIW*) labour. Figure 4.10 shows that the correlation of volume output with both clerical (*LCL*) and unskilled labour has fallen substantially over the period while that with skilled labour has risen gradually. Unskilled labour has the weakest correlation with the other employment levels and its correlation with skilled labour has fallen over the period.

The correlation between own wages and employment for each category of worker is relatively weak and for unskilled labour it is negative (Figure 4.10). The cross correlation between skilled labour and clerical wages has been rising while all other cross correlations between employment levels and wage levels have fallen (see Figure 4.11). Skilled and unskilled wages are strongly correlated (0.9 in 1990) and the correlation of both with clerical wages has risen strongly over the period (from approximately 0.2 in 1979 to 0.8 in 1990).

[23]The reported correlation coefficients between any two variables x and y were calculated as follows: $\sum_i \sum_t (x_{it} - \bar{x})(y_{it} - \bar{y}) / \sqrt{\sum_i \sum_t (x_{it} - \bar{x})^2 \sum_i \sum_t (y_{it} - \bar{y})^2}$ where $t = 1979...1990$, $i = 1..72$.

There is a strong and stable correlation between employment and the number of firms in a sector, especially for unskilled labour. Because these data refer to manufacturing sectors rather than individual firms observed changes in employment will reflect the births or deaths of firms within a sector as well as increases or decreases in employment within firms themselves. A detailed examination of the sectoral data reveals that this does indeed occur in certain sectors. For example the Non-ferrous metals sector (NACE 224) more than halved its *IW* employment in 1983 (from 526 employees to 196 employees), in that year this sector had one (net) firm closure. This can explain the strong correlation between the number of firms and unskilled labour. A recent paper by Barry, Strobl and Walsh. (1996) analysed data on job creation and job destruction in the Irish manufacturing sector over the period 1974-94. They found that approximately one quarter of job creation was due to firm births and 34% of job destruction due to firm deaths. This would tend to confirm the trends in the data reported here, that changes in the number of firms have a strong link with changes in employment. (Of course this is not surprising.) Keating and Keane (1989) show that firm closures from 1979 to 1985 account for a fall of 60,000 in manufacturing employment with contractions in existing firms accounting for a further reduction of 40,000. This is relative to an overall fall of 40,000 in employment in this period. This is a very important point for formulating demand for labour models for econometric estimation, in the absence of firm-level data it would suggest that changes in the number of firms be included as an additional explanatory variable in explaining changes in employment.

Interestingly the period when the total number of firms expanded rapidly (1979-1982) exactly coincides with the period when output growth was at its lowest (the correlation between output and the number of firms is low and declining gradually). Further perusal of Table 4.13 indicates that in this low-growth period the four sectors with the largest increases in the number of firms accounted for almost half of the overall increase in firm numbers. These four sectors, namely Structural Metal Products (NACE 314, +81 firms), Wood Furniture (NACE 467, +74 firms), Finished metal products (NACE 316319, +65 firms) and Carpentry (NACE 463, +46 firms), were all sectors which recorded negative output growth rates in 1979-1982 (see Table 4.11). Furthermore all of these sectors recorded net decreases in the number of firms in the subsequent period 1982-1986. The analysis in Barry, Strobl and Walsh (1996) indicates that the plant birth rate is negatively correlated with overall net *employment* growth. Taken in conjunction with the decline in average plant size, these counter-cyclical movements would suggest that many of the net 'new' firms set up in this recessionary period were small firms set up by ex-employees as a result of redundancies and layoffs.

In Section 4.10 of this chapter we look at indicators of output growth, employment growth, changes in the number of firms in each sector, shifts in employment ratios and corresponding wage ratios. Tables 4.11, 4.12 and 4.13 show the annualised growth rates in these variables for all 72 sectors. In each of these tables the sectors are ranked from 'highest' to 'lowest' based on the individual sector's average output growth over the period 1979-90. Section 4.9 summarises both the cross-section and time-series variation in these indicators. This analysis shows that, while there is considerable variability across both the time and cross section dimension of the panel, there is greater variability in the cross section dimension. In this analysis the data are *not* weighted so that each sector, no matter how small, is accorded equal importance in the analysis.

Tables 4.14 and 4.15 in Section 4.10 show the share of each sector in total manufacturing employment $LTOT$, value added YV and gross output QV in both 1979 and 1990. Clearly there have been some significant changes in the structure of the manufacturing sector over the period. The three sectors with the highest share of employment in both 1979 and 1990 were Printing and Publishing (sector 473474, 5.3% in 1990), Clothing and Accessories (sector 453454, 5.25% in 1990) and Generation and Distribution of Electric Power (sector 161, 5.22% in 1990). The three sectors with the highest share of gross output were Slaughtering, Preparing and Preparation of Meats (sector 412, 9.55% in 1990), Manufacture of Dairy Products (sector 413, 9.85% in 1990) and again Generation and Distribution of Electric Power with 4.73% in 1979, the latter was supplanted in the top three ranking in 1990 by Office and Data Processing (sector 33) with a share of 9.89% in 1990. Finally, the three sectors with the biggest share of value added were Pharmaceuticals (sector 257, 11.73% in 1990), again Generation and Distribution of Electric Power with a share 6.25% in 1979 and Non-metallic Mineral Products (sector 241246) with a share of 5.46% in 1979, these two latter sectors were also supplanted in the top three ranking by Office and Data Processing, with a share of 10.43% in 1990, and Miscellaneous Foodstuffs (sector 417823) with a share of 7.68% in 1990.

4.5.2 Identifying Three Diverse Groups of Sectors

All of these indicators confirm, unsurprisingly, that the Irish manufacturing sector is compositionally extremely heterogeneous in terms of output growth, net change in firm births and deaths, employment growth and wage growth. In this section we divide the data into three stylised groups of sectors based on their output growth performance over the period. We do this because our underlying theoretical model in the next chapter is based on " representative" firm or sector behaviour. Similar work by Neven and Wyplosz (1996) defines homogenous groups in terms of factor intensity. Our central division is between expanding sectors and contracting sectors. However we also identified a third category of "high-growth" sectors which are largely foreign-owned, export-oriented sectors with exceptionally

	High Growth		Medium Growth		Declining	
	1979	*1990*	*1979*	*1990*	*1979*	*1990*
Percentage Share in Total:						
Employment	11.6	22.4	51.5	51.4	36.9	26.2
Value Added	23.9	48.3	50.6	39.7	25.4	12.0
Gross Output	15.0	35.4	59.6	51.3	25.5	13.3
Levels:						
Number of Firms	342	583	2194	2287	2169	1825
Employment	28,396	46,656	124,839	106,802	88,851	54,311

Table 4.5: Some Summary Statistics on the Increase in Importance of the High Growth Sector Relative to the Declining Sector from 1979 to 1990

rapid growth performance over the period.

The isolation of these high-growth sectors from other expanding sectors is essentially arbitrary at the margin. This group, labelled group H (high-growth), includes 12 sectors which recorded average annual growth above 7% (see Table 4.11). This group is dominated by foreign-owned firms with high profitability[24]. Therefore it is within this group that there is the largest potential distortion in the value-added data due to profit-switching transfer pricing distortions. The second group of sectors, labelled group M (medium-growth), covers 30 medium-growth sectors where average annual growth was between 0.5% and 7% per annum. The third group, labelled D (declining), covers 30 declining or low-growth sectors, where average annual growth was below 0.5%. For all but two of these sectors the average annual growth rate was negative.

Table 4.5 presents some summary statistics relating to these three groups of sectors. The high-growth group almost doubled its employment share and more than doubled its output share between 1979 and 1990. By 1990 this group of 583 firms accounted for almost half of total manufacturing value added. The medium-growth group maintained its employment share although its share of gross output fell from 59.6% in 1979 to 51.3% in 1990. The declining group of sectors suffered a sharp decline in both employment and the number of firms. This group includes many so-called "traditional" industries (for example clothing, footwear, jewellery) which are those identified as being most vulnerable to import competi-

[24]O'Malley and Scott (1994) report that 86% of foreign-owned manufacturing firms profits in 1983 were accounted for by the following sectors: Pharmaceuticals (NACE code 257), Office and Data Processing Machinery (NACE code 33), Electrical Engineering (NACE code 34), Instrument Engineering (NACE code 37) and soft-drink concentrates which is part of "Misc. Foods" (NACE 411, 414, 417/8 amd 423). All of these sectors are represented in the High Growth group.

tion from low-wage countries (Wood (1994, p.97)). From the table it can be calculated that the high-growth group of sectors has above average firm size (83 in 1979 and 80 in 1990) while the declining group has below average firm size (41 in 1979 and 30 in 1990) although for each group average firm size has fallen.

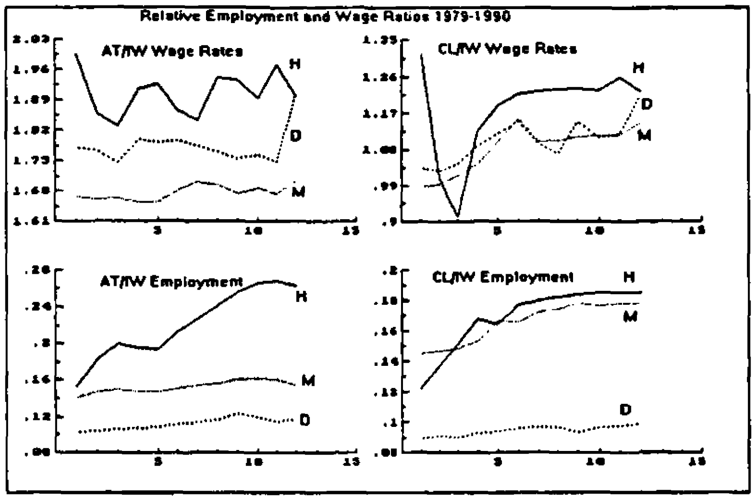

Figure 4.2: Ratio of AT/IW and CL/IW Employment and Wage Rates, 1979-1990, for High Growth (H), Medium Growth (M) and Declining (D) Sectors.

Figure 4.2 plots relative employment and wage ratios for each of these groups of sectors. The ratio of skilled to unskilled labour in 1979 at 0.153 was highest in the high-growth group and during the 1980s it increased rapidly to a level of 0.264 in 1990. The ratio of skilled to unskilled labour was lowest in the declining group increasing marginally from 0.103 in 1979 to 0.116 in 1990 while the ratio in the medium-growth group also increased at a slow pace from 0.14 in 1979 to 0.155 in 1990. Relative skilled wages are also higher in the high-growth group. Note that the fact that relative skilled wages in the declining group are higher than in the medium-growth group is because the gap between skilled and unskilled wages is higher in the declining group although the level of wages is lower for both in the declining group (see Figure 4.3).

A similar pattern emerges in Figures 4.12 and 4.13 which plot employment and wage bill shares for the three groups of sectors. The medium-growth group is the largest and maintains its share of total employment and wages throughout the 1980s while the high-growth group expands in line with a corresponding fall in the share of the declining group.

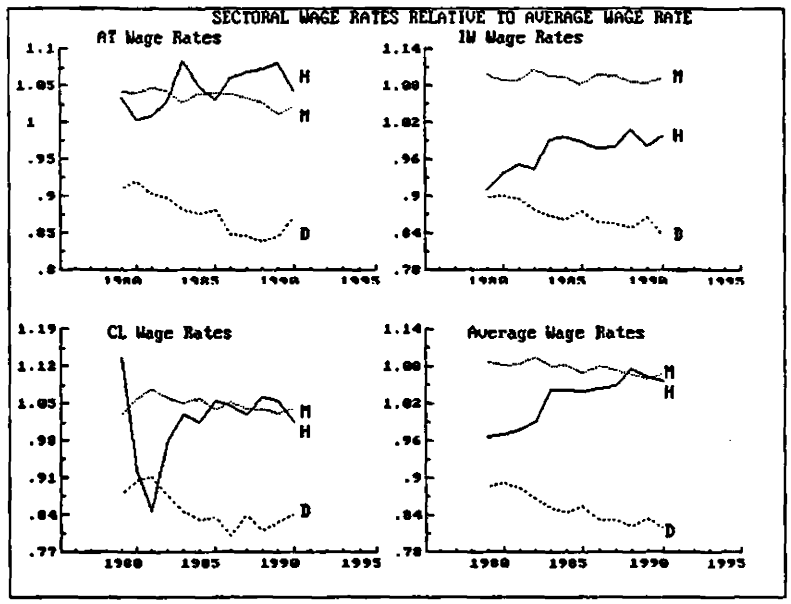

Figure 4.3: Wage Rates in High Growth, Medium Growth and Declining Groups Relative to Average Manufacturing Wage Rates for Skilled (AT), Unskilled (IW), and Clerical (CL) and all workers.

The declining group of sectors has very low wage levels relative to the average manufacturing wage and these fell further from 89% of the average in 1979 to 82% of the average in 1990. Figure 4.3 plots sectoral wage rates relative to the average manufacturing wage rate for skilled, unskilled and clerical workers. In 1990 the average wage for a skilled worker in the declining group was £18,157 while in the high-growth group it was £21,738, almost 20% higher. Furthermore it is in the high-growth group that employment of skilled labour has risen sharply as shown in Figure 4.2. These trends are further clarified by evidence on reported skilled and unskilled labour shortages from a monthly survey of manufacturing firms (Kearney (1997)). This evidence indicates that reported skilled and unskilled labour shortages in the late 1980s (the data begin in September 1984) were highest in the declining group, especially skilled shortages[25]. There were little or no reported shortages in the high-growth group. This would suggest that the declining group of sectors, although seeking to

[25]Reported labour shortages (especially skill shortages) were predominant in "traditional" industries (esp. clothing, footwear and leather and to a lesser extent in timber and wooden furniture and textiles) in the late 1980s and in the mid-1990s while for the manufacturing sector as a whole they were relatively unimportant.

employ more skilled workers, cannot compete on the labour market for skilled workers with the high-growth (and also medium-growth) sectors at the prevailing wage rates.

The medium-growth group had the highest average wage levels in 1979, however the average wage in the medium-growth and high-growth groups had converged by 1990. Interestingly unskilled wages are substantially higher in the medium-growth group than in the high-growth group (this explains this group's higher average wage) although they have been rising in the high-growth group. Despite this convergence unskilled wages in 1990 in the medium-growth group were £12,482, 9% higher than unskilled wages in the high-growth group and 31% higher than in the declining group (at £9,548).

These differences in wage rates across the three groups suggest that the level of embodied skills in the three categories of labour may vary between groups. Under the assumption that the three labour categories measure the same skill levels across sectors we would expect their average wage to be more or less equal across sectors. This seems clearly to be the case for both skilled labour and clerical workers in the medium and high-growth groups. However it is not the case for unskilled labour, where the higher average wage in the medium growth group suggests that unskilled labour in this group may have a relatively higher level of embodied skills than in the high-growth group.

These differences raise some doubts on the equivalence of the definition of unskilled labour in the high growth and medium growth groups. In Table 4.6 we attempt to explore this issue further by looking at the occupational profile of ten manufacturing sectors using Labour Force Survey and Census of Population data. The table shows the employment share of these sectors in each of the three groups of sectors identified here. These data do not reveal any striking differences in the distribution of occupations between the predominantly high growth sectors and the predominantly medium growth sectors. Specifically there is no evidence to suggest that the high growth sectors have a higher proportion of workers with relatively less embodied skills (i.e. more "labourers and others" and fewer "skilled production and maintenance workers" and "production operatives"). Indeed it is the predominantly medium growth sector of "Drink and Tobacco" that has the highest share of "labourers and others".

The evidence is inconclusive but suggests the following. Firstly the lower wage rates in the declining sectors suggest a competitive disadvantage on the labour market which is borne out by the decline in employment in these sectors over the period. Secondly the higher unskilled wages in the medium growth group, despite some catch-up by the high growth group over the period, suggest that unskilled labour in this group is relatively more skilled than in the high growth group.

4.6 Shift-Share Analysis of Sectoral Data and Grouped Data

Section 4.2 outlined the debate on demand-side causes of the observed increase in skilled labour. Many recent studies have used 'shift-share analysis' to decompose the increase in the share of skilled labour into the proportion due to an increase in skilled labour *within* sectors or firms and the proportion due to an increase in employment *between* sectors or firms. Section 4.6.1 shows that, in line with the results from international studies, the within component dominates the between component in explaining shifts in the share of skilled and unskilled labour in Irish manufacturing. The following subsection 4.6.2 decomposes changes in the *levels* of employment and the wage bill for unskilled, skilled and clerical labour. This decomposition includes an estimated 'scale' effect reflecting the underlying expansion or contraction of total employment in different sectors. Note that this scale effect is different from that estimated in the factor demand equations, which tests for non-homotheticity in production (see Chapter 2 for details).

4.6.1 'Between' and 'Within' Effects

In this section we decompose the change in the share of skilled, unskilled and clerical labour in total employment and wages into within sector and between sector changes. This analysis is based on that used in Berman, Bound and Griliches (1994) as follows:

$$\Delta P_j = \underbrace{\sum_i \Delta S_i \overline{P}_{j_i}}_{\text{Between}} + \underbrace{\sum_i \Delta P_{j_i} \overline{S}_i}_{\text{Within}} \tag{4.1}$$

where P_{j_i} is the proportion of type j employment in sector i, S_i is the share of employment in sector i and a bar denotes a mean over time[26]. The total change in type j employment is decomposed into a weighted change in employment shares *between* industries (the first term on the right hand side) and a weighted change in the proportion of j employment *within* sectors (the second term on the right hand side). This type of analysis is now used extensively. Changes in employment shares between sectors are interpreted as evidence of an international trade effect shifting employment from one sector to another. Changes in

[26]This is derived by total differentiation of the following expression:

$$P_j = \sum_i S_i P_{j_i}$$

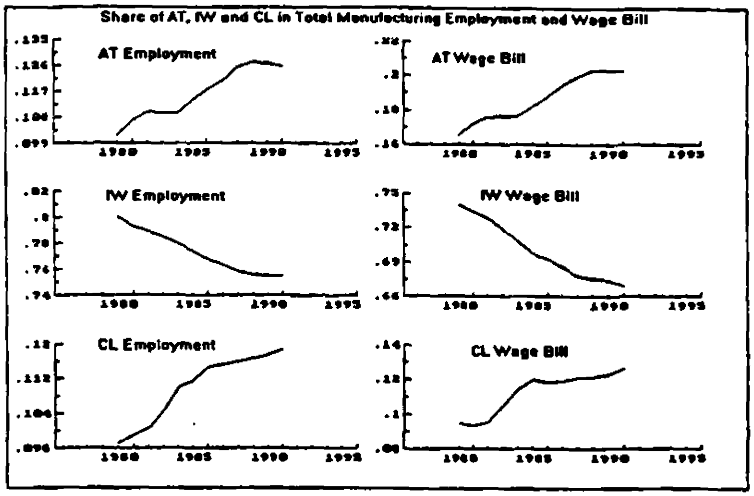

Figure 4.4: Share of Admin/Technical, Industrial and Clerical Workers in Total Manufacturing Employment and Wage Bill

employment shares within sectors are interpreted as evidence of factor-biased technological change altering relative employment shares.

This interpretation is predicated on a number of assumptions. Probably the most important one in using sectoral rather than firm level data is the assumption that changes within sectors are uniform and do not reflect structural change within the sector itself. Also this analysis focuses only on substitution effects. If technology is skill-biased then firms will demand more skilled labour (the substitution effect), however they will also require fewer skilled workers to produce the same amount of output (the income effect) so that the net within sector effect may be ambiguous. Finally aggregation over industries obviously reduces the importance of the between component so the analysis is not invariant to the level of disaggregation used.

Tables 4.16, 4.17 and 4.18 report the results of this decomposition for skilled, unskilled and clerical labour for the sample as a whole and also for the three groups of sectors, high-growth, medium-growth and declining. The between and within decompositions are reported for both the employment share and the wage bill share. We have performed the analysis for the entire sample period and also for two sub-periods, 1979-1987 and 1987-1990.

Looking at Table 4.16 it can be seen that for the total sample the increase in skilled labour's share averaged 1.93% per annum while the wage bill share increased by 1.88% per annum. The sub-period analysis highlights that almost all of this increase occurred in the period 1979-1987. Clerical labour's employment share increased by an annual average of 1.83% while the wage bill share grew strongly at 2.86% per annum. Again this growth was largely concentrated in the period 1979-87. This pattern can be seen in Figure 4.4[27], most of the increase in the skilled and clerical shares (and the consequent decrease in unskilled share) occurred in this period. From 1987 onwards, when growth picked up, there was very little change in relative employment shares.

The high-growth group of sectors had the largest increase in the proportion of skilled labour while both the declining and medium-growth group of sectors recorded growth below the average for all 72 sectors. This is important. Figure 4.5 illustrates this more clearly. It plots the employment and wage shares of each of the three groups of sectors for skilled, unskilled and clerical labour. It can be seen from the graph that the high-growth group (H) has the largest increase in skilled employment and wage shares and the largest falls in unskilled employment and wage shares. The declining (D) group shares are virtually unchanged over the period and the medium-growth group shares exhibit a gradual fall in unskilled shares.

Within Sector Changes as Proportion of Total Change												
	All 72 sectors			High Growth			Medium Growth			Declining		
	AT	*IW*	*CL*	*AT*	*IW*	*CL*	*AT*	*IW*	*CL*	*AT*	*IW*	*CL*
Employment												
1979-90	0.75	0.79	0.83	0.95	0.99	1.07	1.16	0.98	0.92	1.08	1.15	1.27
1979-87	0.81	0.79	0.78	0.95	0.97	1.02	1.00	0.86	0.78	1.06	1.18	2.07
Wage Bill												
1979-90	0.63	0.74	0.86	0.90	0.93	1.03	1.01	0.98	0.97	0.86	0.95	1.07
1979-87	0.66	0.73	0.83	0.88	0.89	0.93	0.90	0.92	0.92	0.89	1.00	1.21

Table 4.6: Within Sector Changes for AT, IW and CL workers as Proportion of Total Change in Employment Shares and Wage Bill Shares

The within sector component of the total change in shares dominates. Table 4.6 summarises this estimated within sector component for the entire period and for the first sub-period 1979-1987 when most of the shifts occured. Seventy-five percent of the total change in skilled labour's share was due to within sector changes. This proportion is even higher for unskilled and clerical labour.

[27]These data are slightly different from those shown for the aggregate manufacturing sector in Table 4.1. This is because these data are the weighted sum of shares for 72 sectors, while the data in Table 4.1 refer to aggregate data for the 69 manufacturing sectors.

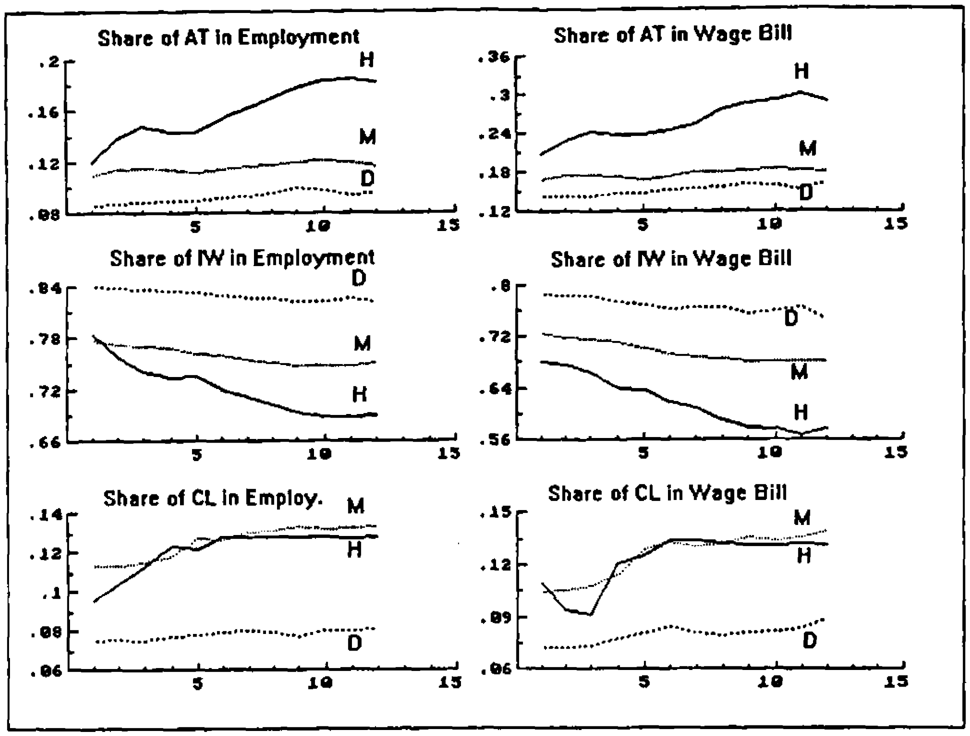

Figure 4.5: Share of AT, IW and CL in High Growth, Medium Growth and Declining Sectors' Total Employment and Wage Bill.

This analysis suggests that there has been a large increase in the relative demand for skilled labour within the high-growth sectors of Irish manufacturing. Notably virtually all of this increase occurred in a period of relatively low growth. This would suggest that the increase in skill intensity improved growth performance, *ceteris paribus*, which rose strongly in the subsequent period.

4.6.2 'Scale' Effects

The analysis in the previous sub-section examines changes in the *share* of employment and the wage bill. However it is also instructive to examine changes in the *level* of these variables. For example while the share of unskilled labour has fallen in the high-growth group of sectors the actual level of unskilled labour has risen because these sectors have been growing strongly over the period.

The following decomposition of changes in the level of employment and the wage bill can be used to separately identify 'scale' effects, 'sector' effects and 'occupation' effects as follows[28]:

$$\sum_i \Delta E_{ijt} = \text{Change in } j \text{ employment} = \tag{4.2}$$

$$\sum_i [\underbrace{(g_t \cdot E_{ijt-1} - E_{ijt-1})}_{\text{Scale effect}} + \underbrace{(gi_t \cdot E_{ijt-1} - g_t \cdot E_{ijt-1})}_{\text{Sector effect}} + \underbrace{E_{it-1}(\frac{E_{ijt}}{E_{it}} - \frac{E_{ijt-1}}{E_{it-1}})}_{\text{Occupation effect}} + \underbrace{r_{it}}_{\text{Residual}}]$$

where g_t is the growth rate of total employment, gi_t is the growth rate of employment in sector i, E_{ijt} is employment of worker j in sector i and E_{it} is total employment in sector i. Thus the scale effect measures what the change in employment j would have been if it had grown at exactly the same rate as total employment (not to be confused with the scale effect used elsewhere in this thesis, which tests for non-homotheticity in production). The sector effect measures what the change in employment j would have been if there were no scale effect and if employment j had grown at the same rate as total employment in sector i. The occupation effect measures what the change in employment j would have been if there were no scale or sector effect and if employment in occupation j had grown at the same rate as the growth in the share of occupation j in sector i. Finally r_{it} measures a residual interactive effect.

The results of this decomposition are given in Tables 4.19, 4.20 and 4.21 respectively for skilled, unskilled and clerical labour and wage bill. If we look first at the results for skilled labour we can see that sector effects are negligible. In the period 1979-87 it is estimated that the 'pure' occupation effect would have increased total skilled labour by 2%, this was offset by a negative scale effect of -2.5% so that the net effect was a very modest increase of 0.1% in total skilled labour. In the period 1987-90 these effects were reversed, the scale effect turned positive and the occupation effect was negative but close to zero.

Turning to the same analysis for sectoral groups we can see from Table 4.7 that a positive 'scale effect' of 4.6% accounted for more than half the total increase in skilled labour in the high-growth group with the occupation effect accounting for most of the rest. For the medium-growth and even more for the declining group of sectors the scale effect was negative and dominated the occupation effect. The same pattern emerges for unskilled and clerical labour. Occupation effects are strongest in the high-growth group (strongly positive for clerical and negative for unskilled), sector effects are unimportant and scale effects dominate.

[28]See Corcoran et al. (1992) Appendix III for details.

Annualised % Growth Rates in Employment, 1979-1990												
	All 72 sectors			High Growth			Medium Growth			Declining		
	AT	*IW*	*CL*	*AT*	*IW*	*CL*	*AT*	*IW*	*CL*	*AT*	*IW*	*CL*
Scale	-1.4	-1.4	-1.4	4.6	4.6	4.6	-1.4	-1.4	-1.4	-4.4	-4.4	-4.4
Sector	0.3	-0.1	0.2	0.4	-0.1	0.2	-0.1	-0.0	0.1	0.0	0.0	-0.1
Occupation	1.3	-0.4	1.5	3.8	-1.2	3.1	0.7	-0.3	1.4	1.2	-0.2	0.9
Interactive	0.1	-0.0	-0.1	2.5	-0.6	1.1	-0.1	0.1	-0.3	-0.6	0.1	-0.4
Total	**0.5**	**-1.9**	**0.4**	**8.7**	**3.4**	**7.4**	**-0.8**	**-1.7**	**0.1**	**-3.4**	**-4.5**	**-3.7**

Table 4.7: Growth in AT, IW and CL Employment, 1979-1990, Decomposed into Scale, Sector and Occupation Effects

The decomposition of changes in the nominal wage bill indicates that the wage bill rose much more rapidly in the high-growth group of sectors for each type of labour than in the medium-growth or declining groups. While skilled and clerical wages also show a positive occupation effect the scale effect is strongly dominant in the change in wage bill for each type of labour.

4.7 Stylised Facts

The stylised facts emerging from the analysis in this chapter can be summarised as follows:

- There was a marked shift towards employing more skilled labour over the period 1979 to 1990.
- Most of this shift occurred in the years 1979-1987 when overall employment in manufacturing was falling. This supports evidence from other sources that the rapid increase in long-term unemployment in the 1980s was disproportionately concentrated in unskilled labour.
- The shift towards skilled labour was almost entirely concentrated in a small group of sectors which recorded very high growth rates throughout the period. This group is dominated by foreign-owned, high-technology, export-oriented firms.
- In the other manufacturing sectors the ratio of skilled to unskilled labour was significantly lower than in these high-growth industries and there was little change in this

ratio during the 1980s. Approximately half of these sectors recorded a decline in volume output in absolute terms during this period. These correspond to those sectors with the lowest ratio of skilled to unskilled labour.

- The wage gap between skilled and unskilled labour did widen on average over the period. This gap was highest among the high-growth group of industries both at the beginning and end of the period. Notably, however, the growth in the average wage gap was solely concentrated among the declining group of industries.

- Closer examination of the wage data indicates that both skilled and unskilled wage rates were substantially lower in the declining group of industries than in the other sectors. This would suggest that firms in these sectors were facing a significant competitive disadvantage in the labour market.

- Skilled wage rates were roughly equal in the medium and high-growth groups, however unskilled wage rates were persistently higher in the medium growth group of sectors. This would suggest that the measure of "unskilled labour" is not homogenous across the two groups.

- The wage gap among the high-growth group of industries narrowed slightly through the 1980s despite a large increase in the ratio of skilled-to-unskilled labour. This reflects the ready availability of skilled labour in the 1980s, both through increases in female participation rates and through the migration mechanism, together with a general increase in education levels of the workforce as a whole.

- Clerical workers are identified separately. The ratio of clerical-to-unskilled labour and wages rose over the period. We argue that this reflects the skill-enhancing effect of the widespread use of information technology for this category of worker.

- Shift-share analysis indicated that seventy-five percent of the total change in the skilled labour share was due to changes within sectors. In Chapter 5 we model these within sector changes.

4.8 Conclusions

In this chapter we looked at the shift towards skilled labour in manufacturing employment in the 1980s. Because of the degree of heterogeneity in production within the manufacturing sector, we examined these compositional changes for three different groups of sector, grouped into high-growth, medium-growth and declining sectors.

Despite the fact that relative skilled wages are highest in the high-growth group it is in this group that we observe the biggest shift towards skilled labour. This by itself is clear evidence in favour of skill-biased technological change driving the shift towards skilled labour. However the emerging dominance of this small group of sectors in Irish manufacturing also reflects in part the explicit courting of foreign direct investment (FDI) through both fiscal and financial incentives by Irish industrial policy. This 'FDI effect' is also evident in the increase in high-technology foreign owned industry[29].

Berman Bound and Machin (1998) found that the within industry changes for nine developed countries were positively correlated. In their dataset four industries (Printing and Publishing, Iron and Steel, Machinery (incl. computers) and Electrical Machinery) accounted for most of the within industry shift towards skills. They argue that this "is consistent with the observed shifts being due to the portability and relatively fast adoption of new technologies that replace unskilled labour in similar industries across the world." The Irish data would support this. The industries with the biggest increase in skills are concentrated in sectors where there has been rapid technological change.

However it is also clear from the data that those 'traditional' sectors which are identified by *inter alia* Wood (1994) as being vulnerable to import penetration have suffered a sharp decline in both output and employment growth through the 1980s (the declining group of sectors). This would suggest that the so-called trade effect has also played a role in the restructuring of Irish manufacturing industry away from low-wage, low-skill industries.

[29] Markusen and Venables (1997) argue that the multinational firm and foreign direct investment play a crucial role in explaining the wage gap between skilled and unskilled workers.

4.9 Cross Section and Time Series Variation in the Data

Table 4.8 provides some summary statistics on the (unweighted) annual growth rates in some key variables for the 72 sectors.[30] These statistics describe both the time-series and cross-section variation in the panel dataset.

In the table $\overline{x}$ is the mean value of the *level* of each variable, σ_x is the standard deviation of x, y is the annual growth rate of x and σ_y is the standard deviation of y. These means and standard deviations which relate to the entire sample and are reported in the first four columns of the table are computed as follows:

$$(1)\ \overline{x} = \frac{1}{864}\sum_t\sum_i x_{it},$$

$$(2)\ \sigma_x = \sqrt{\frac{1}{864}\sum_t\sum_i (x_{it}-\overline{x})^2},\ i=1\ldots 72,\ t=1\ldots 12\ (1979-1990)$$

$$(3)\ \overline{y} = \frac{1}{792}\sum_t\sum_i y_{it},\ \text{where } y_{it} = (\Delta x_{it}/x_{it-1})\cdot 100$$

$$(4)\ \sigma_y = \sqrt{\frac{1}{792}\sum_t\sum_i (y_{it}-\overline{y})^2},\ i=1\ldots 72,\ t=1\ldots 11\ (1980-1990)$$

For example the data on total employment ($LTOT$) in the table indicate that mean employment in a sector over the period 1979-1990 year was 3,017 with a standard deviation across the panel of ±2921. Mean annual sectoral growth rates in employment were -1.8% with a very large standard deviation of ±11.5.

The panel structure of the dataset means that the total sample includes both time-series and cross-sectional variation. To analyse the time-series dimension we compute the mean *sectoral* growth rates and measure their variation both across sectors and over time. To analyse the data over the cross-section dimension we compute the mean *temporal* growth rates and measure their variation both across sectors and over time.

- *Time Series Variation*

In columns (5) and (6) of the table we calculate the mean of y for each of the 72 sectors over *time* denoted $\overline{y_i}$. If these 72 mean growth rates vary a lot from the overall sample mean

[30] This section uses the techniques adopted in Frankel and Rose (1996) to describe their panel dataset.

	Levels		Annual Growth Rates (in %)					
	Total Sample		*Total Sample*		*Time Series Variation*		*Cross Section Variation*	
	$\overline{x}$	σ_x	$\overline{y}$	σ_y	$\sigma_{\overline{y}_i}$	$\overline{\sigma}_{y_i}$	$\sigma_{\overline{y}_t}$	$\overline{\sigma}_{y_t}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Volume Output, Total Employment and No. of Firms:								
Q (£'000)	219,040	356,768	2.34	14.96	6.61	10.98	2.60	13.92
LTOT	3,017	2,921	-1.83	11.47	4.51	8.51	2.92	10.46
NO	68	83	.42	10.18	3.60	8.06	3.15	9.09
Value Added per unit of Gross Output:								
YV/QV	0.441	0.147	1.65	12.49	2.66	9.25	1.84	11.60
Value added per Firm and Employment per Firm:								
YV/NO (£'000s)	2,436	3,993	10.98	23.01	6.22	17.72	3.52	21.10
LTOT/NO	91	185	-1.77	12.02	3.03	9.75	3.57	10.83
Employment by Category of Worker:								
LAT	347	354	0.33	17.35	5.59	13.65	3.35	16.09
LIW	2,323	2,284	-2.11	12.18	4.54	9.11	3.03	11.13
LCL	329	452	0.47	19.34	5.92	15.15	2.67	18.07
Relative Employment and Wages by Category of Worker:								
LAT/LIW	0.169	0.102	3.08	17.62	4.20	13.93	2.00	16.46
LCL/LIW	0.146	0.089	3.01	18.41	4.23	14.76	2.08	16.87
CLAT/CLIW	1.741	0.321	0.76	12.22	1.49	10.14	1.34	11.57
CLCL/CLIW	1.058	0.307	2.75	25.84	4.89	17.11	2.78	22.14
Labour Share of Value Added by Category of Worker:								
YWAT/YV	0.096	0.037	1.87	21.47	3.79	18.41	3.25	20.24
YWIW/YV	0.409	0.192	-0.89	16.23	3.04	13.28	2.22	15.30
YWCL/YV	0.052	0.026	4.14	35.33	6.91	26.07	3.23	31.64

Table 4.8: Descriptive Statistics on panel

$\overline{y}$ then this is an indication of substantial variation across the different sectors of the panel. We measure this using the standard deviation of $\overline{y_i}$, denoted $\sigma_{\overline{y}_i}$ in column (5).

$$(5)\ \sigma_{\overline{y}_i} = \sqrt{\frac{1}{72}\sum_i (\overline{y_i} - \overline{y})^2}, \text{ where } \overline{y_i} = \frac{\sum_t y_{it}}{11}$$

Conversely if the 72 temporal standard deviations of these 72 mean growth rates are relatively high then this indicates that each sector's growth rate varies a lot over time. We measure this by calculating the mean of these 72 standard deviations $\overline{\sigma_{y_i}}$.

$$(6)\ \overline{\sigma_{y_i}} = \frac{1}{72}\sum_i \sigma_{y_i}, \text{ where } \sigma_{y_i} = \sqrt{\frac{1}{11}\sum_t (y_{it} - \overline{y_i})^2}$$

If this is high then on average individual sector's growth rates vary a lot over time. Continuing with employment and reading columns (5) and (6) of the table we see that the variation over time of the 72 sectoral employment growth rates (±8.5%) is greater than the variation across sectors (±4.5%).

- *Cross Section Variation*

In the final two columns (7) and (8) of the table we calculate the mean growth rate in each of the 11 years of the panel. $\overline{y_t}$ is the mean value of y in each year, if this varies a lot from the overall panel mean $\overline{y}$ then this is an indication of substantial variation over time in the panel. we measure this by calculating the standard deviation of $\overline{y_t}$ denoted $\sigma_{\overline{y_t}}$. Finally if the 11 individual standard deviations of $\overline{y_t}$ are high then this is an indication that in each year there is considerable variation across sectors in the data, we measure this by calculating the mean of these 11 standard deviations $\overline{\sigma_{y_t}}$.

$$(7)\ \sigma_{\overline{y_t}} = \sqrt{\frac{1}{11}\sum_t (\overline{y_t} - \overline{y})^2}, \text{ where } \overline{y_t} = \frac{\sum_i y_{it}}{72}$$

$$(8)\ \overline{\sigma_{y_t}} = \frac{1}{11}\sum_t \sigma_{y_t}, \text{ where } \sigma_{y_t} = \sqrt{\frac{1}{72}\sum_i (y_{it} - \overline{y_t})^2}$$

The data in columns (7) and (8) for employment indicate that the variation across sectors of the 11 temporal employment growth rates ±10.5% is substantially greater than the variation over time ±2.9%.

Looking at Table 4.8 we can see that the mean standard deviation of the cross section variation (column (8)) is higher than that for time series variation (column (6)) for all of the variables listed. Similarly the standard deviation of the 72 sectoral means (column (5)) is in all but one case ($LTOT/NO$) higher than the standard deviation of the 11 yearly means (column (7)). These results indicate that there is greater variability in the cross section dimension of the data (although the variation in the time dimension is also high). This is an indication of the considerable heterogeneity across sectors in the panel.

The panel mean (column (3)) for output growth was 2.3% per annum while mean employment growth was -1.8% per annum. This fall in sectoral employment is due to a mean decline in sectoral unskilled employment of -2.1% per annum, while sectoral skilled and clerical employment increased at mean growth rate of 0.3% and 0.5% per annum respectively.

The standard deviations (column (4)) for all the variables are very high and indicate that in all cases the growth rates are distributed to include both positive and negative growth, another indication of the degree of heterogeneity in the panel.

4.10 Tables and Graphs

Mnemonic and Sector		Mnemonic and Sector	
132162	Gas: Gasworks	414	Fruit & veg
161	Electricity	415	Fish
170	Water Supply	416	Grain
241246	Non-met Minerals:prdn	417823	Misc. Food
247	Glass	419	Bread etc.
248	Ceramics	420	Sugar
251	Basic Chemicals	421	Cocoa, etc
255	Paints etc.	422	Animal foods
256	Chemicals: ind and agr	424	Spirits
257	Pharmaceuticals	425268	Wine etc
258	Soap, perfumes etc	427	Brewing & malting
259260	Other chemicals	429	Tobacco
221223	Iron and Steel	431	Wool
224	Non-ferr metals: prdn	432	Cotton
311	Foundries	433434	Silk etc
312	Forging etc of metals	436	Knitting
313	Treatment etc. of metals	437439	Misc Textiles
314	Struct. metal products	438	Carpets etc
315	Boilermaking etc	44	Leather
316319	Finished metal products	451	Footwear
32	Mech. engineering	453454	Clothing
33	Office & data process.	455	Household goods
341	Insulated wires & cables	456	Furs
34278	Elec & lighting equip.	461462	Semi-finished wood
343	Elec apparatus	463	Carpentry
344	Telecomm. equip.	464465	Wood products
345	Radio & TV	466	Cork, brooms etc
346	Domestic elec.	467	Wood furniture
35	Motor Vehicles	471472	Paper
361	Shipbuilding	473474	Printing & Publishing
362	Railway rolling stock	14	Mineral oil refining
363365	Cycles & other transp.	481482	Rubber Products
37	Instrument Engin.	483	Plastics
411	Oils & Fats	491	Jewellery
412	Meat	494	Toys etc
413	Dairy products	492935	Other Manuf

Table 4.9: 72 Detailed Industrial Sectors In Panel Data Set: Table lists numeric mnemonics used

Table 4.10: Educational Profile of Detailed Occupational Groups in 1981 and 1991

		Unemp. Rate (1)	% of total Employ't (2)	% employed in Industry (3)	Age at which full-time education ceased: 14 or less % (4)	15-16 % (4)	17-18 % (4)	19+ % (4)
Census Broad Occupational Groups:								
Agricultural Workers	1981	1.6	15.7	0.1	55.7	29	12.1	3.2
	1991	3.1	12.7	0.5	43.7	32.3	18.9	5.1
Managers	1981	3.1	5		8.6	20.6	42.8	28
	1991	4.9	6.3		5.8	17.8	45.5	30.9
Proprietors (Services)	1981	1.8	3.3		24.9	33.6	32.4	9.1
	1991	2.7	3.8		17.2	31.8	38.3	12.7
Managers and Proprietors	1981			17.5				
	1991			16.6				
Professional Workers	1981	2.2	9.4	7.4	1.5	4.3	13.5	80.8
	1991	3.7	11.5	8.5	1.2	4.5	14.1	80.1
Associate Professional Workei	1981	4	4.3	13.4	3.5	12.4	58.4	25.7
	1991	4.9	5.2	15.0	2.1	8.8	50.5	38.5
Clerical Occupations	1981	5	13.9	19.2	6.1	19.2	61.8	13
	1991	8.1	13.9	16.7	3.9	15.8	62	18.3
Skilled Maintenance Workers	1981	8.9	4.8	43.7	12.5	46.4	33.6	7.5
	1991	12.4	4.6	44.8	9.1	39.7	38.2	12.9
Skilled Production Workers	1981	16.5	9.6	52.0	31.1	46.8	19.2	2.9
	1991	22.9	8.7	52.0	19.8	46	29.1	5
Production Operatives	1981	17.9	8.7	88.6	39	40.6	17.8	2.5
	1991	23.6	7.8	86.7	21.7	40.8	32.2	5.4
Transport and Communication	1981	13.8	4.4	21.5	47.7	36.4	13.8	2
	1991	18.1	4	17.8	33.8	39.9	22.8	3.6
Sales Workers	1981	10.1	6.5	10.0	15.5	40.3	37	7.2
	1991	16	7.3	8.2	9.4	32.1	47.4	11.1
Security Workers	1981	7.2	2.7	4.8	27.7	33.7	32.2	6.4
	1991	10	2.9	3.2	19	31.6	41.4	7.9
Personal Service Workers	1981	12	5.3	2.6	36.6	37.7	21.4	4.2
	1991	16.6	6.8	2.1	23.1	35.6	33.4	7.9
Labourers	1981	40.6	6.3	19.4	57.6	31.4	9.6	1.4
	1991	42.6	4.5	23.9	34.2	38.5	23.6	3.7
Total	1981	10.5		23.2	27.4	29.7	28.3	14.6
	1991	13.1		21.6	16.8	27.3	35.8	20.2

Sources:
Canny, Hughes and Sexton (1995), (1996)
(1) Table 3.6: Unemployment Rates for Occupational Groups, (1996)
(2) Table 3.5: Distribution of Persons and Work by Occupational Groups. (1996)
(3) Data for industrial sectors: unpublished detail on employment by industry groups. Source: J. Sexton.
(3) Data for Totals by occupational category fromTable 2.2:Employment by Occupation 1971-98 (1995)
(4) Table 4.6: Educational profiles for persons at work in occupational groups in terms of age at which full-time education ceased for 1981 and 1991. (1996)

Table 4.11: Output and Employment Annual Growth Rates for 72 Sectors

Ranked by LTOT growth 1979-1990

Group H: Very High Growth, Largely Foreign-Owned Sectors

Sector:	Rank	1979-1982	1982-1986	1986-1990	1979-1990	YCL/YV in 1990 **	Rank	LTOT 1979-1987	LTOT 1987-1990	LTOT 1979-1990	LAT 1979-1990	LIW 1979-1990	LCL 1979-1990
33 Office &data process.	1	38.69%	25.80%	15.42%	25.21%	0.15	2	9.10%	6.78%	8.46%	11.22%	5.02%	9.42%
345 Radio & TV	2	18.39%	18.45%	34.67%	24.09%	0.10	13	-2.13%	11.74%	1.47%	18.58%	-1.42%	15.25%
344 Telecomm. equip.	3	20.67%	11.22%	9.40%	13.04%	0.40	3	8.52%	4.75%	7.48%	11.82%	4.90%	12.39%
341 Insulated wires & cables	4	8.79%	13.93%	13.53%	12.36%	0.65	1	9.06%	12.15%	9.89%	4.28%	10.40%	11.60%
258 Soap, perfumes etc	5	14.93%	8.70%	11.21%	11.29%	0.21	14	0.04%	4.87%	1.33%	1.28%	1.59%	0.25%
257 Pharmaceuticals	6	-0.73%	13.88%	14.99%	10.08%	0.12	4	7.34%	7.38%	7.35%	10.74%	6.19%	6.68%
417823 Misc. Food	7	3.27%	11.20%	13.93%	9.94%	0.07	11	0.63%	5.10%	1.83%	3.91%	0.82%	4.15%
132162 Gas: Gasworks	8	20.83%	-1.05%	13.29%	9.76%	0.24	50	-4.78%	-2.32%	-4.12%	-0.73%	-7.58%	3.69%
415 Fish	9	10.09%	2.41%	14.78%	8.87%	0.35	5	7.44%	2.38%	6.03%	8.90%	6.36%	3.37%
37 Instrument Engin.	10	5.09%	7.93%	11.31%	8.36%	0.33	10	1.30%	4.59%	2.19%	3.43%	1.75%	5.92%
346 Domestic elec.	11	9.91%	4.52%	8.59%	7.45%	0.50	6	2.58%	4.67%	3.14%	4.58%	3.26%	-0.61%
424 Spirits	12	17.68%	1.94%	5.32%	7.28%	0.11	9	6.43%	-5.69%	2.98%	8.44%	1.61%	4.97%
Manufacturing		1.5%	6.3%	9.4%	6.1%	0.34		-2.69%	1.92%	-1.45%	0.51%	-1.89%	0.25%

LTOT = Total Employment, LAT = Admin/Tech, LIW = Industrial Workers, LCL = Clerical, CLAT = AT unit cost of labour,
CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
YCL =Total cost of labour, YWAT=AT wage bill. YWIW = IW wage bill, YWCL=Clerical workers wage bill.
** YCL/YV measures labour share of value-added. If this is low, this may be an indicator of transfer pricing.

Group M: Moderate or High Growth sectors

Sector:	Rank	1979-1982	1982-1986	1986-1990	1979-1990	YCL/YV in 1990 **	Rank	LTOT 1979-1987	LTOT 1987-1990	LTOT 1979-1990	LAT 1979-1990	LIW 1979-1990	LCL 1979-1990
492935 Other Manuf	13	5.07%	1.63%	13.95%	6.91%	0.40	12	-2.23%	12.16%	1.50%	2.31%	0.81%	6.88%
251 Basic Chemicals	14	4.24%	9.94%	4.69%	6.45%	0.57	40	-2.97%	-1.62%	-2.61%	-6.03%	-2.31%	-0.16%
363365 Cycles & other transp.	15	1.88%	10.32%	4.03%	5.67%	0.67	7	2.08%	5.91%	3.11%	8.82%	2.92%	1.17%
483 Plastics	16	1.82%	9.16%	5.15%	5.66%	0.48	8	1.77%	6.68%	3.09%	2.50%	2.97%	4.57%
259260 Other chemicals	17	4.19%	2.31%	8.95%	5.20%	0.48	32	-3.50%	2.11%	-2.00%	-0.73%	-2.98%	4.02%
412 Meat	18	-1.93%	8.23%	5.76%	4.48%	0.43	26	-2.50%	3.75%	-0.83%	-0.82%	-0.76%	-1.90%
473474 Printing & Publishing	19	-1.28%	2.81%	10.31%	4.31%	0.59	23	-1.29%	2.53%	-0.26%	-0.98%	-0.60%	2.03%
464465 Wood products	20	2.03%	0.17%	9.01%	3.82%	0.49	41	-5.72%	5.97%	-2.66%	-1.76%	-2.51%	-3.69%
425268 Wine etc	21	2.36%	2.55%	4.78%	3.31%	0.78	51	-6.41%	1.72%	-4.26%	-5.81%	-4.94%	0.11%
221223 Iron and Steel	22	-7.00%	6.67%	7.70%	3.11%	0.53	27	-3.32%	3.55%	-1.49%	-0.31%	-2.07%	2.71%
343 Elec apparatus	23	-3.20%	3.84%	7.11%	3.03%	0.39	22	-3.28%	9.12%	-0.05%	1.13%	4.54%	5.66%
466 Cork, brooms etc	24	-7.36%	17.64%	-3.04%	2.73%	0.56	35	-3.48%	1.60%	-2.12%	-2.22%	-2.04%	-0.74%
161 Electricity	25	0.82%	2.00%	4.86%	2.70%	0.41	25	-0.29%	-2.17%	-0.81%	0.62%	-1.82%	1.24%
413 Dairy products	26	3.40%	2.80%	1.96%	2.66%	0.38	39	-2.94%	-1.35%	-2.51%	1.84%	-3.35%	-2.47%
34278 Elec & lighting equip.	27	3.04%	-0.95%	5.86%	2.57%	0.61	15	-0.43%	4.01%	0.76%	-0.56%	0.92%	-2.31%
32 Mech. engineering	28	-3.91%	4.11%	5.91%	2.49%	0.51	21	-1.63%	4.63%	0.04%	2.66%	-0.28%	-0.13%
461462 Semi-finished wood	29	-8.53%	8.33%	4.57%	2.12%	0.43	36	-4.51%	3.96%	-2.27%	-2.83%	-2.38%	0.29%
421 Cocoa, etc	30	-4.11%	2.08%	7.03%	2.10%	0.52	52	-6.46%	1.53%	-4.35%	-3.42%	-4.56%	-3.56%
422 Animal foods	31	-2.20%	6.46%	0.06%	1.71%	0.34	47	-4.46%	-1.72%	-3.72%	-1.56%	-4.71%	-0.42%
427 Brewing & malting	32	-1.01%	1.27%	4.08%	1.65%	0.30	58	-5.10%	-7.03%	-5.63%	-8.27%	-5.41%	-2.95%
256 Chemicals: ind and agr	33	0.92%	1.34%	2.18%	1.53%	0.48	29	-2.37%	0.52%	-1.59%	3.26%	-2.44%	-5.01%
313 Treatment etc. of metals	34	-3.90%	2.57%	4.55%	1.47%	0.90	18	-1.06%	4.19%	0.35%	1.83%	-0.04%	3.18%
170 Water Supply	35	1.81%	3.61%	-1.43%	1.26%	0.81	20	0.16%	-0.18%	0.06%	3.38%	-0.36%	1.07%
432 Cotton	36	10.84%	-6.58%	2.56%	1.26%	0.61	62	-8.14%	-3.57%	-6.91%	-7.13%	-6.90%	-6.84%
494 Toys etc	37	7.42%	-17.02%	18.02%	1.20%	0.37	24	-1.87%	2.85%	-0.61%	-1.48%	-0.45%	-0.41%
241246 Non-met Minerals prdn	38	-6.50%	0.88%	7.40%	1.09%	0.36	44	-4.13%	-0.09%	-3.04%	-0.92%	-3.52%	-0.99%
455 Household goods	39	-0.79%	-5.53%	9.66%	1.08%	0.61	17	-0.72%	3.93%	0.53%	1.41%	0.20%	3.91%
436 Knitting	40	-4.81%	-0.44%	7.24%	1.04%	0.72	34	-5.08%	6.38%	-2.08%	-7.91%	-1.90%	2.77%
481482 Rubber Products	41	0.92%	-3.24%	5.16%	0.89%	0.56	30	-4.10%	4.70%	-1.77%	-2.00%	-1.46%	-5.82%
471472 Paper	42	-8.21%	2.28%	5.67%	0.49%	0.50	48	-5.77%	1.55%	-3.83%	-1.61%	-4.22%	-3.25%
316319 Finished metal products	43	-2.65%	-1.21%	4.60%	0.46%	0.56	28	-3.63%	4.35%	-1.52%	-1.25%	-1.72%	1.46%

LTOT = Total Employment, LAT = Admin/Tech, LIW = Industrial Workers, LCL = Clerical, CLAT = AT unit cost of labour,
CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
YCL =Total cost of labour. YWAT=AT wage bill, YWIW = IW wage bill, YWCL=Clerical workers wage bill.
** YCL/YV measures labour share of value-added. If this is low, this may be an indicator of transfer pricing.

Group D: Declining or Low Growth Sectors

Sector:	Rank	1979-1982	1982-1986	1986-1990	1979-1990	YCL/YV in 1990 **	Rank	LTOT 1979-1987	LTOT 1987-1990	LTOT 1979-1990	LAT 1979-1990	LIW 1979-1990	LCL 1979-1990
453454 Clothing	44	0.19%	-0.78%	0.71%	0.03%	0.70	42	-2.94%	-2.82%	-2.91%	-3.48%	-2.90%	-2.06%
414 Fruit & veg	45	0.29%	-4.56%	4.27%	-0.10%	0.60	54	-6.83%	0.68%	-4.84%	-5.10%	-5.32%	-1.97%
14 Mineral oil refining	46	-19.31%	15.06%	1.17%	-0.33%	0.51	16	-0.75%	4.83%	0.74%	-1.53%	0.20%	7.02%
311 Foundries	47	-18.58%	6.46%	7.51%	-0.70%	0.58	45	-6.06%	4.80%	-3.22%	-1.83%	-2.94%	-6.11%
467 Wood furniture	48	-1.87%	-6.56%	5.74%	-0.95%	0.56	38	-3.05%	-0.80%	-2.44%	1.71%	-2.33%	-2.22%
247 Glass	49	-3.13%	4.08%	-4.70%	-1.15%	0.79	31	-0.50%	-5.38%	-1.86%	0.87%	-2.16%	-0.33%
44 Leather	50	-10.58%	-2.46%	7.72%	-1.25%	0.45	67	-12.57%	-2.11%	-9.83%	-5.65%	-10.42%	-8.32%
255 Paints etc.	51	2.96%	-2.34%	-3.90%	-1.50%	0.44	37	-2.98%	-0.77%	-2.38%	-2.58%	-2.21%	-2.34%
429 Tobacco	52	-0.66%	-2.77%	-1.90%	-1.88%	0.36	56	-3.71%	-9.60%	-5.36%	-4.09%	-5.93%	-4.41%
362 Railway rolling stock	53	4.56%	8.08%	-15.27%	-1.96%	0.74	43	-0.46%	-9.35%	-2.97%	-0.32%	-2.86%	-7.18%
315 Boilermaking etc	54	-12.35%	-1.37%	5.19%	-2.23%	0.50	46	-6.57%	5.79%	-3.35%	-0.31%	-3.47%	-5.44%
419 Bread etc.	55	1.93%	-5.30%	-2.19%	-2.24%	0.61	55	-4.22%	-6.52%	-4.85%	-3.83%	-4.88%	-3.55%
491 Jewellery	56	-0.13%	-6.58%	0.61%	-2.27%	0.51	19	-0.37%	2.11%	0.30%	-0.28%	0.85%	-2.03%
438 Carpets etc	57	-12.10%	-2.64%	4.32%	-2.91%	0.60	57	-9.01%	4.44%	-5.53%	-10.71%	-5.60%	0.00%
463 Carpentry	58	-3.45%	-7.11%	1.33%	-3.11%	0.62	33	-4.00%	3.42%	-2.03%	1.98%	-1.99%	-1.63%
437439 Misc Textiles	59	-0.81%	-11.50%	4.20%	-3.12%	0.58	53	-6.70%	0.65%	-4.75%	-2.46%	-5.22%	-3.41%
416 Grain	60	-2.75%	-4.48%	-2.78%	-3.40%	0.47	64	-6.63%	-10.79%	-7.78%	-8.09%	-8.22%	-5.56%
314 Struct. metal products	61	-5.72%	-8.59%	2.28%	-3.97%	0.53	49	-4.79%	-2.09%	-4.06%	-2.84%	-4.25%	-3.70%
411 Oils and Fats	62	-0.32%	-6.13%	-4.78%	-4.08%	0.46	66	-6.05%	-14.52%	-8.44%	-4.36%	-10.38%	-5.18%
433434 Silk etc	63	-13.12%	1.33%	-4.44%	-4.88%	0.84	59	-5.28%	-8.29%	-6.11%	-6.32%	-6.00%	-7.75%
420 Sugar	64	-6.83%	0.42%	-9.36%	-5.21%	0.59	61	-6.02%	-9.12%	-6.88%	-4.71%	-7.23%	-7.96%
431 Wool	65	-14.40%	-0.15%	-2.96%	-5.25%	0.70	63	-9.98%	-1.24%	-7.68%	-6.30%	-7.85%	-6.50%
312 Forging etc of metals	66	-17.69%	-10.04%	2.63%	-7.88%	0.46	71	-17.81%	-0.29%	-13.36%	-12.02%	-13.63%	-11.84%
224 Non-ferr metals: prdn	67	-11.60%	-4.65%	-10.24%	-8.63%	0.42	70	-11.32%	-14.08%	-12.08%	-11.05%	-12.46%	-10.45%
361 Shipbuilding	68	-15.08%	-27.00%	19.37%	-9.03%	0.68	68	-17.72%	9.03%	-11.15%	-8.71%	-10.85%	-16.84%
35 Motor Vehicles	69	-3.85%	-20.06%	-0.81%	-9.07%	0.83	60	-10.98%	6.92%	-6.42%	-7.11%	-6.49%	-7.81%
248 Ceramics	70	-7.72%	-15.51%	-4.10%	-9.37%	0.51	65	-11.26%	-0.20%	-8.37%	-2.36%	-9.29%	-2.32%
451 Footwear	71	-6.12%	-14.59%	-12.01%	-11.41%	0.64	72	-13.93%	-13.03%	-13.69%	-9.63%	-14.31%	-10.44%
456 Furs	72	0.44%	-15.59%	-18.91%	-12.77%	0.62	69	-7.82%	-19.85%	-11.27%	-4.54%	-11.24%	-15.84%

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CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
YCL =Total cost of labour, YWAT=AT wage bill, YWIW = IW wage bill, YWCL=Clerical workers wage bill.
** YCL/YV measures labour share of value-added. If this is low, this may be an indicator of transfer pricing

Table 4.12: Employment And Wage Ratios: Annual Growth Rates FOR 72 Sectors

Ranked by LCL/LIW 1979-90

Group H: Very High Growth, Largely Foreign-Owned Sectors

	Sector	Rank	LAT/LIW			Rank	LCL/LIW			Rank	CLAT/CLIW			Rank	CLCL/CLIW		
			1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990
33	Office &dat	8	8 81%	-1.47%	5.90%	15	7.83%	-4.95%	4.19%	64	-1.31%	-1.75%	-1.43%	61	-1.02%	-1.13%	-1.05%
345	Radio & TV	1	26.57%	5.00%	20.28%	1	20.87%	6.94%	16.90%	53	-0.32%	-1.70%	-0.70%	72	-18.07%	-1.32%	-13.81%
344	Telecomm.	7	6.81%	6.04%	6.60%	5	8.24%	4.25%	7.14%	40	-0.02%	0.40%	0 10%	53	0.36%	-1.05%	-0.03%
341	Insulated wi	71	-5 99%	-4.33%	-5.54%	41	-0.75%	6.18%	1.09%	60	-0.74%	-2.07%	-1.11%	56	-0.19%	-0.21%	-0.19%
258	Soap. perfu	53	-1.64%	3.33%	-0.31%	58	-3.55%	4.85%	-1.33%	15	1.70%	-0.46%	1.11%	6	3.03%	5.51%	3.70%
257	Pharmaceu	14	6.39%	-1.16%	4.28%	48	1.17%	-1.40%	0.46%	55	-1.47%	0.99%	-0.80%	40	1.36%	-0.70%	0.80%
417823	Misc. Food	21	1.21%	8.18%	3.07%	19	3.28%	3.36%	3.31%	27	-0.18%	2.69%	0.60%	33	-0.08%	4.41%	1.13%
132162	Gas: Gasw	4	7.31%	7.66%	7.41%	2	15.89%	2.89%	12.19%	69	0.04%	-6.63%	-1.82%	65	-1.01%	-2.52%	-1.42%
415	Fish	30	0.11%	8.72%	2.39%	64	-5.22%	3.89%	-2.81%	56	-0.75%	-1.20%	-0.87%	32	-1.04%	7.40%	1.19%
37	Instrument E	37	3.90%	-4.11%	1.65%	16	4.33%	3.50%	4.10%	49	-1.32%	1.62%	-0.53%	49	-1.13%	3.95%	0.23%
346	Domestic el	41	3.48%	-4.37%	1.28%	68	-3.87%	-3.42%	-3.75%	20	-3.01%	12.01%	0.87%	13	3.59%	1.97%	3.15%
424	Spirits	5	14.61%	-11.75%	6.72%	20	10.79%	-14.29%	3.30%	63	-0.50%	-3.51%	-1.33%	4	7.72%	-3.85%	4.43%
	Manufacturing		3.22%	0.42%	2.45%		2.66%	0.93%	2.19%		0.05%	1.23%	0.37%		1.63%	0.60%	1.35%

LTOT = Total Employment, LAT = Admin/Tech, LIW = Industrial Workers, LCL = Clerical, CLAT = AT unit cost of labour,
CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
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Group M: Moderate or High Growth sectors

	Sector	Rank	LAT/LIW			Rank	LCL/LIW			Rank	CLAT/CLIW			Rank	CLCL/CLIW		
			1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990
492935	Other Manu	39	4.19%	-5.38%	1.49%	7	1.17%	20.12%	6.02%	6	4.02%	-3.36%	1.96%	50	5.19%	-12.19%	0.13%
251	Basic Chem	69	-6.50%	3.75%	-3.81%	31	2.54%	1.26%	2.19%	26	-0.28%	3.00%	0.60%	26	1.07%	2.30%	1.40%
363365	Cycles & ot	10	3.99%	10.52%	5.73%	60	-0.18%	-5.66%	-1.71%	71	-2.60%	-2.10%	-2.46%	22	-1.00%	9.30%	1.71%
483	Plastics	57	0.56%	-3.11%	-0.46%	36	1.90%	0.63%	1.55%	39	0.58%	-1.18%	0.10%	29	-1.33%	8.95%	1.38%
259260	Other chem	31	0.82%	6.45%	2.33%	4	9.22%	2.05%	7.22%	25	0.81%	0.25%	0.66%	18	3.87%	-0.46%	2.67%
412	Meat	50	0.21%	-0.77%	-0.06%	56	-0.15%	-3.78%	-1.15%	29	-0.37%	2.90%	0.51%	45	0.79%	-0.39%	0.46%
473474	Printing & P	56	0.52%	-2.78%	-0.39%	26	4.56%	-2.28%	2.64%	52	-1.35%	1.31%	-0.63%	17	2.19%	3.21%	2.46%
464465	Wood prod.	46	1.79%	-1.89%	0.77%	57	-0.46%	-3.17%	-1.21%	31	0.10%	1.35%	0.44%	43	'1.31%	-1.32%	0.59%
425268	Wine etc	62	-0.14%	-2.96%	-0.92%	10	3.42%	10.51%	5.31%	10	0.40%	3.96%	1.36%	21	1.69%	1.79%	1.72%
221223	Iron and Ste	35	2.60%	-0.29%	1.80%	11	9.26%	-5.95%	4.88%	68	-1.58%	-2.40%	-1.80%	70	-8.00%	0.09%	-5.86%
343	Elec appara	68	-4.26%	-0.57%	-3.27%	42	-2.62%	11.61%	1.07%	1	3.44%	3.18%	3.37%	18	2.38%	1.77%	2.21%
466	Cork, broon	51	-3.86%	10.32%	-0.19%	40	1.88%	-0.16%	1.32%	66	3.33%	-13.77%	-1.65%	41	3.27%	-5.65%	0.76%
161	Electricity	28	5.43%	-4.98%	2.48%	23	2.79%	3.99%	3.12%	48	0.77%	-3.76%	-0.49%	23	2.98%	-1.80%	1.65%
413	Dairy produ	12	4.26%	8.40%	5.37%	45	-0.11%	3.70%	0.91%	47	-0.89%	1.20%	-0.32%	51	1.13%	-2.48%	0.13%
34278	Elec & lighti	65	2.42%	-11.13%	-1.47%	66	1.09%	-13.77%	-3.20%	24	1.33%	-1.09%	0.66%	1	9.50%	-1.04%	6.52%
32	Mech. engir	22	2.93%	3.02%	2.95%	50	0.48%	-0.71%	0.15%	16	1.66%	-0.71%	1.01%	57	0.61%	-2.52%	-0.25%
461462	Semi-finishe	58	-1 06%	1.14%	-0.46%	25	0.43%	9.15%	2.74%	59	-0.59%	-2.34%	-1.07%	39	1.23%	-0.25%	0.82%
421	Cocoa, etc	43	0.38%	3.39%	1.19%	43	0.50%	2.50%	1.04%	4	1.23%	5.03%	2.26%	34	0.44%	2.94%	1.11%
422	Animal food	18	4.68%	-0.28%	3.30%	14	3.38%	7.52%	4.49%	18	-0.07%	3 56%	0.90%	36	-0.02%	3.71%	0.98%
427	Brewing & m	67	-4 92%	2.20%	-3.03%	28	2.50%	2.85%	2.60%	33	-0.92%	4.07%	0.41%	10	2.93%	4.28%	3.29%
256	Chemicals:	9	3.98%	10.95%	5.84%	63	-2.35%	-3.40%	-2.64%	37	0.95%	-1.77%	0.20%	27	1.64%	0.70%	1.39%
313	Treatment e	33	-0.22%	7.69%	1.87%	22	1.19%	8.81%	3.22%	28	-2.12%	8.19%	0.59%	8	2.72%	5.33%	3.43%
170	Water Supp	17	5.61%	-1.05%	3.75%	38	0.23%	4.71%	1.43%	62	-0.82%	-2.08%	-1.24%	60	-0.73%	-1.20%	-0.86%
432	Cotton	52	-3.69%	9.52%	-0.26%	52	-0.82%	2.44%	0.06%	14	3.04%	-3.77%	1.14%	62	4.62%	-14.74%	-1.06%
494	Toys etc	63	2.14%	-9.03%	-1.03%	53	-0.45%	1.36%	0.04%	57	-1.12%	-0.61%	-0.98%	67	-4.04%	4.12%	-1.88%
241246	Non-met Mi	26	6.01%	-5.65%	2.70%	27	4.42%	-2.02%	2.63%	35	0.37%	-0.03%	0.26%	25	2.86%	-2.04%	1.50%
455	Household	42	1.30%	0.98%	1.21%	17	2.13%	8.01%	3.70%	30	1.18%	-1.38%	0.47%	64	-0.70%	-2.97%	-1.33%
436	Knitting	72	-0.09%	-20.52%	-6.13%	12	5.54%	2.71%	4.76%	34	-2.12%	7.47%	0.41%	19	-2.07%	14.43%	2.18%
481482	Rubber Pro	59	-0.12%	-1.67%	-0.55%	69	-4.77%	-3.53%	-4.43%	61	0.76%	-6.05%	-1.14%	14	5.19%	-3.50%	2.74%
471472	Paper	24	3.52%	0.63%	2.72%	44	1.70%	-0.81%	1.01%	50	0.12%	-2.24%	-0.53%	66	-0.92%	-4.38%	-1.87%
316319	Finished me	47	2.21%	-4.00%	0.48%	21	3.46%	2.62%	3.23%	41	-1.25%	3.78%	0.10%	42	0.96%	-0.01%	0.70%

LTOT = Total Employment, LAT = Admin/Tech, LIW = Industrial Workers, LCL = Clerical, CLAT = AT unit cost of labour,
CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
YCL =Total cost of labour, YWAT=AT wage bill, YWIW = IW wage bill, YWCL=Clerical workers wage bill.
** YCL/YV measures labour share of value-added. If this is low, this may be an indicator of transfer pricing.

Group D: Declining or Low Growth Sectors

	Sector	Rank	LAT/LIW			Rank	LCL/LIW			Rank	CLAT/CLIW			Rank	CLCL/CLIW		
			1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990		1979-1987	1987-1990	1979-1990
453454	Clothing	60	0 16%	-2.60%	-0.60%	46	-1 05%	6.15%	0.86%	44	-0.69%	1.33%	-0.14%	35	2.35%	-2.47%	1.01%
414	Fruit & veg	48	0.21%	0.26%	0.23%	18	4 74%	0.38%	3.53%	43	-2.22%	6.12%	-0.01%	48	0 71%	-0.92%	0.26%
14	Mineral oil r	66	-2.65%	0.79%	-1.73%	6	3.96%	14.74%	6.80%	3	2.17%	3.52%	2 53%	3	3 58%	9.70%	5.21%
311	Foundries	44	5.00%	-8 49%	1.14%	67	-3 09%	-3 74%	-3.26%	9	0.67%	3.49%	1 43%	63	0 07%	-4.51%	-1.20%
467	Wood furnit	15	7 78%	-4.96%	4.14%	51	0.94%	-2.05%	0.12%	54	-1 69%	1 84%	-0 74%	59	-0 10%	-1.22%	-0 41%
247	Glass	20	0 60%	10.05%	3.10%	34	1.31%	3 39%	1 87%	13	1.03%	1 63%	1.19%	52	-0 85%	2.20%	-0.02%
44	Leather	13	3 56%	10.19%	5.33%	29	6.91%	-8.89%	2.35%	17	1.93%	-1 53%	0.97%	5	10 01%	-11.15%	3 79%
255	Paints etc.	55	0 38%	-2.36%	-0.38%	54	-0.22%	0.08%	-0.14%	23	0.52%	1.23%	0 72%	11	0.52%	10 97%	3 27%
429	Tobacco	32	2.33%	0.96%	1.96%	35	1.66%	1 50%	1.61%	2	1.05%	7.51%	2.77%	12	3.54%	2.12%	3 15%
362	Railway roll	27	2 00%	4.26%	2.61%	70	-8.54%	7.41%	-4.44%	8	7.91%	-13 83%	1 49%	58	-0.01%	-1.23%	-0.34%
315	Boilermakin	19	6 49%	-4.81%	3.28%	62	2.16%	-12.40%	-2.04%	45	-0 46%	0.65%	-0.16%	30	1.81%	-0.05%	1.30%
419	Bread etc.	45	-0.08%	4.31%	1.09%	39	-0.09%	5.46%	1.39%	42	-0.59%	1.78%	0.05%	7	2.70%	6.04%	3 60%
491	Jewellery	64	2.45%	-10.07%	-1.13%	65	-7.15%	9.58%	-2.86%	70	-0.63%	-7.09%	-2.44%	20	6 64%	-9.11%	2.09%
438	Carpets etc	70	-4 99%	-6.54%	-5.42%	8	8.17%	0.18%	5.93%	21	0.02%	3.11%	0.86%	24	2 97%	-2.27%	1.51%
463	Carpentry	16	7 61%	-4 86%	4.06%	49	0.18%	0 87%	0.37%	19	-0 39%	4.39%	0.89%	28	2 13%	-0.59%	1.38%
437439	Misc Textile	23	7 13%	-7.55%	2.91%	33	2.02%	1.61%	1.91%	11	1.34%	1 27%	1.32%	38	2.67%	-3.78%	0.87%
416	Grain	49	-0 67%	2 37%	0.15%	24	2.33%	4.44%	2 90%	32	-0.79%	3.72%	0 42%	44	2.34%	-3 99%	0 57%
314	Struct. meta	40	3 41%	-3.54%	1 47%	47	1.85%	-2.79%	0.57%	46	0.05%	-0 83%	-0.19%	47	0.17%	1.13%	0.43%
411	Oils and Fa	6	13 52%	-9 51%	6.71%	9	-3.43%	34 94%	5.80%	51	-3 62%	7 85%	-0.62%	54	-0.70%	1 74%	-0.04%
433434	Silk etc	54	-3 16%	7.59%	-0.34%	61	-1 47%	-2.90%	-1.86%	7	1.17%	2 71%	1.59%	69	-1.70%	-12.71%	-4 83%
420	Sugar	25	0 75%	8.14%	2.72%	55	4.13%	-12 80%	-0.79%	12	1 48%	0 82%	1.30%	31	-0.08%	4.99%	1.28%
431	Wool	36	3.66%	-3.43%	1.68%	37	1.11%	2.41%	1.46%	38	-1.32%	4.36%	0.19%	46	0.55%	0.22%	0 46%
312	Forging etc	34	3.55%	-2.52%	1.86%	32	2.72%	0.35%	2.07%	5	0.28%	6.65%	1.98%	71	-12 63%	-15 01%	-13 29%
224	Non-ferr me	38	11 10%	-19.93%	1.61%	30	1.20%	5.26%	2.29%	22	-0 54%	4.57%	0.82%	68	2.78%	-17.17%	-3.09%
361	Shipbuilding	29	4 76%	-3 66%	2.39%	72	-3 07%	-15.80%	-6 72%	65	-5 41%	9 85%	-1 47%	55	-5.64%	16 33%	-0 10%
35	Motor Vehic	61	1.11%	-5.22%	-0.66%	59	-2.75%	2.26%	-1 41%	58	-1 22%	-0.42%	-1.00%	9	-0 68%	14 95%	3 36%
248	Ceramics	2	11.24%	-1.39%	7.65%	3	13.42%	-6.25%	7 68%	36	0.29%	0 04%	0.22%	2	5.71%	4 48%	5 38%
451	Footwear	11	6.13%	3.67%	5.45%	13	2.59%	9.82%	4.51%	72	-4.06%	-2.41%	-3.61%	15	2.90%	2.18%	2.70%
456	Furs	3	13.60%	-7 03%	7.56%	71	-2.87%	-11.08%	-5.18%	67	-2.49%	0 64%	-1.65%	37	-5.48%	20.26%	0.94%

LTOT = Total Employment, LAT = Admin/Tech, LIW = Industrial Workers, LCL = Clerical, CLAT = AT unit cost of labour,
CLIW= IW unit cost of labour, CLCL = CW unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output,
YCL =Total cost of labour, YWAT=AT wage bill, YWIW = IW wage bill, YWCL=Clerical workers wage bill.
** YCL/YV measures labour share of value-added. If this is low, this may be an indicator of transfer pricing.

Table 4.13: Productivity Measures and Number of Firms: Indicators for 72 Sectors

Group 1: Very High Growth, Largely Foreign-Owned Sectors

	Sector	YV/QV 1979-1990	YV/YCL 1979-1990	Q/LAT 1979-1990	Q/LIW 1979-1990	Q/LCL 1979-1990	YV/YWAT 1979-1990	YV/YWIW 1979-1990	YV/YWCL 1979-1990	Number of Firms: Absolute changes: Rank	Number of Firms: Absolute changes: 1979-1990
33	Office &data process.	0.93%	3.78%	12.57%	19.22%	14.43%	2.56%	7.08%	-6.98%	5	34
345	Radio & TV	3.88%	15.60%	4.65%	25.87%	7.67%	0.95%	20.58%	19.66%	10	18
344	Telecomm. equip.	-0.99%	-0.06%	1.09%	7.76%	0.58%	-4.01%	2.42%	-4.38%	2	86
341	Insulated wires & cables	1.73%	0.38%	7.75%	1.78%	0.68%	6.61%	-0.41%	-1.29%	12	15
258	Soap, perfumes etc	1.22%	7.24%	9.88%	9.54%	11.01%	7.02%	7.87%	5.42%	28	2
257	Pharmaceuticals	0.10%	-3.23%	-0.59%	3.66%	3.19%	-5.30%	-2.04%	-3.27%	7	29
417823	Misc. Food	1.61%	4.84%	5.80%	9.05%	5.56%	2.73%	6.51%	1.96%	16	11
132162	Gas: Gasworks	8.49%	11.33%	10.57%	18.76%	5.86%	8.61%	14.53%	3.56%	34	1
415	Fish	1.67%	1.71%	-0.02%	2.36%	5.33%	0.30%	1.80%	3.51%	8	23
37	Instrument Engin.	1.81%	1.92%	4.77%	6.50%	2.30%	1.39%	2.52%	-1.74%	11	16
346	Domestic elec.	-0.28%	1.08%	2.74%	4.06%	8.11%	-0.83%	1.31%	2.05%	25	4
424	Spirits	2.17%	3.94%	-1.08%	5.57%	2.20%	0.68%	6.02%	-1.73%	31	2
	Manufacturing	2.26%	3.52%	5.52%	8.10%	5.79%	1.54%	4.42%	0.82%		-3

Note: LTOT = Total Employment, LAT = Admin/Tech Emp, LIW = Industrial Workers Emp, LCL = Clerical Emp, CLAT = Admin/Tech unit cost of labour, CLIW= Industrial Workers unit cost of labour, CLCL = Clerical Workers unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output, YCL =Total cost of labour,, YWAT=Admin/Tech wage bill, YWIW = Industrial Workers wage bill, YWCL=Clerical workers wage bill.

Group M: Moderate or High Growth sectors

	Sector	YV/QV 1979-1990	YV/YCL 1979-1990	Q/LAT 1979-1990	Q/LIW 1979-1990	Q/LCL 1979-1990	YV/YWAT 1979-1990	YV/YWIW 1979-1990	YV/YWCL 1979-1990	Number of Firms: Absolute changes: Rank	Number of Firms: Absolute changes: 1979-1990
492935	Other Manuf	0.34%	1.10%	4.50%	6.05%	0.03%	-1.03%	2.41%	-3.54%	32	1
251	Basic Chemicals	-0.83%	0.85%	13.27%	8.96%	6.62%	3.98%	0.62%	-2.91%	19	9
363365	Cycles & other transp.	-1.32%	2.47%	-2.89%	2.67%	4.46%	-0.32%	2.80%	2.82%	23	5
483	Plastics	2.11%	1.24%	3.08%	2.61%	1.04%	1.82%	1.45%	-1.46%	1	88
259260	Other chemicals	0.21%	-0.33%	5.97%	8.43%	1.13%	-1.84%	1.11%	-8.15%	50	-5
412	Meat	0.74%	2.18%	5.34%	5.28%	6.50%	1.72%	2.18%	2.89%	20	8
473474	Printing & Publishing	-0.40%	0.18%	5.35%	4.94%	2.23%	1.84%	0.80%	-4.16%	4	37
464465	Wood products	-0.90%	1.42%	5.68%	6.49%	7.80%	0.22%	1.44%	2.08%	45	-4
425268	Wine etc	-2.33%	-3.36%	9.67%	8.67%	3.19%	-2.72%	-2.30%	-8.79%	61	-16
221223	Iron and Steel	-0.03%	1.55%	3.43%	5.30%	0.40%	1.45%	1.94%	-2.15%	24	5
343	Elec apparatus	3.28%	2.67%	1.88%	-1.45%	-2.50%	2.92%	2.91%	-0.39%	27	2
466	Cork, brooms etc	1.85%	0.96%	5.07%	4.87%	3.51%	2.79%	0.92%	-1.14%	54	-7
161	Electricity	2.55%	2.62%	2.07%	4.61%	1 45%	2.09%	4.12%	-0.67%	39	-1
413	Dairy products	2.61%	2.84%	0.80%	6.22%	5.26%	-1.02%	3.96%	2.89%	56	-10
34278	Elec & lighting equip.	0.36%	0.54%	3.15%	1.63%	5.00%	1.36%	0.54%	-2.49%	22	6
32	Mech. engineering	0.93%	0.65%	-0.16%	2.79%	2.63%	-2.55%	1.55%	-0.20%	3	77
461462	Semi-finished wood	0.07%	2.18%	5.10%	4.62%	1.83%	4.03%	2.44%	-1.10%	69	-43
421	Cocoa, etc	2.92%	3.04%	5.72%	6.97%	5.87%	0.46%	3.94%	1.74%	52	-6
422	Animal foods	2.14%	1.41%	3.32%	6.73%	2.14%	-1.28%	2.90%	-2.49%	68	-36
427	Brewing & malting	1.31%	4.10%	10.82%	7.46%	4.74%	6.88%	4.07%	-1.80%	37	0
256	Chemicals: ind and agr	0.08%	-1.49%	-1.68%	4.06%	6.89%	-5.58%	0.13%	1.44%	18	9
313	Treatment etc. of metals	-3.40%	-4.83%	-0.36%	1.51%	-1.66%	-6.24%	-3.92%	-10.00%	42	-2
170	Water Supply	3.96%	9.18%	-2.05%	1.62%	0.19%	7.01%	9.65%	9.04%	53	-7
432	Cotton	0.94%	1.38%	9.04%	8.76%	8.70%	0.58%	1.46%	2.49%	59	-11
494	Toys etc	1.85%	1.01%	2.72%	1.66%	1.62%	2.55%	0.49%	2.38%	17	9
241246	Non-met Minerals:prdn	0.64%	1.09%	2.03%	4.78%	2.10%	-0.84%	2.09%	-1.99%	67	-31
455	Household goods	1.51%	0.36%	-0.33%	0.88%	-2.73%	-0.75%	0.92%	-1.37%	14	13
436	Knitting	-0.29%	0.76%	9.73%	3.00%	-1.68%	6 44%	0.32%	-6.27%	65	-28
481482	Rubber Products	1.00%	1.67%	2.94%	2.38%	7.13%	3 17%	1.43%	3.30%	15	13
471472	Paper	-0.11%	1.39%	2.14%	4.92%	3.87%	-0.54%	1.62%	2.53%	9	18
316319	Finished metal products	-0.58%	1.12%	1.73%	2.22%	-0.98%	0.90%	1.48%	-2.37%	13	15

Note: LTOT = Total Employment, LAT = Admin/Tech Emp, LIW = Industrial Workers Emp, LCL = Clerical Emp, CLAT = Admin/Tech unit cost of labour, CLIW= Industrial Workers unit cost of labour, CLCL = Clerical Workers unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output, YCL =Total cost of labour,, YWAT=Admin/Tech wage bill, YWIW = Industrial Workers wage bill, YWCL=Clerical workers wage bill.

Group D: Declining or Low Growth Sectors

	Sector	YV/QV 1979-1990	YV/YCL 1979-1990	Q/LAT 1979-1990	Q/LIW 1979-1990	Q/LCL 1979-1990	YV/YWAT 1979-1990	YV/YWIW 1979-1990	YV/YWCL 1979-1990	Number of Firms: Absolute changes: Rank	Number of Firms: Absolute changes: 1979-1990
453454	Clothing	-0.35%	-0 14%	3.64%	3 01%	2.13%	0 60%	-0.15%	-2.00%	72	-100
414	Fruit & veg	2.66%	3 71%	5.27%	5.51%	1 91%	3.99%	4.21%	0 39%	41	-2
14	Mineral oil refining	3.76%	-3.36%	1 22%	-0.53%	-6 86%	-2.56%	-1.81%	-12.62%	33	1
311	Foundries	-0.86%	0.82%	1 16%	2.31%	5 76%	-1.78%	0.76%	5.43%	48	-5
467	Wood furniture	0 03%	0 73%	-2 62%	1.42%	1.30%	-2 13%	1.17%	1.47%	70	-45
247	Glass	-0.56%	-0.67%	-2.01%	1.03%	-0.83%	-4 20%	-0.06%	-1.87%	21	6
44	Leather	-2 24%	1.40%	4.67%	10.25%	7.72%	-3.69%	2.43%	-3.57%	62	-18
255	Paints etc.	0.92%	-0.52%	1.11%	0.73%	0.86%	-0.20%	0.13%	-2.91%	29	2
429	Tobacco	2.39%	2.05%	2.30%	4.30%	2.64%	-0.52%	4.24%	-0.55%	38	0
362	Railway rolling stock	0.11%	3.26%	-1.64%	0.93%	5.62%	-0.87%	3.23%	8.40%	36	0
315	Boilermaking etc	1.05%	1.27%	-1.93%	1.29%	3.40%	-1.40%	1.67%	2.45%	43	-3
419	Bread etc.	0.82%	1.72%	1.66%	2.78%	1.37%	1.07%	2.22%	-2.68%	71	-94
491	Jewellery	3.12%	1.35%	-1.99%	-3.09%	-0.24%	4.50%	0.61%	1.65%	30	2
438	Carpets etc	0.98%	-0.81%	8.74%	2.85%	-2.91%	4 03%	-0.77%	-7.72%	51	-6
463	Carpentry	-0 90%	0.09%	-4.99%	-1.14%	-1.50%	-3.90%	0.89%	-0.85%	63	-19
437439	Misc Textiles	1.98%	-2.28%	-0.68%	2.21%	0.30%	-5.37%	-1.33%	-4.01%	57	-10
416	Grain	0.45%	-0.43%	5 10%	5.26%	2.29%	-0.38%	0.18%	-3.20%	58	-11
314	Struct metal products	-0.10%	0.52%	-1.16%	0.29%	-0.28%	-0 44%	0.82%	-0.17%	6	31
411	Oils and Fats	6.41%	0.37%	0.29%	7.03%	1.16%	-3.08%	2.79%	-2.81%	35	1
433434	Silk etc	0.53%	-1 57%	1.53%	1.18%	3.11%	-2.91%	-1.70%	5.26%	44	-3
420	Sugar	1.25%	-1.81%	-0.53%	2.17%	2.99%	-4.68%	-0.82%	-1.29%	40	-2
431	Wool	-0.08%	-1.38%	1.13%	2.82%	1.34%	-2.89%	-1.07%	-2.94%	64	-24
312	Forging etc of metals	1.91%	2.53%	4.70%	6.65%	4.49%	-1.26%	2.57%	15.89%	47	-4
224	Non-ferr metals: prdn	-3.02%	2.36%	2.72%	4.37%	2.04%	0.29%	2.75%	3.66%	26	3
361	Shipbuilding	5.60%	4.29%	-0.35%	2.04%	9.39%	2.93%	3.84%	11.44%	60	-12
35	Motor Vehicles	4.05%	1 34%	-2.11%	-2.76%	-1.37%	3.08%	1.38%	-0.51%	66	-29
248	Ceramics	4 28%	3.60%	-7.18%	-0.09%	-7.21%	-1 82%	5 91%	-6.66%	46	-4
451	Footwear	0.12%	0 60%	-1.96%	3 38%	-1.08%	-0 19%	1.45%	-5.43%	55	-9
456	Furs	-3.53%	-1.31%	-8.63%	-1.72%	3 65%	-6.12%	-0.68%	3.77%	49	-5

Note: LTOT = Total Employment, LAT = Admin/Tech Emp, LIW = Industrial Workers Emp, LCL = Clerical Emp, CLAT = Admin/Tech unit cost of labour, CLIW= Industrial Workers unit cost of labour, CLCL = Clerical Workers unit cost of labour, YV= Value-added, QV = Gross Output, Q = Volume Output, YCL =Total cost of labour,, YWAT=Admin/Tech wage bill, YWIW = Industrial Workers wage bill, YWCL=Clerical workers wage bill.

Table 4.14: Selected Indicators for 1979 for 72 Sectors

		Percentage Shares in Total:			Size of Sectors:			Unit Labour Costs:		
		LTOT	*YV*	*QV*	*QV/NO* (in £'000)	*YV/NO* (in £'000)	*LTOT/NO*	*CLAT* (in £'000)	*CLIW* (in £'000)	*CLCLER* (in £'000)
Group H: Very High Growth, Largely Foreign-Owned Sectors										
33	Office &data process.	1.25%	3.23%	2.64%	8,750	3,791	138	11.147	4.854	6.600
345	Radio & TV	1.26%	1.11%	0.83%	3,344	1,594	171	8.261	4.212	25.646
344	Telecomm. equip.	1.22%	1.40%	0.87%	1,994	1,131	93	7.601	4.044	4.775
341	Insulated wires & cables	0.64%	0.40%	0.45%	3,000	936	141	9.440	4.004	6.076
258	Soap, perfumes etc	0.43%	0.48%	0.39%	926	403	34	6.291	4.856	4.711
257	Pharmaceuticals	1.17%	8.59%	4.04%	6,544	4,929	63	9.244	5.925	5.125
417823	Misc. Food	0.85%	3.81%	1.99%	4,154	2,809	59	8.528	4.715	4.574
132162	Gas; Gasworks	0.67%	0.45%	0.52%	4,233	1,289	182	8.120	5.303	4.413
415	Fish	0.48%	0.42%	0.46%	591	191	21	7.727	3.801	3.855
37	Instrument Engin.	2.55%	2.80%	1.78%	1,998	1,111	96	8.650	4.118	5.229
346	Domestic elec.	0.88%	0.65%	0.50%	4,011	1,856	238	8.659	4.149	4.012
424	Spirits	0.16%	0.57%	0.47%	4,313	1,825	50	10.204	5.578	4.389
Group M: Moderate or High Growth sectors										
492935	Other Manuf	0.35%	0.31%	0.19%	526	296	32	8.029	3.804	3.838
251	Basic Chemicals	1.43%	1.74%	2.16%	6,296	1,792	139	10.240	7.950	6.096
363365	Cycles & other transp.	0.79%	0.75%	0.42%	4,400	2,757	274	14.457	9.051	5.967
483	Plastics	2.07%	1.83%	1.79%	1,005	362	39	8.384	4.743	4.826
259260	Other chemicals	0.79%	0.81%	0.75%	2,491	955	88	7.952	4.856	3.741
412	Meat	4.81%	4.35%	11.84%	6,907	898	94	8.873	4.998	4.761
473474	Printing & Publishing	4.66%	4.42%	2.35%	552	368	37	9.243	5.751	4.910
464465	Wood products	0.31%	0.20%	0.16%	256	116	17	6.751	3.718	4.307
425268	Wine etc	1.10%	1.12%	0.83%	1,260	600	56	8.592	5.304	4.747
221223	Iron and Steel	0.75%	0.62%	0.64%	1,730	596	68	8.253	4.934	8.572
343	Elec apparatus	0.50%	0.29%	0.27%	924	362	58	6.203	4.845	4.437
466	Cork, brooms etc	0.16%	0.09%	0.07%	385	185	29	7.547	3.687	3.783
161	Electricity	4.88%	6.25%	4.73%	12,325	5,757	425	12.295	7.183	6.600
413	Dairy products	4.14%	4.34%	11.43%	7,790	1,046	94	8.285	5.618	4.215
34278	Elec & lighting equip.	1.23%	0.87%	0.67%	704	326	43	7.893	4.326	2.488
32	Mech. engineering	3.45%	2.80%	2.35%	854	360	42	6.912	4.459	5.078
461462	Semi-finished wood	0.86%	0.60%	0.58%	430	157	21	6.919	3.829	4.150
421	Cocoa, etc	2.16%	1.54%	2.06%	3,579	945	126	9.210	5.011	4.674
422	Animal foods	1.24%	1.72%	3.78%	2,172	349	24	8.312	5.677	4.525
427	Brewing & malting	1.96%	3.40%	1.95%	7,105	4,390	239	11.477	8.214	6.168
256	Chemicals: ind and agr	0.61%	0.99%	0.68%	1,896	985	57	9.599	6.694	6.061
313	Treatment etc. of metals	0.48%	0.43%	0.26%	525	311	32	7.828	4.908	3.691
170	Water Supply	0.92%	0.18%	0.16%	189	73	36	8.282	4.061	4.115
432	Cotton	1.60%	0.86%	1.04%	3,450	1,014	177	6.702	3.808	3.894
494	Toys etc	0.45%	0.35%	0.32%	755	294	35	6.722	3.023	4.541
241246	Non-met Minerals:prdn	3.74%	5.46%	4.41%	1,173	514	33	9.527	5.961	5.988
455	Household goods	0.45%	0.24%	0.28%	427	131	23	6.126	3.381	4.251
436	Knitting	2.32%	1.06%	0.82%	578	265	55	7.242	3.298	3.913
481482	Rubber Products	1.21%	1.05%	0.83%	2,083	931	102	11.148	5.872	4.900
471472	Paper	2.15%	1.96%	1.73%	1,830	735	76	8.419	5.355	5.356
Group D: Declining or Low Growth Sectors										
316319	Finished metal products	2.99%	2.04%	1.60%	423	191	26	7.117	4.354	3.949
453454	Clothing	6.20%	2.67%	1.97%	409	196	43	6.873	2.911	3.686
414	Fruit & veg	0.88%	0.49%	0.52%	1,800	605	102	8.733	4.513	4.557
14	Mineral oil refining	0.16%	0.33%	2.32%	21,188	1,075	49	10.065	7.284	5.147
311	Foundries	0.41%	0.30%	0.19%	636	355	45	6.950	4.839	5.024
467	Wood furniture	1.68%	0.88%	0.70%	199	89	16	6.164	3.396	3.391
247	Glass	1.98%	1.60%	0.94%	1,676	1,010	118	9.886	6.070	6.093
44	Leather	0.64%	0.49%	0.65%	1,002	270	33	5.657	4.241	2.508
255	Paints etc.	0.41%	0.52%	0.45%	1,495	609	46	7.697	5.152	4.030
429	Tobacco	0.97%	1.47%	0.97%	8,800	4,738	295	10.598	6.349	6.396
362	Railway rolling stock	0.64%	0.32%	0.15%	10,600	8,300	1561	7.370	5.461	6.683
315	Boilermaking etc	0.58%	0.46%	0.38%	724	313	37	7.144	4.707	4.056
419	Bread etc.	3.86%	2.13%	1.87%	425	171	29	7.062	4.261	3.695
491	Jewellery	0.35%	0.24%	0.22%	533	207	29	8.467	4.174	3.022
438	Carpets etc	0.77%	0.66%	0.62%	2,528	944	104	7.157	4.720	4.331
463	Carpentry	1.01%	0.60%	0.49%	258	112	18	6.186	4.094	3.594
437439	Misc Textiles	0.98%	0.98%	0.94%	1,586	591	56	7.031	4.544	4.002
416	Grain	0.67%	0.93%	1.54%	2,955	634	43	7.483	6.592	5.613
314	Struct. metal products	2.23%	1.77%	1.50%	596	248	30	7.164	4.479	4.381
411	Oils and Fats	0.27%	0.32%	0.56%	8,120	1,660	131	9.259	5.698	4.823
433434	Silk etc	0.25%	0.16%	0.17%	1,220	410	61	8.383	4.404	5.174
420	Sugar	0.83%	1.15%	1.13%	16,500	5,940	406	9.388	6.779	6.238
431	Wool	1.63%	1.10%	1.16%	1,594	538	75	7.336	4.076	4.107
312	Forging etc of metals	0.23%	0.19%	0.15%	1,200	544	62	7.028	5.161	6.445
224	Non-ferr metals prdn	0.33%	0.32%	0.37%	2,730	820	81	8.267	5.170	4.827
361	Shipbuilding	0.88%	0.45%	0.63%	1,251	314	58	10.449	5.589	5.926
35	Motor Vehicles	2.70%	1.63%	2.31%	1,517	378	59	9.225	5.879	6.179
248	Ceramics	0.73%	0.40%	0.39%	1,410	520	89	9.589	4.148	4.305
451	Footwear	1.52%	0.75%	0.55%	1,250	603	116	9.408	3.243	3.067
456	Furs	0.11%	0.07%	0.05%	292	142	21	6.641	3.663	2.519
	Manufacturing Industries				1,498	522	50	8.514	4.634	4.851

Note: LTOT = Total Employment, NO = number of firms in a sector, QVf = Gross Output produced by foreign owned firms,
CLAT = Admin/Tech unit cost of labour, CLIW= Industrial Workers unit cost of labour, CLCL = Clerical Workers unit cost of labour,
YV=value-added, QV = Gross Output.

Table 4.15: Selected Indicators for 1990 for 72 Sectors

		Percentage Shares in Total:				Size of Sectors:			Unit Labour Costs:		
		LTOT	YV	QV	QVf/QV 90	QV/NO (in £'000)	YV/NO (in £'000)	LTOT/NO	CLAT (in £'000)	CLIW (in £'000)	CLCLER (in £'000)
Group H: Very High Growth, Largely Foreign-Owned Sectors											
33	Office &data process.	3.56%	10.43%	9.89%	97.88%	37,070	17,782	133	31.282	15.957	19.315
345	Radio & TV	1.74%	6.31%	3.96%	87.50%	23,092	16,742	101	23.995	13.214	15.694
344	Telecomm. equip.	3.17%	2.59%	2.31%	87.50%	4,118	2,093	56	23.806	12.531	14.752
341	Insulated wires & cables	2.10%	0.92%	1.11%	87.50%	8,965	3,381	169	25.118	12.044	17.893
258	Soap, perfumes etc	0.58%	0.95%	0.87%	86.63%	5,515	2,745	36	24.765	12.852	18.598
257	Pharmaceuticals	2.98%	11.73%	7.01%	96.26%	19,881	15,145	84	27.698	19.402	18.311
417823	Misc. Food	1.22%	7.68%	4.34%	78.92%	19,798	15,954	55	31.037	16.075	17.641
132162	Gas: Gasworks	0.49%	1.09%	0.67%		14,010	10,450	103	31.964	25.554	18.164
415	Fish	1.07%	0.67%	0.79%	78.92%	2,074	805	28	17.292	9.367	10.821
37	Instrument Engin.	3.79%	3.86%	2.59%	96.51%	6,725	4,551	98	26.181	13.209	17.203
346	Domestic elec.	1.44%	0.77%	0.78%	87.50%	12.577	5,638	231	25.470	11.089	15.076
424	Spirits	0.26%	1.31%	1.11%	80.68%	23,300	12,490	55	33.229	21.047	26 690
Group M: Moderate or High Growth sectors											
492935	Other Manuf	0.49%	0.29%	0.22%	29.80%	1,679	982	36	24.050	9.207	9.427
251	Basic Chemicals	1.25%	1.23%	2.16%	37.67%	13,353	3,468	77	34.781	25.276	22.594
363365	Cycles & other transp.	1.29%	1.04%	0.88%	13.19%	15,358	8,317	224	30.575	25.177	20.000
483	Plastics	3.38%	2.09%	2.10%	51.70%	2,024	917	32	22.257	12.455	14.730
259260	Other chemicals	0.74%	0.59%	0.69%	86.63%	8,506	3,335	91	28.529	16.209	16.688
412	Meat	5.13%	2.96%	9.55%	9.98%	15,068	2,126	80	20.271	10.793	10.818
473474	Printing & Publishing	5.30%	3.54%	2.52%	10.19%	1,527	974	32	24.998	16.674	18.603
464465	Wood products	0.27%	0.11%	0.12%	16.62%	620	254	14	16.024	8.405	10.388
425268	Wine etc	0.60%	0.48%	0.59%	80.68%	3,888	1,428	52	35.639	18.969	20.478
221223	Iron and Steel	0.74%	0.58%	0.77%	10.58%	5,041	1,731	48	25.069	18.308	16.372
343	Elec apparatus	0.58%	0.37%	0.30%	87.50%	2,778	1,552	52	18 780	10.188	11.866
466	Cork, brooms etc	0.14%	0.08%	0.07%	16.62%	2,300	1,350	50	24.074	14.115	15.732
161	Electricity	5.22%	5.47%	4.04%		31,441	19,367	403	29.668	18.287	20.128
413	Dairy products	3.66%	3.86%	9.85%	11.36%	21,322	3,802	79	25 002	17.570	13.375
34278	Elec & lighting equip.	1.56%	0.68%	0.64%	87.50%	1,785	860	43	20.727	10.567	12.174
32	Mech. engineering	4.06%	2.42%	2.35%	65.79%	1,778	830	30	21.951	12.682	14.042
461462	Semi-finished wood	0.79%	0.53%	0.66%	16.62%	2,475	907	29	20.151	12.556	14.893
421	Cocoa, etc	1.55%	1.15%	1.44%	70.60%	8,386	3,042	90	35.440	15.085	15.894
422	Animal foods	0.96%	0.97%	2.18%	0.00%	5,025	1,019	22	23.838	14.746	13.089
427	Brewing & malting	1.21%	2.98%	1.90%	80.68%	19,985	14,255	127	46.365	31.709	34.014
256	Chemicals: ind and agr	0.60%	0.57%	0.50%	86.63%	2,989	1,566	35	27.161	18.525	19.516
313	Treatment etc. of metals	0.58%	0.23%	0.26%	37.61%	1,597	647	36	25.566	15.026	16.374
170	Water Supply	1.08%	0.37%	0.28%		1,052	623	40	20.692	11.634	10.719
432	Cotton	0.85%	0.48%	0.67%	80.28%	12,764	4,155	161	29.107	14.602	13.281
494	Toys etc	0.49%	0.35%	0.33%	29.80%	1,745	830	26	21.913	10.985	13.389
241246	Non-met Minerals:prdn	3.12%	3.53%	3.34%	49.38%	2,890	1,388	27	27.726	16.861	19.953
455	Household goods	0.55%	0.19%	0.24%	29.06%	828	300	19	16.570	8.663	9.428
436	Knitting	2.15%	0.58%	0.59%	60.60%	1,665	740	60	18.346	7.988	12.012
481482	Rubber Products	1.16%	0.75%	0.68%	90.21%	3,400	1,695	58	26 037	15.564	17.496
471472	Paper	1.64%	1.18%	1.35%	32.99%	3,267	1,295	39	23.751	16.021	13.013
Group D: Declining or Low Growth Sectors											
316319	Finished metal products	2.96%	1.45%	1.56%	37.61%	1,125	475	21	19.452	11.775	11.528
453454	Clothing	5.25%	1.31%	1.29%	29.06%	1,076	497	44	17.209	7.405	10.477
414	Fruit & veg	0.60%	0.34%	0.35%	78.92%	3,847	1,726	66	26.082	13.499	14.031
14	Mineral oil refining	0.20%	0.19%	1.16%	29.80%	27,144	2,067	47	34.278	18.840	23.282
311	Foundries	0.33%	0.16%	0.14%	37.61%	1,741	682	41	19.969	11.889	10.802
467	Wood furniture	1.50%	0.54%	0.55%	16.62%	547	245	15	14.752	8.818	8.418
247	Glass	1.89%	0.91%	0.73%	49.38%	3,272	1,853	84	30.330	16.346	16.363
44	Leather	0.24%	0.13%	0.27%	5.00%	1,969	414	17	15.330	10.330	9 193
255	Paints etc.	0.37%	0.32%	0.33%	86.63%	2.867	1,292	32	24.276	15.026	16.746
429	Tobacco	0.62%	1.04%	0.68%	80 68%	17,875	12.475	161	46.772	20.742	29 389
362	Railway rolling stock	0.54%	0.23%	0.13%	13.19%	27,900	22,100	1121	22.400	14.106	16.625
315	Boilermaking etc	0.47%	0.28%	0.26%	37.61%	1,549	751	28	19 090	12.800	12.715
419	Bread etc.	2.62%	0.99%	1.03%	0.00%	949	418	24	16.684	10.013	12.809
491	Jewellery	0.43%	0.20%	0.17%	29.80%	1,088	591	28	16.401	10.608	9.643
438	Carpets etc	0.48%	0.24%	0.27%	80.28%	4,650	1,933	84	22.002	13.211	14.303
463	Carpentry	0.94%	0.35%	0.40%	16.62%	708	278	16	16.541	9.929	10.134
437439	Misc Textiles	0.67%	0.36%	0.35%	80.28%	2,248	1,039	42	22.901	12.810	12.409
416	Grain	0.32%	0.25%	0.51%	0.00%	3,944	889	25	19.654	16.538	14.998
314	Struct. metal products	1.66%	0.82%	0.91%	37 61%	884	364	16	17.705	11.302	11.585
411	Oils and Fats	0.12%	0.12%	0.14%	78.92%	4.900	1,983	41	30.604	20.158	16 990
433434	Silk etc	0.15%	0.05%	0.06%	80.28%	1,886	671	44	27.259	12.035	8 198
420	Sugar	0 44%	0.34%	0 38%	70.60%	26,400	10.900	309	29 750	18.642	19 730
431	Wool	0.79%	0 30%	0.41%	59 77%	2,990	1,000	57	21 068	11.470	12 157
312	Forging etc of metals	0 06%	0.04%	0 03%	37.61%	1,360	760	23	25 638	15.176	3 949
224	Non-ferr metals: prdn	0.09%	0.06%	0.13%	10.58%	2,154	462	15	21 233	12 131	8.015
361	Shipbuilding	0.28%	0 11%	0.11%	13.19%	912	416	23	18 579	11 699	12 270
35	Motor Vehicles	1.52%	0 57%	0.67%	29.08%	1,718	663	39	19 252	13.708	20.721
248	Ceramics	0 33%	0 18%	0.14%	49.38%	1,806	1,056	43	24 799	10.473	19.337
451	Footwear	0.35%	0 12%	0.11%	5.00%	996	467	32	16 963	8 774	11.128
456	Furs	0.03%	0.01%	0.02%	29.06%	486	157	10	14 341	9.546	7.234
	Manufacturing Industries					4,335	1,932	42	25.169	13.715	15.948

Note: LTOT = Total Employment, NO = number of firms in a sector, QVf = Gross Output produced by foreign owned firms,
CLAT = Admin/Tech unit cost of labour, CLIW= Industrial Workers unit cost of labour, CLCL = Clerical Workers unit cost of labour,
YV=value-added, QV = Gross Output.

Figure 4.6: Occupational Profile of 10 Industrial Sectors: 1983, 1990 and 1997

Distribution of Occupations in 10 Industrial Sectors*

		Engineering	Chemicals	Mining and utilities	Paper and printing	Food	Drink and tobacco	Other manufacturing	Textiles	Metals	Clothing and footwear
Agricultural Workers	1983	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%
	1990	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%
	1997	0%	0%	1%	0%	0%	6%	0%	0%	0%	0%
Managers and Proprietors	1983	7%	12%	4%	9%	7%	2%	6%	6%	7%	7%
	1990	7%	11%	3%	9%	8%	2%	5%	6%	8%	6%
	1997	7%	9%	4%	12%	8%	3%	7%	7%	8%	8%
Professional Workers	1983	11%	14%	9%	13%	4%	10%	4%	4%	5%	2%
	1990	13%	18%	8%	12%	6%	11%	4%	5%	4%	2%
	1997	19%	23%	10%	14%	7%	12%	4%	4%	6%	4%
Clerical Workers	1983	12%	16%	14%	16%	11%	4%	7%	10%	11%	6%
	1990	11%	16%	16%	20%	12%	4%	8%	8%	7%	8%
	1997	10%	15%	13%	15%	10%	3%	6%	8%	8%	6%
Skilled Workers (Maintenance & Production)	1983	35%	16%	27%	27%	11%	19%	46%	50%	26%	68%
	1990	28%	14%	25%	26%	8%	17%	47%	41%	30%	67%
	1997	25%	13%	30%	24%	7%	14%	47%	49%	29%	61%
Production Operatives	1983	29%	28%	26%	24%	44%	5%	26%	25%	39%	11%
	1990	36%	29%	28%	22%	47%	3%	25%	34%	39%	12%
	1997	35%	32%	22%	27%	52%	4%	26%	26%	39%	16%
Transport & Communication workers	1983	1%	4%	6%	3%	9%	3%	5%	1%	2%	0%
	1990	1%	2%	6%	3%	8%	4%	4%	1%	1%	0%
	1997	0%	3%	6%	2%	6%	6%	4%	0%	1%	0%
Sales, Security & Service Workers	1983	2%	8%	4%	5%	11%	3%	1%	3%	4%	4%
	1990	2%	7%	4%	6%	6%	4%	2%	3%	3%	5%
	1997	2%	3%	5%	5%	8%	2%	3%	3%	2%	5%
Labourers & Others	1983	3%	2%	11%	3%	4%	50%	4%	2%	5%	1%
	1990	2%	3%	10%	2%	4%	50%	5%	1%	7%	0%
	1997	1%	1%	9%	1%	2%	50%	4%	2%	6%	1%

Employment Share in Groups of Sectors

		Engineering	Chemicals	Mining and utilities	Paper and printing	Food	Drink and tobacco	Other manufacturing	Textiles	Metals	Clothing and footwear
12 High Growth Sectors	1979	43%	33%	10%	0%	7%	3%	0%	0%	0%	0%
	1990	62%	55%	7%	0%	13%	8%	0%	0%	0%	0%
30 Medium Growth Sectors	1979	33%	58%	90%	100%	64%	61%	61%	52%	15%	5%
	1990	29%	40%	93%	100%	66%	60%	65%	59%	19%	9%
30 Declining Sectors	1979	23%	9%	0%	0%	29%	36%	39%	48%	85%	95%
	1990	9%	6%	0%	0%	21%	32%	35%	41%	81%	91%

* Labour Force Survey and Census data, updated from data in Corcoran, Sexton and O'Donoghue (1992)

All results are reported at annualised rates.

Table 4.16: Decomposition of change in share of AT workers in total employment and total wage bill

	Employment				Wage Bill			
	*Total **	*Between*	*Within*	*% contrib. of within component*	*Total **	*Between*	*Within*	*% contrib. of within component*
TOTAL: 72 SECTORS IN PANEL								
1979-90	1.93%	0.49%	1.45%	74.7%	1.88%	0.69%	1.19%	63.4%
1979-87	2.65%	0.51%	2.14%	80.8%	2.37%	0.81%	1.57%	66.0%
1987-90	0.05%	0.50%	-0.44%	-820.8%	0.58%	0.44%	0.14%	23.7%
GROUP H: 12 SECTORS HIGH GROWTH GROUP								
1979-90	3.88%	0.18%	3.69%	95.3%	3.07%	0.30%	2.77%	90.2%
1979-87	5.06%	0.24%	4.81%	95.2%	4.14%	0.51%	3.63%	87.6%
1987-90	0.80%	0.21%	0.59%	73.4%	0.29%	-0.21%	0.50%	171.5%
GROUP M: 30 MEDIUM GROWTH SECTORS								
1979-90	0.58%	-0.09%	0.68%	116.1%	0.53%	-0.01%	0.54%	101.0%
1979-87	1.16%	0.00%	1.16%	99.8%	0.93%	0.09%	0.84%	89.9%
1987-90	-0.94%	-0.30%	-0.65%	68.7%	-0.51%	-0.21%	-0.30%	59.2%
GROUP D: 30 DECLINING SECTORS								
1979-90	1.01%	-0.08%	1.09%	107.9%	1.31%	0.19%	1.13%	85.9%
1979-87	1.97%	-0.11%	2.08%	105.7%	1.57%	0.17%	1.40%	89.2%
1987-90	-1.51%	-0.09%	-1.42%	94.0%	0.64%	-0.04%	0.67%	105.9%

* Annualised Percentage changes

Table 4.17: Decomposition of change in share of IW workers in total employment and total wage bill

	Employment				Wage Bill			
	*Total **	*Between*	*Within*	*% contrib. of within component*	*Total **	*Between*	*Within*	*% contrib. of within component*
TOTAL: 72 SECTORS IN PANEL								
1979-90	-0.53%	-0.11%	-0.42%	78.6%	-0.89%	-0.24%	-0.66%	73.5%
1979-87	-0.68%	-0.14%	-0.54%	79.4%	-1.07%	-0.29%	-0.79%	73.4%
1987-90	-0.13%	-0.07%	-0.06%	44.8%	-0.42%	-0.12%	-0.30%	70.8%
GROUP H: 12 SECTORS HIGH GROWTH GROUP								
1979-90	-1.16%	-0.01%	-1.15%	99.3%	-1.49%	-0.11%	-1.38%	92.9%
1979-87	-1.51%	-0.04%	-1.47%	97.5%	-2.00%	-0.23%	-1.77%	88.7%
1987-90	-0.21%	0.01%	-0.22%	104.6%	-0.12%	0.23%	-0.35%	301.9%
GROUP M: 30 MEDIUM GROWTH SECTORS								
1979-90	-0.33%	-0.01%	-0.32%	98.1%	-0.58%	-0.01%	-0.57%	97.9%
1979-87	-0.50%	-0.07%	-0.43%	85.7%	-0.78%	-0.07%	-0.71%	91.5%
1987-90	0.14%	0.17%	-0.03%	-25.0%	-0.04%	0.16%	-0.21%	481.9%
GROUP D: 30 DECLINING SECTORS								
1979-90	-0.18%	0.03%	-0.21%	115.3%	-0.46%	-0.02%	-0.44%	95.1%
1979-87	-0.25%	0.05%	-0.29%	118.1%	-0.45%	0.00%	-0.45%	99.6%
1987-90	0.01%	0.01%	0.00%	39.0%	-0.49%	-0.03%	-0.45%	93.1%

* Annualised Percentage changes

All results are reported at ...

Table 4.18: Decomposition of change in share of CL workers in total employment and total wage bill

	Employment				Wage Bill			
	*Total **	*Between*	*Within*	*% contrib. of within component*	*Total **	*Between*	*Within*	*% contrib. of within component*
TOTAL: 72 SECTORS IN PANEL								
1979-90	1.83%	0.31%	1.51%	82.9%	2.68%	0.39%	2.29%	85.5%
1979-87	2.21%	0.49%	1.72%	77.7%	3.18%	0.55%	2.64%	82.8%
1987-90	0.80%	-0.06%	0.86%	107.8%	1.36%	-0.05%	1.41%	103.5%
GROUP H: 12 SECTORS HIGH GROWTH GROUP								
1979-90	2.65%	-0.19%	2.84%	107.3%	1.64%	-0.06%	1.70%	103.4%
1979-87	3.65%	-0.06%	3.72%	101.7%	2.32%	0.17%	2.15%	92.6%
1987-90	0.02%	-0.35%	0.37%	1781.3%	-0.13%	-0.57%	0.44%	-333.3%
GROUP M: 30 MEDIUM GROWTH SECTORS								
1979-90	1.51%	0.12%	1.38%	91.7%	2.64%	0.08%	2.56%	97.0%
1979-87	2.05%	0.45%	1.61%	78.3%	3.30%	0.26%	3.05%	92.2%
1987-90	0.07%	-0.70%	0.77%	1168.9%	0.90%	-0.54%	1.44%	160.2%
GROUP D: 30 DECLINING SECTORS								
1979-90	0.73%	-0.20%	0.93%	127.0%	1.92%	-0.14%	2.06%	107.1%
1979-87	0.34%	-0.36%	0.69%	206.5%	1.48%	-0.32%	1.80%	121.4%
1987-90	1.80%	0.05%	1.75%	97.1%	3.11%	0.37%	2.74%	88.0%

* Annualised Percentage changes

Table 4.19: Decomposition of change in AT employment and wage bill

	Employment *					Wage Bill **				
	Total	*Scale*	*Sector*	*Occupation*	*Interactive*	*Total*	*Scale*	*Sector*	*Occupation*	*Interactive*
TOTAL: 72 SECTORS IN PANEL										
1979-90	0.5%	-1.4%	0.3%	1.3%	0.1%	10.3%	8.3%	1.3%	1.1%	2.2%
1979-87	0.1%	-2.5%	0.3%	2.0%	-0.1%	11.7%	9.1%	1.3%	1.4%	2.1%
1987-90	1.7%	1.6%	0.6%	-0.4%	-0.1%	6.7%	6.1%	0.6%	0.2%	-0.1%
GROUP H: 12 SECTORS HIGH GROWTH GROUP										
1979-90	8.7%	4.6%	0.4%	3.8%	2.5%	19.4%	15.8%	1.8%	2.8%	8.3%
1979-87	9.4%	4.1%	0.5%	4.9%	1.8%	22.5%	17.7%	2.1%	3.7%	8.2%
1987-90	6.9%	6.0%	0.2%	0.6%	0.1%	11.4%	11.0%	-0.3%	0.5%	0.3%
GROUP M: 30 MEDIUM GROWTH SECTORS										
1979-90	-0.8%	-1.4%	-0.1%	0.7%	-0.1%	8.7%	8.1%	0.0%	0.5%	0.7%
1979-87	-1.5%	-2.6%	0.0%	1.1%	-0.1%	9.8%	8.8%	0.2%	0.8%	0.8%
1987-90	0.9%	1.8%	-0.3%	-0.6%	-0.1%	5.5%	6.1%	-0.2%	-0.3%	-0.2%
GROUP D: 30 DECLINING SECTORS										
1979-90	-3.4%	-4.4%	0.0%	1.2%	-0.6%	5.6%	4.2%	0.3%	1.1%	0.7%
1979-87	-3.4%	-5.3%	0.0%	2.2%	-1.0%	6.8%	5.2%	0.3%	1.4%	0.7%
1987-90	-3.5%	-2.0%	0.1%	-1.2%	-0.2%	2.4%	1.7%	0.2%	0.9%	-0.5%

* Results are expressed as a percentage of the number of AT workers employed at the beginning of the period.
** Results are expressed as a percentage of the AT wage bill at the beginning of the period.
All results are reported at annualised rates.

Table 4.20: Decomposition of change in IW employment and wage bill

	Employment *					Wage Bill **				
	Total	*Scale*	*Sector*	*Occupation*	*Interactive*	*Total*	*Scale*	*Sector*	*Occupation*	*Interactive*
TOTAL: 72 SECTORS IN PANEL										
1979-90	-1.9%	-1.4%	-0.1%	-0.4%	0.0%	7.3%	8.3%	-0.5%	-0.6%	-1.1%
1979-87	-3.1%	-2.5%	-0.1%	-0.5%	0.0%	4.8%	5.6%	-0.2%	-0.4%	-0.5%
1987-90	1.5%	1.6%	-0.1%	-0.1%	0.0%	4.9%	5.2%	-0.1%	-0.3%	0.0%
GROUP H: 12 SECTORS HIGH GROWTH GROUP										
1979-90	3.4%	4.6%	-0.1%	-1.2%	-0.6%	14.1%	15.8%	-0.7%	-1.4%	-7.0%
1979-87	2.5%	4.1%	-0.1%	-1.5%	-0.4%	6.7%	8.0%	-0.2%	-0.5%	-1.5%
1987-90	5.8%	6.0%	0.0%	-0.2%	-0.1%	8.2%	8.3%	0.3%	-0.2%	-0.2%
GROUP M: 30 MEDIUM GROWTH SECTORS										
1979-90	-1.7%	-1.4%	0.0%	-0.3%	0.1%	7.4%	8.1%	0.0%	-0.6%	-0.8%
1979-87	-3.1%	-2.6%	0.0%	-0.4%	0.1%	4.8%	5.4%	-0.1%	-0.4%	-0.4%
1987-90	2.0%	1.8%	0.2%	-0.1%	0.0%	5.1%	5.1%	0.1%	-0.2%	0.0%
GROUP D: 30 DECLINING SECTORS										
1979-90	-4.5%	-4.4%	0.0%	-0.2%	0.1%	3.7%	4.2%	0.0%	-0.4%	-0.3%
1979-87	-5.5%	-5.3%	0.0%	-0.3%	0.1%	3.4%	3.8%	0.0%	-0.3%	-0.2%
1987-90	-2.0%	-2.0%	0.0%	0.0%	0.1%	1.2%	1.6%	-0.1%	-0.5%	0.1%

* Results are expressed as a percentage of the number of IW workers employed at the beginning of the period.
** Results are expressed as a percentage of the IW wage bill at the beginning of the period.
All results are reported at annualised rates.

Table 4.21: Decomposition of change in CL employment and wage bill

	Employment *					Wage Bill **				
	Total	*Scale*	*Sector*	*Occupation*	*Interactive*	*Total*	*Scale*	*Sector*	*Occupation*	*Interactive*
TOTAL: 72 SECTORS IN PANEL										
1979-90	0.4%	-1.4%	0.2%	1.5%	-0.1%	11.2%	8.3%	1.0%	2.3%	3.1%
1979-87	-0.3%	-2.5%	0.4%	1.7%	-0.2%	12.6%	9.1%	1.0%	2.6%	3.0%
1987-90	2.5%	1.6%	0.0%	0.9%	-0.1%	7.6%	6.1%	-0.1%	1.4%	0.3%
GROUP H: 12 SECTORS HIGH GROWTH GROUP										
1979-90	7.4%	4.6%	0.2%	3.1%	1.1%	17.7%	15.8%	0.3%	1.8%	5.1%
1979-87	7.9%	4.1%	0.3%	4.0%	0.8%	20.4%	17.7%	0.3%	2.1%	5.6%
1987-90	6.1%	6.0%	-0.5%	0.3%	0.2%	10.9%	11.0%	-1.0%	0.3%	0.5%
GROUP M: 30 MEDIUM GROWTH SECTORS										
1979-90	0.1%	-1.4%	0.1%	1.4%	-0.3%	10.9%	8.1%	0.2%	2.6%	3.3%
1979-87	-0.6%	-2.6%	0.4%	1.6%	-0.3%	12.4%	8.8%	0.5%	3.0%	3.1%
1987-90	1.9%	1.8%	-0.7%	0.8%	-0.1%	7.0%	6.1%	-0.6%	1.5%	0.2%
GROUP D: 30 DECLINING SECTORS										
1979-90	-3.7%	-4.4%	-0.1%	0.9%	-0.4%	6.2%	4.2%	-0.3%	2.0%	1.3%
1979-87	-4.9%	-5.3%	-0.2%	0.8%	-0.4%	6.7%	5.2%	-0.6%	1.7%	1.1%
1987-90	-0.2%	-2.0%	0.1%	1.8%	-0.3%	4.9%	1.7%	0.3%	2.6%	0.4%

* Results are expressed as a percentage of the number of CL workers employed at the beginning of the period.

** Results are expressed as a percentage of the CL wage bill at the beginning of the period.

All results are reported at annualised rates.

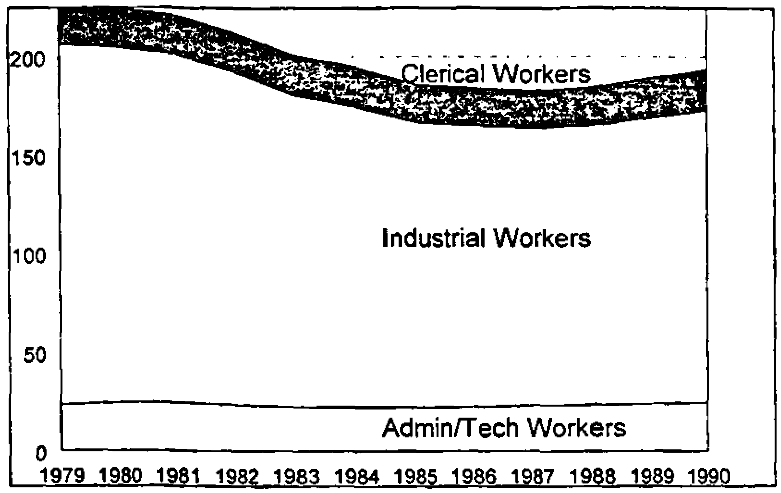

Figure 4.7: Different Categories of Employment in Manufacturing Sector

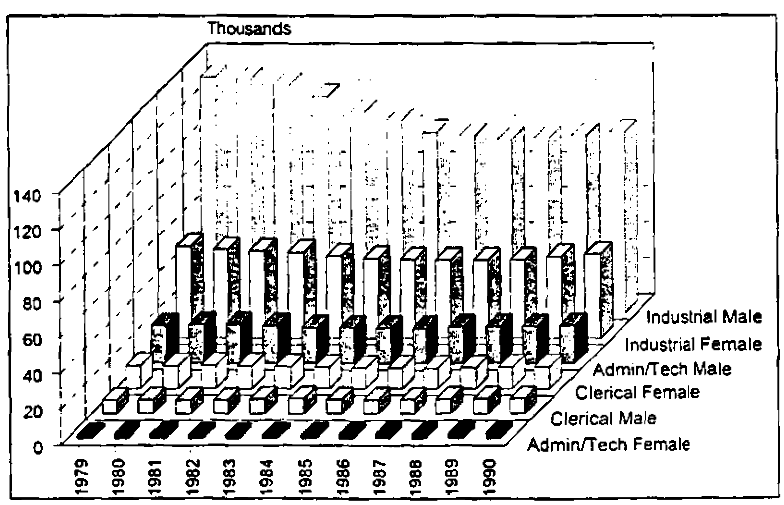

Figure 4.8: Decomposition of Male and Female Employment in Manufacturing Sector

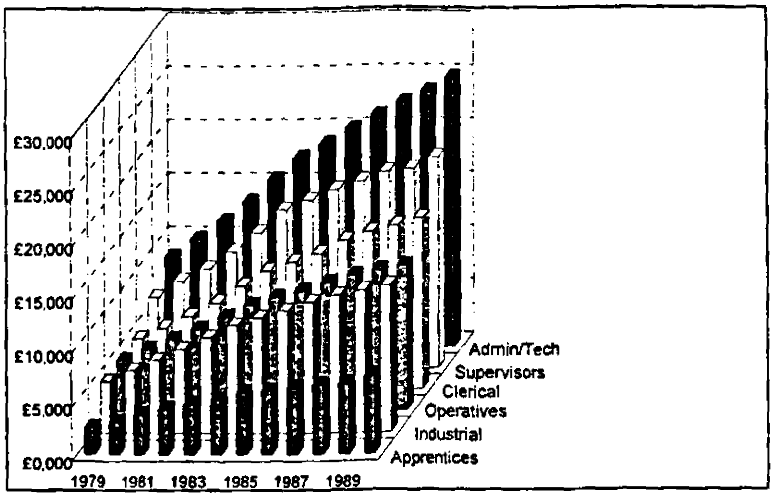

Figure 4.9: Labour Costs Per Worker for different Types of Labour in Manufacturing Sector.

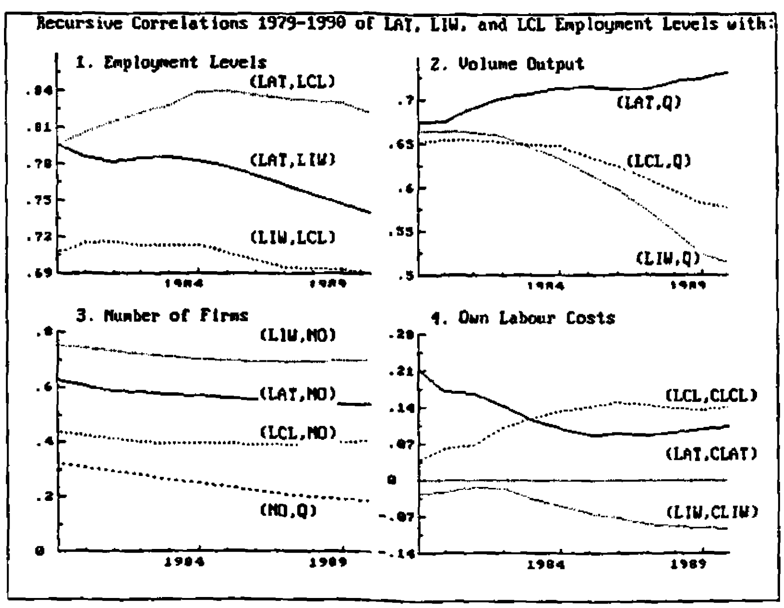

Figure 4.10: Recursive Correlations 1979-1990 of LAT, LIW and LCL Employment Levels with Selected Variables

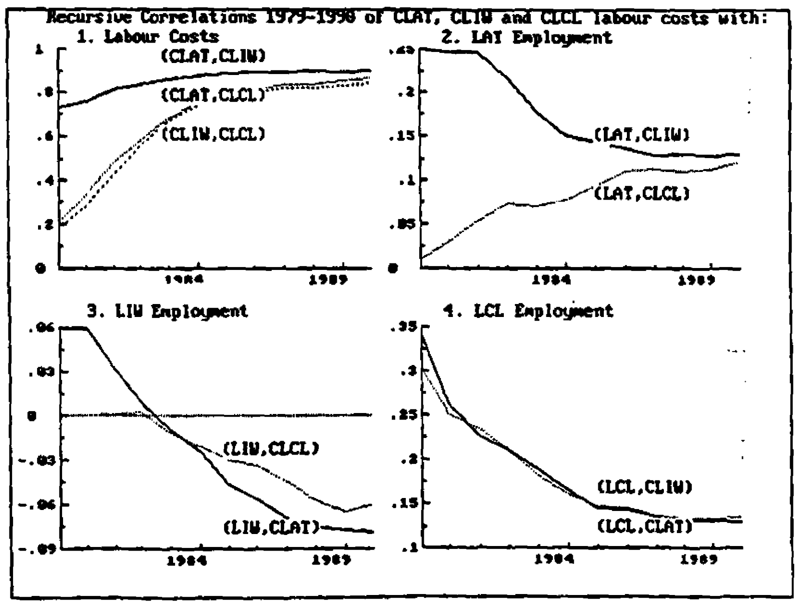

Figure 4.11: Recursive Correlations 1979-1990 of CLAT, CLIW and CLCL Labour Costs with Selected Variables

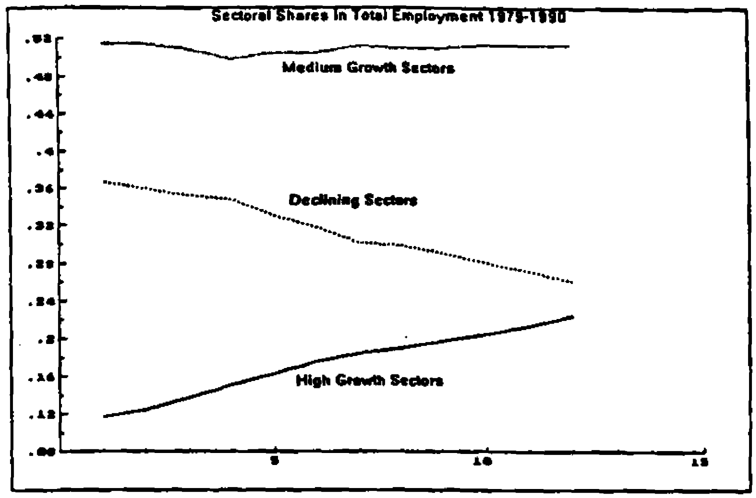

Figure 4.12: Share of High Growth, Medium Growth and Declining Industries in Total Employment, 1979-1990

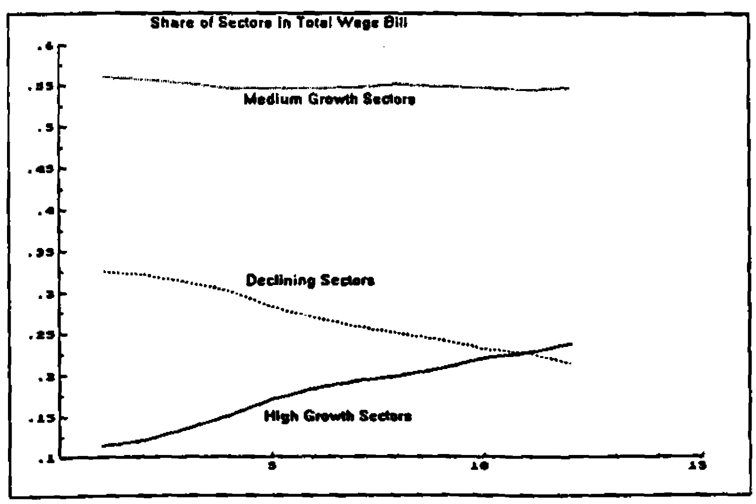

Figure 4.13: Share of High Growth, Medium Growth and Declining Sectors in Total Wage Bill, 1979-1990.

4.11 The Panel Data Set

This section describes the dataset used in Part II of this thesis. The data are from the annual *Census of Industrial Production* (CIP) which is published by the Irish Central Statistics Office (CSO). This census has 90% coverage of Irish industry and has been published since 1953. In 1973 a move to the NACE sectoral classification system, on accession to the EC, led to major revisions and changes in the definitions of sectors which makes a comparison with the earlier data virtually impossible at a detailed sectoral level. (A similar major classification change was introduced in 1991 and affects comparison with earlier years.) The CIP provides data on the value of gross output, intermediate inputs, net output, persons engaged, wages and salaries and remainder of net output for 75 detailed sectors. With the exception of the employment figures, all of these data are based on the financial accounting year nearest to the reference calendar year, in most cases (77% in 1990) this coincides with the calendar year. These data are used by the CSO to calculate sectoral volume of production index numbers. The panel data set begins in 1979 because the disaggregated employment and wage data, which are not published in full, were not provided to me by the CSO before this date.

Table 4.9 lists the 72 detailed sectors included in the panel data set. These exclude the three sectors "Mining, Quarrying and Turf" (NACE 11,21,23). They are excluded because the data for them are incomplete.

4.11.1 The Disaggregated Employment and Wage Data

These data distinguish five categories of worker for both employment and wages (see copy of CIP questionnaire in Appendix B.4):

1. Managerial, technical and other salaried staff
2. Manual supervisory staff
3. Manual workers
4. Apprentices
5. Industrial workers = (2) + (3) + (4)
6. Clerical and other office staff

The employment figures are disaggregated into male and female workers, unfortunately this disaggregation is not available for the wage data.

These employment data are published by the CSO. However they do not publish a full disaggregation of the wage bill data, they simply distinguish between the Industrial Workers wage bill and Other Employees wage bill. The CSO supplied me with a disaggregation of these unpublished wage data for the categories listed above from 1979 to 1990.

These employment and wage data exclude Proprietors and Outside Piece Workers. Outside Piece Workers are in general excluded from measures of aggregate employment (=Total Persons Engaged). However there is a minor difference between these disaggregated data and the figures I use for aggregate employment which includes Proprietors. These differences are negligible. For example in 1990 total persons engaged in manufacturing industries was 194,177 of which 590 were Proprietors (in addition there were 1,707 Outside Piece Workers). There is a similar minor discrepancy in the aggregate wage data I use. Proprietors earnings do not form a part of the wage bill (in fact they are not recorded in the CIP) but the aggregate wage bill figures do include Outside Piece Workers. In 1990 the total wage bill for manufacturing industries was £2,449,023 of which £2,200 was paid to Outside Piece Workers so again the discrepancy is a very minor one.

I made some adjustments to the disaggregated data I received on disk from the CSO. Since the CSO did not provide me with the Clerical Staff wage bill numbers these had to be calculated as a residual. Because the total wage bill data have been revised more frequently than the disaggregated numbers this led in a few cases to some strange calculations of the Clerical wage rate. Therefore I made a full comparison of the published data in each year with the revised data on disk to check for consistency and adding-up. In almost all cases the revisions to the published data were minor. In a few cases it was necessary to use the unrevised data where rounding up in the revised data was distorting the residual numbers for the clerical wage bill for small sectors (e.g. sector 433434) or where there were clear typos on disk (sectors 411 and 412). In the other cases where I used the unrevised numbers the revised figures varied by more than 70% of the original number. Also in three cases I used the unrevised Industrial employment data to avoid negative numbers for Proprietors in individual sectors. In total the adjustments included three (sector 161 in 1984, sector 251 in 1984 and sector 422 in 1982) adjustments to the "Industrial Workers" employment category and also three (sector 411 in 1990, sector 412 in 1990 and sector 422 in 1982) adjustments to the "Industrial Workers" wage bill category. I also made nine adjustments to the total wage bill (sector 256 in 1990, sector 33 in 1979, sector 312 in 1987, sector 343 in 1990, sector 422 in 1982, sector 424 in 1988, sector 433434 in 1982 and 1983 and sector 456 in 1986). All of these adjustments used the published data.

In all cases where the CSO have made revisions to the aggregate employment and wage data (and there are often a lot, some quite substantial!) I have no choice but to use the disaggregated data totals because I don't have the corresponding revisions for the disaggregated data. The aggregate employment data *LTOT* has been substantially revised by the CSO for the early years of the sample in twelve sectors (33, 343, 344, 345, 419, 463, 467, 34278, 241246, 316319, 453454, 473474) and there are minor revisions for many others. *LTOT* is not used to compute any of the variables I use in modelling, but I do report it in the tables and graphs in the appendix. This means that Table 4.11 must be read with care. For example sector 343 reports growth in each of *LAT*, *LIW* and *LCL* but total employment *LTOT* falls because the aggregate data were substantially revised upwards for the early years of the sample period. I can only assume that the revisions do not imply a change in employment ratios.

4.11.2 The Variables Used

Six variables are defined - namely employment L_j, cost of labour P_{L_j}, value added YV, labour share of value added S_{L_j}, gross output QV and volume production Q.

1. **Employment L_j**

   This variable measures the numbers employed (excluding outside piece workers) in each sector. It is measured at the second week of September in each year. It is disaggregated into five worker categories by sex as described in Section 4.11.1.

2. **Cost of Labour P_{L_j}**

   This variable measures the annual end-of-payroll-year wage bill per worker including non-wage labour costs. It is also disaggregated by "type" of worker as described in Section 4.11.1. Because non-wage labour costs are not reported in the Census of Establishments in the CIP I use the ratio of non-wage labour costs to wages and salaries as reported in the smaller Census of Enterprises to adjust my wage data. These data are only available at the broad NACE sector level for aggregate employment numbers so the adjustment does not alter relative wage measures but provides a more accurate measure of labour share of value added.

3. **Value Added YV**

   The variable YV measures annual *net* output.

4. **Volume Production Q**

   The variable Q measures annual gross output at constant 1985 prices.

5. **Labour Share of Value Added S_{L_j}**

This is defined as

$$\frac{L_j \cdot P_{L_j}}{YV}$$

Note that the discrepancies between the aggregate and disaggregate wage and employment data mentioned above clearly do not affect calculations of the AT, IW and CL wage rates. However in calculating labour share of value-added, the fact that the AT, IW and CL wage bills do not sum to the total wage bill means that the difference, which is a measure of capital services, includes the wage bill of Outside Piece Workers. But the difference is negligible (Outside Piece Workers wage bill was less than 0.1% of the total wage bill in 1990).

1. **Cost of Capital P_K**

   The *pre-tax cost of capital* is measured as

$$P_{Kt} = p_{It}\frac{(1-g_t)}{(1-\tau_t)}(i_t - \gamma_t + \delta) \tag{4.3}$$

   where p_I is the price of investment goods, γ is the rate of change of investment goods prices, δ is the rate of economic depreciation, i is the nominal rate of interest, g is an average measure of the present value of tax allowances and investment grants and τ is the rate of corporation tax. The level of sector-specific variation in the cost of capital series is low. The only sector-specific components are the depreciation rate which differs for the 12 major sectors and the exports weights which are different for the 33 broad sectors (see Appendix B.3 for further details) The corresponding cost of capital series for the 72 detailed industrial sectors in the panel data set were simply matched from broad to detailed sector so that the cost of capital series is the same for all detailed sectors included in a single broad sector.

Chapter 5

Single Equation Estimates of the Long Run Demand For Skilled Labour Relative to Unskilled Labour Using a GMM Estimator

5.1 Introduction

In the previous chapter we found that there was a persistent trend toward the employment of relatively more skilled labour in manufacturing in the 1980s. Furthermore we found that skill-intensity was growing fastest in the high-growth group of sectors. In this and the next chapter we switch our attention from examining these broad compositional changes in employment between sectors to estimating the substitution possibilities between skilled and unskilled labour *within* these groups of sectors.

We begin by specifying a system of factor share equations derived from the translog cost function. The estimating equations include period-specific time dummies as a proxy for technical progress, and gross output to test for scale effects. The estimated parameters on the relative factor price terms are used to compute own- and cross-wage elasticities of demand for skilled and unskilled labour. International evidence on labour demand suggest that the demand for unskilled labour is more wage-elastic than the demand for skilled labour (see Chapter 1, Section 1.3.2). We use our computed wage elasticity of demand for skilled labour and unskilled labour to assess whether the Irish labour market accords with this international stylised fact.

A fully specified system of factor share equations, including dynamics, includes a large number of parameters for estimation and is therefore complex to implement. However, with just two factors of production this factor demand system can be estimated as a single equation. In this chapter we exploit this to estimate the constant-output elasticity of demand for skilled labour relative to unskilled labour in two stages. The first estimates the demand for skilled labour relative to unskilled labour while the second aggregates labour to a single input and estimates the demand for this aggregate labour relative to capital services. By adopting a number of strong assumptions about the underlying relationships between factors, these results can be combined to provide an initial estimate of the constant-output elasticity of demand for skilled and unskilled labour. In the next chapter, we relax these assumptions.

We only have annual data for 12 years from 1979 to 1990. Therefore it is not feasible to implement the encompassing-the-VAR modelling methodology used in Part I, which requires a long time-series of data. Instead the parameters of the translog factor demand system form the initial estimating equation, and we do a series of hypothesis and diagnostic tests on this specification to assess its robustness and search for simplifications. Insofar as the estimating equation is highly parameterised, this approach is inferior to the general-to-specific approach which first looks for data congruence among the variables of interest before testing for parametric restrictions. However this disadvantage is overcome to the extent that tests on the estimating equation can be used *ex post* to check the robustness of the results. In estimation we pool the cross-section and time-series data into a panel, Section 5.3 looks at the econometric issues involved in estimating single-equation dynamic models with a short panel of data.

Chapter 4 identified three similar sector types within the manufacturing sector, and we aggregate these into three groups of panel data. Estimation is then based on the assumption that all sectors within each group have a similar responsiveness to relative prices, technical change and scale. The only parameter that varies across sectors in estimation is the intercept term. The data are based on sectors rather than firms, so that a net new additional firm could alter this intercept term. To control for this we include the number of firms per sector as an additional variable to test for "firm turnover effects".

5.2 The Estimating Equation

Section 2.1 of Chapter 2 contains a full discussion of the theoretical framework we adopt in deriving a specification for the demand for labour. For a panel of sectors, the long-run version of the translog total cost function for sector s is given by

$$\ln TC_s = \alpha_{0s}+\sum_{i=1}^{K}\alpha_{is}\ln P_{is}+\frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\gamma_{ij}\ln P_{is}\ln P_{js}+\alpha_q\ln Q_s+\frac{1}{2}\gamma_{qq}\ln(Q_s)^2+\sum_{i=1}^{K}\gamma_{iq}\ln P_{is}\ln Q_s \tag{5.1}$$

where TC_s is total cost for sector s, P_{is} is the price of factor i in sector s, P_{js} is the price of factor j in sector s and Q_s is volume output in sector s. Total cost is the sum of the cost of the K different factor inputs

$$TC_s = \sum_{i}^{K} P_{is}.X_{is} \tag{5.2}$$

where X_{is} denotes the quantity of factor i in sector s.

The constant term α_{0s} and the α_{is} parameters are sector-specific, but all other parameters are assumed to be identical across all sectors, which implies that all of the sectors included in (5.1) have common underlying technological parameters. This is a strong assumption emphasising the need to group the sectors by type. The cost share (S_{is}) equations for sector s are:

$$S_{is} = \alpha_{is} + \sum_{j=1}^{K}\gamma_{ij}\ln P_{js} + \gamma_{iq}\ln Q_s \tag{5.3}$$

Adding-up gives the following restrictions:

$$\sum_{i}^{K}\alpha_{is} = 1,\ \sum_{i}^{K}\gamma_{ij} = 0,\ \sum_{i}^{K}\gamma_{iq} = 0 \tag{5.4}$$

Price homogeneity and symmetry imply the further set of restrictions:

$$\begin{aligned} \sum_{j=1}^{K}\gamma_{ij} &= 0 \ \text{(Price homogeneity)} \\ \gamma_{ij} &= \gamma_{ji},\ \forall i,j; i \neq j \ \text{(Symmetry)} \end{aligned} \tag{5.5}$$

The Allen-Uzawa partial elasticities of substitution σ_{ij} are given by

$$\sigma_{ij} = (\gamma_{ij} + S_i.S_j)/S_iS_j, i \neq j, \text{ otherwise } \sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i)/S_i^2 \tag{5.6}$$

Own- and cross-price elasticities of demand are given by

$$\varepsilon_{ij} = S_j\sigma_{ij}, \quad \varepsilon_{ii} = S_i\sigma_{ii} \tag{5.7}$$

Symmetry of the cost function ensures that the elasticity of substitution estimates are pair-wise equal. However this is not true of the cross elasticities of demand.

The Allen-Uzawa elasticities measure the percentage change in the ratio of two factors X_i/X_j given a one percentage change in the ratio of the two factor prices P_j/P_i holding output constant. Hamermesh (1993, p35) points out that this is useful mainly for classifying pairs of inputs according to the sign of σ_{ij}, since its *magnitude* depends on the particular values of input prices. Blackorby and Russell (1989) argue that the Morishima elasticity of substitution, μ_{ij},

$$\mu_{ij} = \varepsilon_{ij} - \varepsilon_{jj} \tag{5.8}$$

is a more economically relevant concept than the Allen partial elasticity of substitution. Under cost minimisation[1] this measures the percentage change in the ratio of two factors for a percentage change in one factor price. In contrast to the Allen elasticity measure, the Morishima elasticity is not symmetric (except where there are only two inputs). If two inputs are Allen substitutes ($\varepsilon_{ij} > 0$) then the Morishima measure will always classify them as substitutes ($\mu_{ij} > 0$). But if two inputs are Allen complements ($\varepsilon_{ij} < 0$) they will be classified as complements or substitutes according to the Morishima measure depending on the sign of $\varepsilon_{ij} - \varepsilon_{jj}$. If $\mid \varepsilon_{ij} \mid < \mid \varepsilon_{jj} \mid$ where $\varepsilon_{ij} < 0$ then $\mu_{ij} > 0$, i.e. the input *ratio* X_i/X_j will increase if the price of input j increases, even though the demand for both input i and j decreases.

The long-run set of factor demand equations for estimation is the same as in Chapter 2 but also includes an extra term to test for firm turnover effects:

$$S_{ist} = \alpha_{is} + \sum_{j=1}^{K} \gamma_{ij} \ln P_{jst} + \gamma_{it} + \gamma_{iq} \ln Q_{st} + \gamma_{in} \ln NO_{st} + \gamma_{it} t \tag{5.9}$$

The number of firms in a sector (NO_s) is included to control for the effects of firm entry to and exit from a sector on the demand for labour. In equation (5.3) we have assumed that all sectors in each group have a similar underlying production technology, but that the intercept term, the α_{is}, can vary across sectors. Analagously, we assume that changes in the number of firms within sectors will not affect the underlying technology but that they may alter the intercept term if the firm exiting or entering the sector has a labour share which is different from the average for the sector. In the absence of firm-level data, including NO_s as an additional variable means that the coefficients on relative factor prices are estimated conditional on the number of firms per sector.

[1]Davis and Shumway (1996) have shown that it is only under cost minimisation that the Morishima measure is *always* the correct measure of curvature and elasticity.

5.2.1 Assumptions Underlying Single Equation Estimation

With only two factors of production (5.9) can be estimated as a single equation given the adding-up condition. The underlying assumption is that the production function is of the form

$$Y = F(K, L), \quad L = G(L_s, L_u)$$

where the function $G(\cdot)$ aggregates skilled (L_s) and unskilled (L_u) labour and this aggregation is separable from capital (K). If this is true then we can estimate the demand for skilled labour and unskilled labour in two stages.

- In the first stage we estimate the demand for skilled labour relative to unskilled labour, assuming that this skilled-unskilled factor bundle is weakly separable from all other factors of production - function $G(\cdot)$. This is conditional on a constant level of aggregate labour L.

- The second stage aggregates labour to a single input (aggregating skilled and unskilled labour) and estimates the demand for this aggregate labour input relative to capital services - function $F(\cdot)$. This is specified conditional on a constant level of output.

These implies strong *a priori* assumptions. The first assumes that skilled labour and unskilled labour have an identical, unitary, elasticity of substitution with capital. The second assumes that skilled and unskilled labour are perfect substitutes. A third more general restriction is that the two factors cannot be complements within this framework.

The estimated results are used to get a first estimate of the constant-output own- and cross- elasticities of demand. Recall the relationship between *constant-output* and *variable-output* elasticities in Chapter 2. We use an analogous decomposition to compute the constant-output elasticity of demand for skilled and unskilled labour. Given a set of *constant-labour* demand elasticities (ε_{ss}, ε_{su}, ε_{us}, ε_{uu}) for skilled (s) and unskilled (u) labour, and the constant-output price elasticity of demand for aggregate labour (ε_{ll}), we can compute the *constant-output* demand elasticities as follows (Hamermesh, 1993, p.67):

$$\begin{aligned} \varepsilon^*_{su} &= \varepsilon_{su} + S_u \varepsilon_{ll}, \quad \varepsilon^*_{ss} = \varepsilon_{ss} + S_s \varepsilon_{ll} \\ \varepsilon^*_{us} &= \varepsilon_{us} + S_s \varepsilon_{ll}, \quad \varepsilon^*_{ss} = \varepsilon_{uu} + S_u \varepsilon_{ll} \end{aligned} \tag{5.10}$$

where S_s and S_u are the share of skilled and unskilled labour in the total wage bill.

5.2.2 Short-Run Dynamics

The dynamic specification of the factor demand equation for factor i in error correction form, where there are only two factors i and j, with price homogeneity imposed and including two lags is as follows :

$$\begin{aligned}\Delta S_{ist} &= \beta_i \Delta S_{ist-1} + \delta_{ij0}\Delta \ln \frac{P_{jst}}{P_{ist}} + \delta_{ij1}\Delta \ln \frac{P_{jst-1}}{P_{ist-1}} \\ &\quad + \delta_{iq0}\Delta \ln Q_{st} + \delta_{iq1}\Delta \ln Q_{st-1} + \delta_{in0}\Delta \ln NO_{st} + \delta_{in1}\Delta \ln NO_{st-1} \\ &\quad - \lambda_i \left[S_{ist-2} - \alpha_{is} - \gamma_{ij} \ln \frac{P_{jst-2}}{P_{ist-2}} - \gamma_{iq} \ln Q_{st-2} - \gamma_{in} \ln NO_{st-2} \right]\end{aligned} \quad (5.11)$$

For ease of presentation we assume two lags and omit time dummies. The final term in brackets is the long-run factor demand equation (5.9) for factor i. Theoretical restrictions on these long-run parameters imply the following simplifications:

$$\gamma_{ij}=\gamma_{ji},\ \gamma_{iq} = -\gamma_{jq},\ \gamma_{in} = -\gamma_{jn} \quad (5.12)$$

These can be used to recover the long-run parameters of the factor j equation. There are no theoretical restrictions on the short-run coefficients on the exogenous variables in this equation, however their interpretation can be of interest in determining the speed of adjustment for different factors. For instance Holly and Smith(1989) interpret the parameter $\delta_{iq0} \succ (\prec)0$ as evidence of short-run increasing (decreasing) returns to scale for factor i. Note that within this framework we do not estimate the short-run coefficients on the exogenous variables for the j equation, while the short-run adjustment coefficient on the lagged dependent variable for the second j equation is simply $-\beta_i$.

All parameters are identical across sectors except the long-run intercept term α_{is} which is sector-specific. This parameter captures unidentified or idiosyncratic effects in different sectors. It permits that, in the absence of any relative price or other effects, equilibrium factor shares in different sectors may be permanently different. Such differences can be due to idiosyncratic differences which lie outside the scope of a simple stylised factor demand model to explain. For example they may reflect differences in the historical accumulation of technologies in different sectors, assuming any such differences in the rate of accumulation of technology between sectors have asymptoted out before the beginning of the sample. The presence of this sector-specific term has important implications for econometric estimation of equation (5.11) which are discussed in the next section.

Because the sector-specific effect is unobservable it is typically eliminated from the estimating equation by a suitable transformation. Here we use first differences to eliminate this sector-specific effect. The consequences of such a transformation for estimation are discussed in the next section. In first differences equation (5.11) can be written as:

$$\begin{aligned}\Delta S_{ist} &= \pi_1 \Delta S_{ist-1} + \pi_2 \Delta S_{ist-2} \\ &+\pi_{ij0}\Delta \ln \frac{P_{jst}}{P_{ist}} + \pi_{ij1}\Delta \ln \frac{P_{jst-1}}{P_{ist-1}} + \pi_{ij2}\Delta \ln \frac{P_{jst-2}}{P_{ist-2}} \\ &+\pi_{iq0}\Delta \ln Q_{st} + \pi_{iq1}\Delta \ln Q_{st-1} + \pi_{iq2}\Delta \ln Q_{st-2} \\ &+\pi_{in0}\Delta \ln NO_{st} + \pi_{in1}\Delta \ln NO_{st-1} + \pi_{in2}\Delta \ln NO_{st-2}\end{aligned} \tag{5.13}$$

This is the form we use for estimation. The two formulations are observationally equivalent (see for example Greenhalgh, et al. (1990)) so that the parameters of interest in equation (5.11) can be recovered from the estimating equation (5.13) as follows:

Short-Run Adjustment:		Long-Run Parameters:
$\beta_i = \pi_1 - 1$	$\lambda_i = (1 - \pi_1 - \pi_2)$	
$\delta_{ij0} = \pi_{ij0}$	$\delta_{ij1} = \pi_{ij0} + \pi_{ij1}$	$\gamma_{ij} = (\pi_{ij0} + \pi_{ij1} + \pi_{ij2})/(1 - \pi_1 - \pi_2)$
$\delta_{iq0} = \pi_{iq0}$	$\delta_{iq1} = \pi_{iq0} + \pi_{iq1}$	$\gamma_{iq} = (\pi_{iq0} + \pi_{iq1} + \pi_{iq2})/(1 - \pi_1 - \pi_2)$
$\delta_{in0} = \pi_{in0}$	$\delta_{in1} = \pi_{in0} + \pi_{in1}$	$\gamma_{in} = (\pi_{in0} + \pi_{in1} + \pi_{in2})/(1 - \pi_1 - \pi_2)$

Note that the intercept term α_{is} has disappeared in the first-differenced estimating equation (5.13). Period-specific time dummies are included in all the estimating equations.

5.3 Dynamic Modelling With Panel Data

A general specification of a linear dynamic equation for a panel of industrial sectors, where $i = 1, ..., N$ is an index of sectors, can be written as

$$y_{it} = \sum_{j=1}^{p} \alpha_j y_{i(t-j)} + \underline{\beta}'(L)\underline{x}_{it} + \lambda_t + u_{it} \tag{5.14}$$

where $t = q + 1, ..., T$ is an index of time, $\underline{x}_{it}$ is a $k \times 1$ vector of the k explanatory variables and $\underline{\beta}(L)$ is an $k \times 1$ vector of lag polynomials of order m in the lag operator. The maximum lag in the model is q where $m \leq kq$ and $p \leq q$. The λ_t is a period-specific time effect. Since this effect is common across all sectors it is often referred to as an 'aggregate' or 'macro' effect. The residual term u_{it} is the sum of a sector-specific effect η_i and an idiosyncratic error term v_{it}. $u_{it} = \eta_i + v_{it}$.

Given the structure of our data panel we proceed on the assumption that N is large relative to T. In this situation panel data estimators are evaluated using their so-called "semi-asymptotic behaviour" (Sevestre and Trognon[2], p95) where $N \to \infty$ while T is kept finite. This has some crucial implications for the properties of these estimators. Firstly, in contrast to time-series estimators, with T finite the assumption of stationarity is not necessary. Secondly, and again in direct contrast to time-series estimators, the generation process of the initial observations y_{i1} is important.

Much of the research on dynamic panel data estimators centres on the assumptions surrounding these initial observations. In equation (5.14) these initial observations will depend on the sector-specific effects η_i, the past of the exogenous variables $\underline{x}_{i,t-j}$, an aggregate effect λ_1 and on a serially uncorrelated disturbance ν_{i1}

$$y_{i1} = f(\underline{x}_{i,t-j}, \eta_i, \lambda_1, \nu_{i1})$$

and the properties of these initial observations will influence the semi-asymptotic property of the estimators. The appropriate modelling approach now depends on whether the η_i's are treated as fixed effects or random effects.

The treatment of unobservable effects as fixed or random in a dynamic panel data context is widely discussed in the literature. Ultimately the choice relates to the type of inference required. A common quotation on this issue from Hsaio (1985, p131) points out: "It is up to the investigator to decide whether he wants to make inference with respect to the population characteristics [random effects] or only with respect to the effects that are in the sample [fixed effects]." Since our sample data are more or less exhaustive, i.e. they cover all industrial sectors, we can treat the sample as the population for inference purposes and therefore we treat the η_i's as fixed effects (see Balestra (1992) p.27).

This fixed effects specification faces problems for least squares estimation. These relate to the semi-inconsistency of least squares estimators. Specifically there is an asymptotic correlation between the lagged endogenous variable and the error term due to the influence of the initial observations on the semi-asymptotics with T finite.

Because of these difficulties with least squares estimators, research has centred on developing instrumental variables estimators. Within this class of estimators Arrellano and Bond (1991) (AB) have developed a generalised methods of moments (GMM) estimator for such dynamic fixed effects models which can tackle these bias and inconsistency problems. This estimator requires minimal assumptions on the properties of the explanatory variables. The x_{it}'s may or may not be correlated with the fixed effects η_i's and in either case the x_{it}'s may be strictly exogenous, predetermined or endogenous variables with respect to the error term v_{it} (see Arellano and Bond, 1988). The error terms are assumed to have zero mean, finite

[2]Much of this section follows the review of linear dynamic panel data models in Sevestre and Trognon (1992).

moments and to exhibit no serial correlation:

$$E(v_{it}) = E(v_{it}v_{is}) = 0 \text{ for } t \neq s$$

However arbitrary forms of heteroscedasticity across sectors and time are possible:

$$E(v_{it}v_{it}) = \sigma_{it}^2$$

This is important since panel data are typically characterised by heteroscedastic error terms.

Taking first differences of equation (5.14), which eliminates the fixed effects terms, AB exploit all the linear moment restrictions which are implied by the assumed absence of serial correlation in the error term to construct a set of valid instruments for the lagged endogenous variable. In first differences the second lag of the dependent variable is uncorrelated with the error term: $E(\Delta v_{it}, y_{it-2}) = 0$, and so can be used as an instrumental variable if the order of serial correlation for Δv_{it} is not higher than one, see below. Similarly all further lags of the dependent variable are valid instruments based on the linear moment restrictions:

$$E(\Delta v_{it}, y_{it-j}) = 0 \; j = 2, ..., t-(q+1); t = (q+1), ..., T \tag{5.15}$$

The AB GMM estimator is derived using these conditions without necessitating further assumptions on the initial conditions y_{i1}, the fixed effects η_i or on the distributions of the error terms v_{it}. If an x_{it} variable is not strictly exogenous[3], analogous instruments using lags greater than one can be used for this explanatory variable. For this reason Sevestre and Trognon (1992) recommend the use of this AB GMM estimator in models where the explanatory variables are not (or are suspected not to be) strictly exogenous. In our estimating equation (5.13) of the previous section the relative price term is not strictly exogenous given its definitional relationship with the dependent variable[4], so we consider this AB GMM panel data estimator to be particularly suited for estimation of dynamic equations such as equation (5.13).

If we stack all the observations in equation (5.14) over time we can rewrite the equation as

$$y_i = W_i\underline{\delta} + i_i\eta_i + v_i \tag{5.16}$$

where $\underline{\delta}$ is a parameter vector including the α_k's, β's and the λ's, W_i contains the time series of the lagged endogenous variables, the x's and the time dummies, and i_i is a $T \times 1$ vector of ones. Then the GMM first difference estimator is given by

$$\delta = [(\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' W_i^*)]^{-1} [(\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' y_i^*)] \tag{5.17}$$

[3]Strict exogeneity between x_{it} and v_{it} requires $E(x_{it}, v_{it}) = 0$.

[4]The definitional relationship between S_l and $\frac{P_k}{P_l}$ is $S_l = \frac{P_l X_l}{P_l X_l + P_k X_k} = (1 + \frac{P_k}{P_l}\frac{X_k}{X_l})^{-1}$.

where

$$A_N = \frac{1}{N}\sum_i (Z_i' H_i Z_i)^{-1}$$

Z_i is the matrix of instrumental variables, H_i is a weighting matrix and * denotes transformation to first differences. For the AB GMM one-step first difference estimator H_i is given by

$$\begin{pmatrix} 2 & -1 & \dots & & 0 \\ -1 & 2 & \dots & & 0 \\ . & . & & & . \\ . & . & & & -1 \\ 0 & 0 & \dots & -1 & 2 \end{pmatrix}$$

In our empirical analysis we use this one-step estimator where the reported standard errors are corrected for heteroscedasticity[5].

The instrument matrix Z_i is based on the orthogonality conditions. For example assume a fixed effects model given by $y_{it} = \alpha y_{it-1} + \underline{x}_{it}'\underline{\beta} + \eta_i + v_{it}$ where the panel data set covers 5 time periods. With lags and first differences this leaves 3 time series observations for estimation. In the first cross section, with $t = 3$, the only valid instrument for the endogenous variable is y_{i1}. In the second cross-section, $t = 4$, y_{i2} is now also orthogonal to the error term and therefore an additional valid instrument. The complete set of instrumental variables for this model is given by

$$Z_i = \begin{pmatrix} y_{i1} & 0 & 0 & 0 & 0 & 0 & \Delta\underline{x}_{i2}' & 0 & 0 \\ 0 & y_{i1} & y_{i2} & 0 & 0 & 0 & 0 & \Delta\underline{x}_{i3}' & 0 \\ 0 & 0 & 0 & y_{i1} & y_{i2} & y_{i3} & 0 & 0 & \Delta\underline{x}_{i4}' \end{pmatrix} \qquad (5.18)$$

Further columns can be added to Z_i, either lags of the x instruments or other external variables. Restricting the number of moment restrictions relating to the endogenous variables will cause a loss of efficiency. However computational considerations typically mean that the full instrument set is not used in estimation: "[a] judicious choice of the Z_i matrix should strike a compromise between prior knowledge ... the characteristics of the sample and computer limitations." (Arellano and Bond, 1988, p. 6).

In first differences the Δv_{it} error term is $MA(1)$, however further serial correlation would invalidate the orthogonality conditions. So the validity of the use of the set of instruments

[5] While the two-step estimator, which uses the estimated errors from the first round of estimation to construct H_i, is more efficient if the v_{it} are heteroscedastic (Urga, p388), the estimated standard errors for the two-step estimator can be somewhat unstable in relatively small samples. Because of this we chose to use the one-step estimates.

depends crucially on the absence of serial correlation of an order higher than one. Therefore we report tests for first-order and second-order serial correlation. In addition we use a Sargan test of the validity of the instrument set for the equation diagnostics.

5.4 Empirical Issues in Estimation

We begin with the most general specification possible given data restrictions and then test the validity of alternative reductions of this "general specification". Because we are dealing with a panel of data it is not possible to adopt the general-to-specific approach used in Part I. Instead our data generation process is based on the conditional distribution of the factor shares, conditional on a set of variables suggested by economic theory and our preliminary analysis of the data in Chapter 4.

The data cover 69 manufacturing sectors over the period 1979-1990[6]. The variables include data on employment and wages for skilled labour, unskilled labour and clerical labour. Chapter 4 contains a full discussion of the definition of, and a preliminary analysis of, these variables. In addition we have data on the cost of capital for each sector, the value of capital services in each sector, gross output at constant prices in each sector and the number of firms per sector. Section 4.11 in Chpater 4 contains a full description of the panel data set.

The data are divided into three stylised groups of sectors based on their output growth performance over the period. The high-growth group includes 11 sectors which recorded average annual growth above 7%. The second group, labelled M (medium-growth), covers 29 medium-growth sectors where average annual growth was between 0% and 7% per annum. The third group, labelled D (declining), includes 29 sectors in which average annual growth was negative.

Data contraints mean that we are restricted in the number of lags we include in estimation. We include a maximum of two lags based on Nickell (1986). In an analysis of the impact of aggregation on the estimation of dynamic models of labour demand, he shows that aggregation across firms or across different types of labour induces a second-order lag of the dependent variable.

The data panel covers 12 years. First differencing and including two lags leaves $T = 9$ for each group. In the M and D groups there are 29 sectors so that N is much larger than T, this is why we adopt the econometric methodology outlined in the previous section which is based on the assumption that N is large relative to T. However in our panel N is not

[6]We exclude three of the 72 sectors analysed in Chapter 4. These are potential outliers in the overall cost minimisation framework, these are the utilities industries (Electricity, Gas and Water: NACE: 161, 132162, 170) which are dominated by state-owned monopolies.

as large as in typical panel data sets which are based on a large sample of individuals, and this must qualify interpretation of the results. Furthermore in the H group there are only 11 sectors so that while $N > T$ the sample size is very small. This severely reduced the degrees of freedom available in estimation for the H sector and poses problems in estimation, as we shall see below.

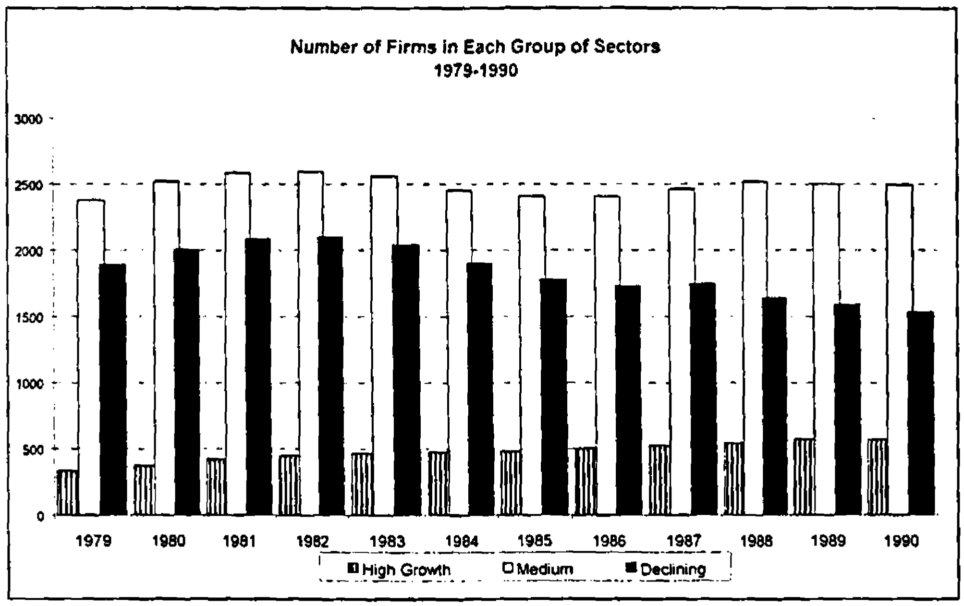

Figure 5.1: Number of Firms in High Growth, Medium Growth and Declining Groups of Sectors, 1979-1990

While the total number of firms in the overall manufacturing sector fell by a trivial 3 firms between 1979 and 1990, at a grouped-sector level the net changes in the number for firms have been significant. In the high-growth group the net entry of firms totalled 240 between 1979 and 1990, an increase of over 70%, while in the declining group there was a net exit of 359 firms over the same period. In the medium-growth group the change was a more modest net increase of 116 firms. Figure 5.1 shows the time path of the number of firms in each group.

We estimate equation (5.13) using the DPD package developed by Arellano and Bond (1988).The most complicated empirical feature of this estimation was the choice of instrument set for the Z matrix in (5.18). The final choice of instrument set was based on preliminary testing of a wide range of instruments. There were two central issues:

1. The endogeneity of the lagged dependent variable S_{it} means that lags of two or higher are uncorrelated with the differenced error term as shown in (5.15). However in practice we found it was better to start with the third lag (based on the Sargan test)[7].

2. The definitional relationship between the endogenous variable and the factor price terms means that the factor price terms are also endogenous[8]. Some studies omit relative price terms altogether because of this definitional problem (e.g. Berman, Bound and Griliches (1994)) however we need them to estimate parameters of interest in the elasticity calculations. At the same time we do not want the instrument set to include variables which are highly correlated with each other. Therefore we used the lags of the endogenous variable to also serve as instruments for relative prices. Two further potential instruments were ΔQ and ΔNO (see (5.18)). Estimation both with and without these variables did not significantly alter the results.

In all cases where the equation included period-specific dummies these were also included in the instrument set.

The regressions are weighted by each sector's average share in total factor cost (as defined in (5.2)) for all sectors, following Bound et al. (1994). This means that the dependent variable, when aggregated across sectors, is the weighted share in total cost. In first differences this sums to the 'within' variation of the previous chapter which was identified as the principal reason for the overall shift towards skilled labour.

Weighting the regressions also serves to reduce noise in the data, particularly in small sectors, and to reduce noise due to firm migration between sectors (Berman et al. (1994) p.384). This is illustrated in Figures 5.2 and 5.3. These graphs show data on the skilled labour share of the total (skilled plus unskilled) wage bill for the medium-growth group of sectors plotted against log gross output. Figure 5.2 plots the actual (unweighted) data while Figure 5.3 plots the data weighted by each sector's average share in the total wage bill for all 29 sectors. The weighted data highlight much more clearly a discernable positive relationship between the skilled wage bill share and gross output. In the sections which follow all descriptive statistics refer to weighted data.

[7]Denny and Van Reenen (1993) adopted a similar formulation of their instrument set.

[8]Underlying the cost minimisation framework is the assumption that factor prices are exogenously determined, i.e. firms are price-takers on factor markets. Clearly this assumption will be violated in macroeconomic studies of the demand for labour and these often focus on suitable instruments for factor prices. However with highly disaggregated sectoral data this assumption is reasonable. Our concern is therefore purely related to definitional rather than behavioural endogeneity.

5.5 Empirical Results

In this section we present the results of estimating the single equation dynamic labour demand function defined by (5.11) for our three groups of sectors. Section 5.5.1 gives the results of estimating the demand for skilled labour relative to unskilled labour. Section 5.5.2 gives the results of estimating the demand for aggregate labour relative to capital. The two-factor cost minimisation framework in the first case is specified conditional on a constant level of aggregate labour (skilled plus unskilled) - *constant labour* - while the second is specified conditional on a constant level of output - *constant-output.*

5.5.1 The Demand for Skilled Labour

The general specification of the equation for modelling the demand for skilled labour (AT) relative to unskilled (IW) is given by[9]:

$$
\begin{aligned}
\Delta SLAT_t \;=\; & \pi_1 \Delta SLAT_{t-1} + \pi_2 \Delta SLAT_{t-2} + \pi_{su0} \Delta \ln(\frac{CLIW}{CLAT})_t \\
& + \pi_{su1} \Delta \ln(\frac{CLIW}{CLAT})_{t-1} + \pi_{su2} \Delta \ln(\frac{CLIW}{CLAT})_{t-2} \\
& + \pi_{su0d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t} + \pi_{su1d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t-1} \\
& + \pi_{su2d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t-2} + \pi_{sn0} \Delta \ln(NO)_t \\
& + \pi_{sn1} \Delta \ln(NO)_{t-1} + \pi_{sn2} \Delta \ln(NO)_{t-2} + \pi_{sq0} \Delta \ln(Q)_t \\
& + \pi_{sq1} \Delta \ln(Q)_{t-1} + \pi_{sq2} \Delta \ln(Q)_{t-2} + \pi_{82} D_{82} + \pi_t D_t
\end{aligned}
\tag{5.19}
$$

This specification is estimated over the period 1982-1990 (allowing for the loss of three years due to lags and first differencing) and includes an interactive dummy on the relative factor price term for the years 1987-1990. This dummy is included to test for any structural break in the estimated elasticities of substitution and demand in this later period. The analysis of Chapter 4 suggested that most of the restructuring from unskilled to skilled labour occurred in the earlier period 1979-1987 with little further change in relative factor shares in the later period 1987-1990.

Estimation is done using the AB GMM estimator. Time dummies D_t are included in each of the general specifications. In estimation the coefficients on these are measured as

[9] SLAT is skilled workers' wage bill share; CLAT is the cost of a skilled worker; CLIW is cost of an unskilled worker; NO is the number of firms in a sector; Q is gross output measured at 1985 prices; s is an index across sectors, t over time.

deviations from the constant term π_{82} where the coefficient on the constant term is an estimate of the intercept in the first cross-section used in estimation, here 1982. These time dummies allow for different intercept terms in each year, common across all sectors, which cause upward or downward shifts in the factor share.

The Demand for Skilled Labour : Medium Growth Sectors

This section reports the results of estimating equation (5.19) for the medium-growth group of sectors over the period 1979-1990 using the share of skilled labour in the total wage bill[10] as the dependent variable. The variables used are the share of skilled labour in the total wage bill ($SLAT_{st}$), the ratio of skilled to unskilled wages ($\frac{CLAT}{CLIW}_{st}$), the number of firms in each sector (NO_{st}) and gross output in each sector (Q_{st}, in £000s). Table 5.1 gives some summary statistics on these data.

Skilled Labour, 29 Medium-Growth Sectors						
	$SLAT_{st}$	$CLAT_{st}$	$CLIW_{st}$	$\frac{CLAT}{CLIW}_{st}$	NO_{st}	Q
Mean	0.20	£17,670	£10,586	1.74	86	£259,020
Standard Deviation	0.06	£7,127	£5,051	0.32	90	£359,870

Table 5.1: Descriptive Statistics on Panel Data for Medium Growth Sectors

Table 5.2 reports diagnostic tests of equation (5.19) for medium growth sectors[11]. In this and subsequent summary diagnostics tables the test statistics are as follows:

- Joint tests of significance are Wald tests asymptotically distributed as $\chi_2(k)$ under the null of no relationship.
- The Sargan statistic is a test of the overidentifying restrictions, asymptotically distributed as $\chi_2(k)$ under the null.
- m_1 is a test for first-order serial correlation in the residuals, asymptotically distributed as $N(0,1)$ under the null of no serial correlation.
- m_2 is a test for second-order serial correlation in the residuals, asymptotically distributed as $N(0,1)$ under the null of no serial correlation.

[10] The total wage bill here excludes the wage bill of clerical workers.

[11] The table reports computed statistics followed by the p-value in brackets. Estimation is done using the DPD program supplied by Steve Bond. All reported results are GMM one step estimates with test statistics robust to heteroscedasticity.

- (a) lag=2 tests the joint significance of all second-order lags.
- (b) lag=2 tests the joint significance of all second-order lags excluding the second-order lag of the dependent variable.

Estimation Diagnostics for Equation (5.19)						
Joint Significance of:	(1)		(2)		(3)	
$\Delta \ln(\frac{CLIW}{CLAT})$	30.83 (.00)	$\chi_2(3)$	20.23 (.00)	$\chi_2(3)$	24.28(.00)	$\chi_2(3)$
$\Delta \ln(\frac{CLIW}{CLAT}) \cdot D_{8790}$	7.24 (.07)	$\chi_2(3)$	2.79 (.43)	$\chi_2(3)$		
$\Delta \ln(NO)$	17.24 (.00)	$\chi_2(3)$	8.60 (.04)	$\chi_2(3)$	6.03(.11)	$\chi_2(3)$
$\Delta \ln(Q)$	15.68 (.00)	$\chi_2(3)$	8.83 (.03)	$\chi_2(3)$	6.08(.11)	$\chi_2(3)$
(a) lag=2	11.65 (.04)	$\chi_2(5)$	42.25 (.00)	$\chi_2(5)$	17.71(.00)	$\chi_2(4)$
(b) lag=2	10.79 (.03)	$\chi_2(4)$	6.56 (.16)	$\chi_2(4)$	6.15(.10)	$\chi_2(3)$
Time Dummies	12.47 (.19)	$\chi_2(9)$				
Other Diagnostics:						
Sargan Test	22.53 (.76)	$\chi_2(28)$	25.75 (.59)	$\chi_2(28)$	33.41(.35)	$\chi_2(31)$
m_1	-3.07 (.00)	$N(0,1)$	-2.65 (.01)	$N(0,1)$	-2.40(.02)	$N(0,1)$
m_2	1.50 (.14)	$N(0,1)$	1.47 (.14)	$N(0,1)$	1.06(.29)	$N(0,1)$
Instruments Used:	$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-3}...SLAT_{t-9}$	
Observations:	261=29x9 (82-90)		261=29x9 (82-90)		261=29x9 (82-90)	

Table 5.2: Demand for Skilled Labour in Medium Growth Sectors: Testing General Specification

The diagnostic tests for the general specification (1) indicate that the time dummies are jointly insignificant. All other variables are jointly significant, although the significance of the structural dummy is only marginal at the 7% level. Diagnostic tests indicate that there is no second order serial correlation while the Sargan test accepts the validity of the instruments used.

The second specification (2) re-estimates the equations omitting the time dummies. This reduction does not introduce any misspecification (as measured by the diagnostic tests), however the interactive 1987-90 structural break variables are now jointly insignificant. The second lag of the independent variables is also now insignificant however the joint significance of all second order lags (including the dependent variable) is increased.

The third specification (3) omits the structural break variables. This reduction is accepted by the diagnostic tests. The gross output, firm entry/exit variables and second lag of the independent variables are now only significant at the 10% level, however excluding these regressors introduces statistical misspecification into the model as signalled by the Sargan statistic[12]. Therefore our final preferred specification (3) includes all second lags of the three variables, relative factor prices, the number of firms per sector and gross output per sector. This model is statistically well-specified based on the diagnostics and the implied behavioural parameters do not violate any economic theory restrictions. Table 5.25 gives the detailed coefficient estimates for the general specification (1) and the preferred specification (3).

We look first at the implied behavioural parameters of equation (5.11) which is the general specification (1) with no restrictions. Tables 5.3 and 5.4 show these coefficient estimates and implied elasticities respectively.

Estimated Coefficients: Specification (1)								
	Adjustment Coefficients				Long_Run Parameters			
SLAT	λ_s	0.780	β_s	-0.340	*Skilled*		*Unskilled*	
$\ln(\frac{CLIW}{CLAT})$	δ_{su0}	-0.171	δ_{su1}	-0.079	γ_{su}	-0.087	γ_{us}	-0.087
$\ln(\frac{CLIW}{CLAT}) \cdot D_{8790}$	δ_{su0d}	-0.021	δ_{su1d}	-0.009	γ_{sud}	-0.081	γ_{usd}	-0.081
$\ln(NO)$	δ_{sn0}	0.192	δ_{sn1}	0.085	γ_{sn}	0.265	γ_{un}	-0.265
$\ln(Q)$	δ_{sq0}	0.046	δ_{sq1}	-0.120	γ_{sq}	-0.153	γ_{uq}	0.153

Table 5.3: Estimated Coefficients of Equation (5.11): Demand for Skilled Labour in Medium Growth Sectors

The coefficient on firm entry/exit (γ_{sn}) indicates that the higher the number of firms in a sector the higher is the skilled wage bill share - evidence of increased skill-intensity in expanding sectors. On average a 1% increase in the number of firms in a sector will cause a 1.3% growth[13] in that sector's skilled wage share.

The results indicate modest short-run increasing returns to scale for skilled labour, while in the long run there is a negative, albeit weak, relationship with gross output.

The constant-labour elasticity estimates[14] indicate low substitutability between skilled and unskilled labour in production and inelastic own and cross price elasticities of demand, particularly for unskilled labour. The structural break coefficients suggest that in the later period substitution possibilities were zero and that production moved more towards a Leontief-type technology with fixed input ratios.

[12]The Sargan test statistics for dropping these sets of variables were[$\ln(NO)$ 58.39 (.01)], [$\ln(Q)$ 55.57 (.01)], [(b) lag = 258.65 (.01)].

[13]Calculated using the average skilled workers' share of 0.20 from Table 5.1.

[14]The elasticity estimates in the table are read as follows: s=skilled; u=unskilled; σ_{su} is the elasticity of substitution between s and u; ε_{su} is the cross-elasticity of demand between s and u ; $*$ indicates that the elasticity has been evaluated using structural break coefficients 1987-1990.

Elasticity Estimates: Specification (1)			
	Substitution	Own and Cross Demand	
	σ_{su}	$\varepsilon_{su} = -\varepsilon_{ss}$	$\varepsilon_{us} = -\varepsilon_{uu}$
Period average	0.462	0.369	0.093
1979	0.446	0.360	0.087
1990	0.481	0.379	0.102
1990*	-0.007	-0.005	-0.001

Table 5.4: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in Medium Growth Sectors

These results suggest an interesting pattern. In the pre-1987 period there were limited substitution possibilities between skilled and unskilled labour, in the post-1987 period any change in the skilled-unskilled mix reflects sectoral firm entry and exit effects rather than substitution possibilities within individual firms.

Estimated Coefficients: Specification (3)								
	Adjustment Coefficients				Long_Run Parameters			
SLAT	λ_s	0.507	β_s	-0.211	*Skilled*		*Unskilled*	
$\ln(\frac{CLIW}{CLAT})$	δ_{su0}	-0.181	δ_{su1}	-0.083	γ_{su}	-0.123	γ_{us}	-0.123
$\ln(NO)$	δ_{sn0}	0.127	δ_{sn1}	-0.011	γ_{sn}	0.187	γ_{un}	-0.187
$\ln(Q)$	δ_{sq0}	0.086	δ_{sq1}	-0.039	γ_{sq}	-0.012	γ_{uq}	0.012

Table 5.5: Estimated Coefficients of Equation (5.11): Demand for Skilled Labour in Medium Growth Sectors

Tables 5.5 and 5.6 show the behavioural parameters and estimated elasticities from our preferred specification (3). The estimated elasticities of substitution and demand are again very low, especially for unskilled labour. The long-run scale effect, while negative, is close to zero. The long-run firm entry/exit effect is positive and indicates that the overall net increase of 116 firms added one percentage point to the skilled labour share in this group of sectors.

The absence of time effects confirms the profile of this group of sectors,described in the previous chapter, as representing the median sector in Irish manufacturing during the 1980s. While there was a massive restructuring in overall manufacturing, this group of industries experienced little change in the underlying production process.

Overall these results suggest that changes in the share of skilled labour in the medium-growth group of sectors are most strongly related to firm turnover effects. On average a

Elasticity Estimates: Specification (3)			
	Substitution	Own and Cross Demand	
	σ_{su}	$\varepsilon_{su} = -\varepsilon_{ss}$	$\varepsilon_{us} = -\varepsilon_{uu}$
Period average	0.236	0.188	0.048
1979	0.213	0.172	0.041
1990	0.262	0.207	0.055

Table 5.6: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in Medium Growth Sectors

net additional firm will increase the skill intensity of this group. Substitution possibilities between skilled and unskilled labour are very low. Long-run scale effects are negligible and there is no evidence of significant technological shocks.

The Demand for Skilled Labour : High Growth Sectors

Table 5.7 gives some descriptive statistics on the data for the high growth group of sectors.

Skilled Labour, 11 High Growth Sectors						
	$SLAT_{st}$	$CLAT_{st}$	$CLIW_{st}$	$\frac{CLAT}{CLIW}_{st}$	NO_{st}	Q_{st}
Mean	0.27	£18,320	£9,925	1.89	43	£429,340
Standard Deviation	0.11	£6,633	£4,004	0.26	27	£585,863

Table 5.7: Descriptive Statistics on Panel Data for High Growth Sectors

Table 5.8 gives the diagnostic results of estimating equation (5.19) for the high-growth group of sectors. Degrees of freedom limitations meant that not all variables could be included in estimation. Therefore the table reports four alternative variants on a simple labour demand function with time dummies: specification (1) estimates scale effects, specification (2) estimates firm entry/exit effects, specification (3) estimates a 1987-1990 structural break effect and specification (4) estimates a simple labour demand function with time dummies. In all four specifications the Sargan statistic suggests evidence of misspecification.

The table also includes the implied average elasticity of substitution between skilled and unskilled labour for each of these variants. These estimates indicate that by controlling for scale effects or firm entry/exit effects, the elasticity falls by more than half in magnitude. This is unsurprising since both scale effects and firm entry/exit effects will be very important in a high-technology group of sectors which is growing rapidly and which is the main location for technological progress and innovation, imported or otherwise.

Estimation Diagnostics for Equation (5.19): General Specification								
Joint Significance of:	(1)		(2)		(3)		(4)	
$\Delta\ln(\frac{CLTW}{CLAT})$	395.9(.00)	$\chi_2(3)$	175.5(.00)	$\chi_2(3)$	535.2(.00)	$\chi_2(3)$	284.9(.00)	$\chi_2(3)$
$\Delta\ln(\frac{CLTW}{CLAT})\cdot D_{8790}$					4.5(.22)	$\chi_2(3)$		
$\Delta\ln(NO)$			12.2(.01)	$\chi_2(3)$				
$\Delta\ln(Q)$	31.8(.00)	$\chi_2(3)$						
(a) lag=2	113.4(.00)	$\chi_2(3)$	148.9(.00)	$\chi_2(3)$	19.4(.00)	$\chi_2(3)$	28.5(.00)	$\chi_2(3)$
Time Dummies	218.7(.00)	$\chi_2(9)$	58.7(.00)	$\chi_2(9)$	47.3(.00)	$\chi_2(9)$	322.9(.00)	$\chi_2(9)$
Other Diagnostics:								
Sargan Test	53.0(.02)	$\chi_2(34)$	48.7(.05)	$\chi_2(34)$	55.8(.01)	$\chi_2(34)$	57.4(.02)	$\chi_2(37)$
m_1	−2.8(.00)	$N(0,1)$	−2.6(.01)	$N(0,1)$	−2.7(.01)	$N(0,1)$	−2.7(.01)	$N(0,1)$
m_2	−0.7(.47)	$N(0,1)$	−0.1(.93)	$N(0,1)$	−1.0(.33)	$N(0,1)$	−0.6(.52)	$N(0,1)$
Instruments Used:	$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-3}...SLAT_{t-9}$	
Observations:	99=11x9(82−90)		99=11x9(82−90)		99=11x9(82−90)		99=11x9(82−90)	
Average σ_{su}		1.49		1.46		3.37		3.37

Table 5.8: Demand for Skilled Labour in High Growth Sectors: Testing General Specification

The estimated behavioural parameters from specification (2) are shown in Table 5.9. (Table 5.26 lists the full set of estimated coefficients for specifications (1) and (2).) The coefficients on the time dummies[15] suggest that technological shocks have had both positive and negative impacts on the skilled labour share (a strong positive effect in 1984 and a strong negative effect in 1990). β_s is positive suggesting overadjustment in the short-run. Both short-run and long-run firm entry/exit and scale effects are positive.

The estimated elasticities for specification (2) are shown in Table 5.10. The constant-labour own elasticities of demand are implausibly high. The evidence on misspecification means that little reliance can be placed on these results. As mentioned earlier, the small number of cross-section observations ($N = 11$) in the H group cast doubt on the appropriateness of the estimator used.

The Demand for Skilled Labour: Declining Sectors

Table 5.1 gives some descriptive statistics on the data for the declining group of sectors.

The diagnostic results of estimating equation (5.19) for this group of sectors reported

[15]These should be multiplied by 11, the number of sectors, to arrive at meaningful magnitudes since we are using weighted data.

Estimated Coefficients: Specification (2)								
	Adjustment Coefficients				Long_Run Parameters			
SLAT	λ_s	0.193	β_s	0.099	*Skilled*		*Unskilled*	
$\ln(\frac{CLIW}{CLAT})$	δ_{su0}	-0.131	δ_{su1}	0.018	γ_{su}	0.096	γ_{us}	0.096
$\ln(NO)$	δ_{sn0}	0.009	δ_{sn1}	-.0556	γ_{sn}	0.127	γ_{un}	-0.127
Constant	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}	D_{88}	D_{89}	D_{90}
-.0013	.0007	.0028	.0010	.0018	.0012	.0004	.0023	-.0002

Table 5.9: Estimated Coefficients of Equation (5.11): Demand for Skilled Labour in High Growth Sectors

Elasticity Estimates: Specification (2)			
	Substitution	Own and Cross Demand	
	σ_{su}	$\varepsilon_{su} = -\varepsilon_{ss}$	$\varepsilon_{us} = -\varepsilon_{uu}$
Period average	1.46	1.03	0.43
1979	1.52	1.15	0.37
1990	1.43	0.95	0.48

Table 5.10: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in High Growth Sectors

in Table 5.12 indicate some of the misspecification problems encountered in attempting to model a long-run demand for labour function for this sector. The most general specification (1) was rejected by the m_1 first-order serial correlation test. This invalidates the AB GMM estimator.

Dropping the time dummies did not improve the diagnostics despite their joint insignificance in specification (1), in particular there was still no evidence of first order autocorrelation. So we decided to proceed via an alternative route, omitting the second lag, extending the instrument set and omitting the 1987-1990 structural break variable. The diagnostics for this specification (2) are given in Table 5.12. The diagnostics for this specification are marginally better, however the hypothesis of no second-order serial correlation is only marginally accepted at the 6% level while the Sargan test decisively rejects the overidentifying restrictions. Indeed the Sargan test rejects every reduction of specification (1) for the declining sectors.

The implied coefficients of specification (2) violate standard economic theory (negative elasticity of substitution and positive own elasticity of demand). A further reduction of specification (1) omitting both the firm entry/exit and scale effects is not rejected by the m_1 and m_2 diagnostic tests. These tests are shown as specification (3) in Table (5.12). (The

Skilled Labour, 29 Declining Sectors						
	$SLAT_{st}$	$CLAT_{st}$	$CLIW_{st}$	$\frac{CLAT}{CLIW}_{st}$	NO_{st}	Q_{st}
Mean	0.19	£15,971	£9,566	1.67	63	£85,315
Standard Deviation	0.09	£6,384	£3,770	0.33	90	£74,729

Table 5.11: Descriptive Statistics on Panel Data for Declining Sectors

Estimation Diagnostics for Equation (5.19)						
Joint Significance of:	(1)		(2)		(3)	
$\Delta\ln(\frac{CLIW}{CLAT})$	15.39 (.00)	$\chi_2(3)$	31.05 (.00)	$\chi_2(3)$	61.98(.00)	$\chi_2(3)$
$\Delta\ln(\frac{CLIW}{CLAT})\cdot D_{8790}$	0.99 (.80)	$\chi_2(3)$				
$\Delta\ln(NO)$	16.97 (.00)	$\chi_2(3)$	3.06 (.22)	$\chi_2(3)$		
$\Delta\ln(Q)$	5.25 (.16)	$\chi_2(3)$	5.39 (.07)	$\chi_2(3)$		
(a) lag=2	6.37 (.27)	$\chi_2(5)$				
Time Dummies	4.56 (.87)	$\chi_2(9)$	23.66 (.01)	$\chi_2(10)$	46.16(.00)	$\chi_2(10)$
Other Diagnostics:						
Sargan Test	40.71(.06)	$\chi_2(28)$	72.23 (.01)	$\chi_2(45)$	101.63(.00)	$\chi_2(49)$
m_1	-0.73 (.47)	$N(0,1)$	-2.82 (.01)	$N(0,1)$	-3.33(.00)	$N(0,1)$
m_2	-0.57 (.57)	$N(0,1)$	-1.87 (.06)	$N(0,1)$	-1.61(.11)	$N(0,1)$
Instruments Used:	$SLAT_{t-3}...SLAT_{t-9}$		$SLAT_{t-2}...SLAT_{t-9}$		$SLAT_{t-2}...SLAT_{t-9}$	
Observations:	261=29x9 (82-90)		290=29x10 (81-90)		290=29x10 (81-90)	

Table 5.12: Demand for Skilled Labour in Declining Sectors: Testing General Specification

detailed coefficient estimates of specification (3) are given in Table 5.26.)

The estimated behavioural parameters and implied elasticity estimates from specification (3) are given in Tables 5.13 and 5.14. The results indicate that the constant labour elasticity of substitution and demand between skilled and unskilled labour is zero. Time specific effects are jointly significant suggesting the importance of technological shocks to labour demand for this group of sectors. The signs of the coefficients suggest that in most years technological shocks have been biased in favour of skilled labour (with the notable exception of 1988 where an estimated 0.7 was knocked off the skilled labour share)[16].

[16]The time effect coefficients are presented as deviations from the constant term in each period. Note that in interpreting these coefficients they should be multiplied by 29, the number of sectors, to arrive at meaningful magnitudes since we are using weighted data.

Estimated Coefficients: Specification (3)						
Adjustment Coefficients			Long_Run Parameters			
SLAT	λ_s	0.363	*Skilled*		*Unskilled*	
$\ln(\frac{CLIW}{CLAT})$	δ_{su0}	-0.112	γ_{su}	-0.143	γ_{us}	-0.143
Constant	D_{82}	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}
-.00001	.00009	.00004	.00007	-.00001	.00017	.00008
D_{88}	D_{89}	D_{90}				
-.00025	.00006	.00029				

Table 5.13: Estimated Coefficients of Equation (5.11): Demand for Skilled Labour in Declining Sectors

Elasticity Estimates: Specification (3)			
	Substitution	Own and Cross Demand	
	σ_{su}	$\varepsilon_{su} = -\varepsilon_{ss}$	$\varepsilon_{us} = -\varepsilon_{uu}$
Period average	-0.028	-0.024	-0.005
1979	-0.095	-0.081	-0.015
1990	0.047	0.038	0.009

Table 5.14: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in Declining Sectors

5.5.2 The Demand for Aggregate Labour

In this section we present the results of estimating the demand for aggregate labour relative to capital. Labour is defined as a single input, aggregated across the skilled and unskilled labour categories. The general specification of the equation for the demand for labour, where there are only two inputs, labour and capital, is given by:

$$\begin{aligned}\Delta SL_t = \; & \pi_1 \Delta SL_{t-1} + \pi_2 \Delta SL_{t-2} \\ & + \pi_{lk0} \Delta \ln(\frac{PK}{CL})_t + \pi_{lk1} \Delta \ln(\frac{PK}{CL})_{t-1} + \pi_{lk2} \Delta \ln(\frac{PK}{CL})_{t-2} \\ & + \pi_{lk0d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t} + \pi_{lk1d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t-1} \\ & + \pi_{lk2d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t-2} \\ & + \pi_{ln0} \Delta \ln(NO)_t + \pi_{ln1} \Delta \ln(NO)_{t-1} + \pi_{ln2} \Delta \ln(NO)_{t-2} \qquad (5.20)\end{aligned}$$

$$+\pi_{lq0}\Delta\ln(Q)_t + \pi_{lq1}\Delta\ln(Q)_{t-1} + \pi_{lq2}\Delta\ln(Q)_{t-2}$$
$$+\pi_{82}D_{82} + \pi_t D_t$$

The Demand for Aggregate Labour : Medium Growth Sectors

Table 5.15 reports the diagnostic tests of estimating equation (5.20) for the medium-growth group of sectors. The general specification (1) is rejected by the Sargan test, while specification (2), which re-estimates this omitting time dummies (given their insignificance), is marginally accepted by the Sargan test.

Estimation Diagnostics for Equation (5.20)				
Joint Significance of:	(1)		(2)	
$\Delta\ln(\frac{PK}{CL})$	5.58 (.13)	$\chi_2(3)$	4.37 (.22)	$\chi_2(3)$
$\Delta\ln(\frac{PK}{CL})\cdot D_{8790}$	8.45 (.04)	$\chi_2(3)$	6.80 (.02)	$\chi_2(3)$
$\Delta\ln(NO)$	4.88 (.18)	$\chi_2(3)$	5.23 (.16)	$\chi_2(3)$
$\Delta\ln(Q)$	19.31 (.00)	$\chi_2(3)$	36.32 (.00)	$\chi_2(3)$
(a) lag=2	12.62 (.03)	$\chi_2(5)$	17.17 (.00)	$\chi_2(5)$
(b) lag=2	12.61 (.01)	$\chi_2(4)$	16.97 (.00)	$\chi_2(4)$
Time Dummies	10.97 (.28)	$\chi_2(9)$		
Other Diagnostics:				
Sargan Test	46.40 (.02)	$\chi_2(28)$	41.15 (.05)	$\chi_2(28)$
m_1	-2.48 (.01)	$N(0,1)$	-2.40 (.02)	$N(0,1)$
m_2	0.94 (.35)	$N(0,1)$	1.04 (.30)	$N(0,1)$
Instruments Used:	$SL_{t-3}...SL_{t-9}$		$SL_{t-3}...SL_{t-9}$	
Observations:	261=29x9 (82-90)		261=29x9 (82-90)	

Table 5.15: Demand for Aggregated Labour in Medium Growth Sectors: Testing General Specification

The parameter estimates for specification (2) indicate a similar pattern in relation to the firm entry/exit and scale effects as for the skilled results, with the scale effect much weaker than the firm turnover effect. A net new firm will increase labour's share of value added while an increase in scale will increase capital's share of value added.

The estimated elasticity of substitution between labour and capital is high (close to two in 1990), while the price elasticities of demand for labour and capital indicate inelastic demand. The price and firm turnover terms are not jointly significant in specification (2), however omitting them introduces further evidence of misspecification.

Estimated Coefficients: Specification (2)									
	Adjustment Coefficients				Long_Run Parameters				
SL	λ_s	0.793	β_s	-0.748	*Labour*		*Capital*		
$\ln(\frac{PK}{CL})$	δ_{lk0}	0.026	δ_{lk1}	-0.027	γ_{lk}	0.079	γ_{kl}	0.079
$\ln(\frac{PK}{CL}) \cdot D_{8790}$	δ_{lk0d}	0.037	δ_{lk1d}	0.080	γ_{lkd}	0.159	γ_{kld}	0.159
$\ln(NO)$	δ_{ln0}	-0.079	δ_{ln1}	-0.162	γ_{ln}	0.263	γ_{kn}	-0.263
$\ln(Q)$	δ_{lq0}	-0.452	δ_{lq1}	-0.479	γ_{lq}	-0.094	γ_{kq}	0.094

Table 5.16: Estimated Coefficients of Equation (5.11): Demand for Aggregated Labour in Medium Growth Sectors

Elasticity Estimates: Specification (2)			
	Substitution	Own and Cross Demand	
	σ_{lk}	$\varepsilon_{lk} = -\varepsilon_{ll}$	$\varepsilon_{kl} = -\varepsilon_{kk}$
Period average	1.317	0.618	0.699
1979	1.319	0.589	0.730
1990	1.316	0.680	0.636
1990*	1.951	1.009	0.943

Table 5.17: Estimated Elasticities of Substitution and Demand For Labour and Capital in Medium Growth Sectors

The Demand for Aggregate Labour : High Growth Sectors

Degrees of freedom restrictions meant that equation (5.20) could not be estimated for the eleven high-growth sectors. Instead we estimated several competing reductions of this equation: Table 5.18 gives the diagnostic test results for the more important of these. For all four variants the Sargan test did not signify any evidence of misspecification.

Specification (1) omits the scale variable and the structural break variable, this specification is rejected at the margin by the m_1 first-order autocorrelation test. Specification (2) omits the firm entry/exit variable and the structural break variable; while the diagnostic tests do not signal any serious misspecification problems the implied elasticity of substitution is negative violating standard economic theory. The relative price term in this specification is not significant. Specification (3) omits both the scale and firm entry/exit variables, this specification is rejected by the diagnostic tests (m_1). In addition this specification indicates that both the time dummies and the structural break dummies are insignificant.

Specification (4), which excludes any price variables but includes both scale and firm entry/exit effects, is the only one without specification problems based on one or more of the following: serial correlation tests, the sign of the estimated elasticities, the significance of the included variables.

Estimation Diagnostics for Equation (5.20): General Specification								
Joint Significance of:	(1)		(2)		(3)		(4)	
$\Delta \ln(\frac{PK}{CL})$	32.0(.00)	$\chi_2(3)$	6.7(.08)	$\chi_2(3)$	16.2(.00)	$\chi_2(3)$		
$\Delta \ln(\frac{PK}{CL}) \cdot D_{8790}$					5.33(.15)	$\chi_2(3)$		
$\Delta \ln(NO)$	22.3(.00)	$\chi_2(3)$					31.2(.00)	$\chi_2(3)$
$\Delta \ln(Q)$			163.6(.00)	$\chi_2(3)$			187.9(.00)	$\chi_2(3)$
(a) lag=2	42.3(.00)	$\chi_2(3)$	18.7(.00)	$\chi_2(3)$	30.5(.00)	$\chi_2(3)$	19.2(.00)	$\chi_2(3)$
Time Dummies	107.7(.00)	$\chi_2(9)$	69.1(.00)	$\chi_2(9)$	12.1(.21)	$\chi_2(9)$	26.3(.00)	$\chi_2(9)$
Other Diagnostics:								
Sargan Test	38.6(.27)	$\chi_2(34)$	39.6(.23)	$\chi_2(34)$	26.9(.80)	$\chi_2(34)$	38.9(.26)	$\chi_2(34)$
m_1	−1.9(.06)	$N(0,1)$	−2.0(.04)	$N(0,1)$	−1.8(.07)	$N(0,1)$	−2.3(.02)	$N(0,1)$
m_2	−0.4(.66)	$N(0,1)$	−1.4(.17)	$N(0,1)$	0.13(.90)	$N(0,1)$	−1.2(.22)	$N(0,1)$
Instruments Used:	$SL_{t-3}...SL_{t-9}$							
Observations:	99 = 11x9(1982 − 1990)							
Average σ_{lk}	0.542		-0.51		1.07		1.00	

Table 5.18: Demand forAggregated Labour in High Growth Sectors: Testing General Specification

Estimated Coefficients: Specification (4)								
	Adjustment Coefficients				Long_Run Parameters			
SL	λ_s	0.404	β_s	-0.597	*Labour*		*Capital*	
ln(*NO*)	δ_{ln0}	0.068	δ_{ln1}	0.036	γ_{ln}	0.007	γ_{kn}	-0.007
ln(*Q*)	δ_{lq0}	-0.107	δ_{lq1}	-0.064	γ_{lq}	-0.012	γ_{kq}	0.012
Constant	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}	D_{88}	D_{89}	D_{90}
-0.0012	0.0012	0.0013	0.0029	0.0012	0.0005	0.0010	-0.0004	0.0031

Table 5.19: Estimated Coefficients of Equation (5.11): Demand for Aggregated Labour in High Growth Sectors

Tables 5.19 and 5.20 give the estimated coefficients and elasticities from specification (4). This estimates a Cobb-Douglas technology with the elasticity of substitution equal to one.

Time dummies indicate that technology shocks were biased in favour of labour pre-1986, in 1987-1989 they were biased against labour and the strongest positive shock is in 1990[17].

Firm entry is biased towards labour while scale effects are biased towards capital (and stronger). These latter may be capturing the distortionary impact which transfer pricing in this group of sectors has on the official data for value-added and output. As mentioned earlier, because of the small N there are some doubts over the appropriateness of the estimator used for the H group.

Elasticity Estimates: Specification (4)			
	Substitution	Own and Cross Demand	
	σ_{lk}	$\varepsilon_{lk} = -\varepsilon_{ll}$	$\varepsilon_{kl} = -\varepsilon_{kk}$
Period average	1.00	0.799	0.201
1979	1.00	0.751	0.249
1990	1.00	0.824	0.176

Table 5.20: Estimated Elasticities of Substitution and Demand For Labour and Capital in High Growth Sectors

[17]These time dummies should be multiplied by 11, the number of sectors, to arrive at meaningful magnitudes since we are using weighted data.

The Demand for Aggregate Labour : Declining Sectors

Diagnostics for Equation (5.20)				
Joint Significance of:	(1)		(2)	
$\Delta \ln(\frac{PK}{CL})$	8.22 (.04)	$\chi_2(3)$	34.1 (.00)	$\chi_2(3)$
$\Delta \ln(\frac{PK}{CL}) \cdot D_{8790}$	4.40 (.22)	$\chi_2(3)$		
$\Delta \ln(NO)$	0.94 (.82)	$\chi_2(3)$		
$\Delta \ln(Q)$	8.87 (.03)	$\chi_2(3)$		
(a) lag=2	12.55 (.03)	$\chi_2(5)$	2.7 (.26)	$\chi_2(2)$
(b) lag=2	7.09 (.13)	$\chi_2(4)$		
Time Dummies	20.28 (.02)	$\chi_2(9)$	29.3 (.00)	$\chi_2(9)$
Other Diagnostics:				
Sargan Test	117.87 (.00)	$\chi_2(28)$	159.7 (.00)	$\chi_2(37)$
m_1	-2.31 (.02)	$N(0,1)$	-1.69 (.09)	$N(0,1)$
m_2	-0.12 (.91)	$N(0,1)$	0.43 (.67)	$N(0,1)$
Instruments Used:	$SL_{t-3}...SL_{t-9}$			
Observations:	261=29x9 (82-90)			

Table 5.21: Demand for Aggregated Labour in Declining Sectors: Testing General Specification

Table 5.21 gives the diagnostic tests for estimating equation (5.20) for the declining group of sectors. As in Section 5.5.1 the Sargan test rejects the overidentifying restrictions for the general specification and for all reductions.

Further reductions of this general specification were rejected by the diagnostic tests. Specification (2) in Table 5.21 reports the results of estimating a simple factor demand system, this is rejected by the first-order autocorrelation tests. Further it violates standard economic theory with an implied elasticity of substitution between labour and capital of -0.135 (based on period average).

There is evidence of a high degree of multicollinearity between the scale variable (Q) and the firm entry/exit variable (NO) in specification (1). To control for this a reparameterisation of these variables was introduced into the equation using NO and $\frac{Q}{NO}$ as regressors. This improved the precision of the NO variable ($\chi_2(3) = 4.39(0.22)$). Any further reductions of this system led to misspecification indicated by the m_1 and m_2 measures of autocorrelation.

Firm exit reduces labour's share of value-added. If we examine Table 4.13 we can see that between 1982 and 1990 (the estimation period) all except one of the 29 sectors in the declining group experienced a decline in the number of firms. From a peak of 2,100 firms in

1982 the total number of firms in these sectors fell to 1,534 by 1990. This suggests that the firms which remain are more capital intensive than those which exited.

The coefficient on gross output is positive, given that all of these sectors experienced a decline in gross output (by definition) this implies an increase in the capital-intensity of production. This coefficient may also be capturing misspecification consequent upon aggregating labour. Time dummies are significant and large. In all but three periods they are biased against labour.

However little reliance can be placed on these results. There is evidence of misspecification from the diagnostic tests and the implied elasticity estimates from specification (1) are negative violating standard economic theory.

Estimated Coefficients: Specification (1)								
	Adjustment Coefficients				Long_Run Parameters			
SL	λ_s	1.037	β_s	-0.857	*Labour*		*Capital*	
$\ln(\frac{PK}{CL})$	δ_{lk0}	-0.454	δ_{lk1}	-0.351	γ_{lk}	-0.528	γ_{kl}	-0.528
$\ln(\frac{PK}{CL}) \cdot D_{8790}$	δ_{lk0d}	-0.073	δ_{lk1d}	-0.108	γ_{lkd}	0.087	γ_{kld}	0.087
$\ln(NO)$	δ_{ln0}	0.259	δ_{ln1}	0.223	γ_{ln}	0.497	γ_{kn}	-0.497
$\ln(Q)$	δ_{lq0}	-0.181	δ_{lq1}	0.190	γ_{lq}	0.128	γ_{kq}	-0.128
Constant	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}	D_{88}	D_{89}	D_{90}
-.0017	.0016	.0028	.0005	.0027	-.0009	.0014	.0029	.0014

Table 5.22: Estimated Coefficients of Equation (5.11): Demand for Aggregated Labour in Declining Sectors

Elasticity Estimates: Specification 1			
	Substitution	Own and Cross Demand	
	σ_{lk}	$\varepsilon_{lk} = -\varepsilon_{ll}$	$\varepsilon_{kl} = -\varepsilon_{kk}$
Period average	-1.35	-0.46	-0.89
1979	-1.31	-0.46	-0.84
1990	-1.22	-0.48	-0.74
1990*	-0.85	-0.33	-0.52

Table 5.23: Estimated Elasticities of Substitution and Demand For Labour and Capital in Declining Sectors

5.6 Discussion of Results

$\varepsilon^*_{ij} = \varepsilon_{ij} + S_j\varepsilon_{ll}$				
ij	ε^*_{ij}	ε_{ij}	S_j	ε_{ll}
Medium Growth (M) Group				
ss	-0.31	-0.19	0.20	-0.62
su	-0.31	0.19	0.80	-0.62
us	-0.08	0.05	0.20	-0.62
uu	-0.54	0.05	0.80	-0.62
High Growth (H) Group				
ss	-1.25	-1.03	0.27	-0.80
su	0.45	1.03	0.73	-0.80
us	0.21	0.43	0.27	-0.80
uu	-1.01	-0.43	0.73	-0.80
Declining (D) Group				
ss	-0.06	0.02	0.19	-0.46
su	-0.40	-0.02	0.81	-0.46
us	-0.09	-0.005	0.19	-0.46
uu	-0.37	0.005	0.81	-0.46

Table 5.24: Constant Output Elasticity of Demand For Skilled and Unskilled Labour From Single Equation Estimates

Table 5.24 computes the constant output elasticity of demand for skilled and unskilled labour using the estimated results. These suggest the following:

- Skilled labour and unskilled labour are limited complements in the M and D groups for unchanged output while they remain substitutes in the H group.

- The demand for skilled labour is much more responsive to changes in the price of unskilled labour than the demand for unskilled labour is to changes in the price of skilled labour.

These results must be interpreted with caution. Firstly there were problems of misspecification in estimation for the D group in estimating the demand for skilled and aggregate labour and for the H group in estimating the demand for skilled labour. Secondly the results for the H group are based on an estimator which assumes N is large, when for the H group

$N = 11$. Thirdly the results for the M group for the demand for aggregate labour suggested that price effects were not significant, although omitting them introduced misspecification.

This implies that only the results for the demand for skilled labour for the M group were robust and plausible. These indicated the following:

1. For unchanged employment and output, substitution between skilled and unskilled labour is low.
2. Expanding sectors (measured by net firm turnover) are more skill-intensive and capital-intensive than average.
3. An expansion in scale is unskilled-intensive.
4. There are no discernable skill-biased technology effects.

5.7 Conclusions

In this chapter we presented single equation estimates of the demand for skilled labour and the demand for aggregate labour for three groups of sectors. Estimation was done using a GMM estimator. There was evidence of misspecification in the results for four of the six estimated equations. The exceptions were in estimation of the demand for skilled labour for the medium growth sector and the demand for aggregated labour for the high-growth sector. For the latter, however, the small size of the cross-section meant that there were degrees of freedom problems in estimation.

5.8 The Empirical Results in More Detail

5.8.1 The Estimated Coefficients

	Medium Growth Group					
	Spec. (1)			Spec. (3)		
	coeff.	s.e.	pr.	coeff.	s.e.	pr.
π_1	.660	.212	.00	.789	.179	.00
π_2	-.440	.234	.06	-.296	.131	.02
π_{su0}	-.171	.035	.00	-.181	.039	.00
π_{su1}	.092	.065	.16	.098	.049	.05
π_{su2}	.011	.060	.85	.021	.044	.63
π_{su0d}	-.021	.021	.31			
π_{su1d}	.012	.021	.55			
π_{su2d}	-.055	.024	.03			
π_{sn0}	.192	.087	.03	.127	.062	.04
π_{sn1}	-.107	.110	.33	-.138	.093	.14
π_{sn2}	.122	.080	.13	.107	.083	.20
π_{sq0}	.046	.055	.40	.085	.047	.07
π_{sq1}	-.166	.073	.02	-.125	.064	.05
π_{sq2}	.001	.047	.99	.033	.042	.43
π_{82}	-.0002	.0004	.65			
π_{83}	.0001	.0005	.83			
π_{84}	.0005	.0003	.14			
π_{85}	.0004	.0005	.40			
π_{86}	.0005	.0004	.23			
π_{87}	-.0001	.0005	.82			
π_{88}	.0003	.0006	.59			
π_{89}	-.0004	.0005	.39			
π_{90}	.0004	.0004	.31			
Estimation of equation (5.19) using the						
AB GMM estimator as described in Section 5.5.1.						
Standard errors are robust to heteroscedasticity.						
The table also shows significance levels denoted *pr*.						

Table 5.25: The Demand for Skilled Labour in the Medium Growth Group: Detailed Estimation Results for Single Equation Model

	High Growth Group						Declining		
	Spec. (1)			Spec. (2)			Spec. (3)		
	coeff.	s.e.	pr.	coeff.	s.e.	pr.	coeff.	s.e.	pr.
π_1	1.086	.091	.00	1.099	.097	.00	.637	.082	.00
π_2	-.404	.135	.00	-.292	.132	.03			
π_{su0}	-.126	.020	.00	-.131	.018	.00	-.113	.029	.00
π_{su1}	.165	.011	.00	.149	.023	.00	.061	.013	.00
π_{su2}	-.007	.039	.85	.001	.038	.99			
π_{su0d}									
π_{su1d}									
π_{su2d}									
π_{sn0}				.009	.024	.69			
π_{sn1}				-.065	.024	.01			
π_{sn2}				.080	.024	.00			
π_{sq0}	.039	.025	.11						
π_{sq1}	-.039	.014	.01						
π_{sq2}	.028	.014	.04						
π_{81}							-.00001	.0001	.93
π_{82}	-.0008	.0006	.15	-.0013	.0007	.05	.00009	.0002	.60
π_{83}	.0004	.0008	.58	.0007	.0009	.44	.00004	.0002	.82
π_{84}	.0023	.0013	.07	.0028	.0015	.05	.00007	.0001	.55
π_{85}	.0004	.0009	.68	.0010	.0010	.34	-.00001	.0002	.93
π_{86}	.0014	.0008	.07	.0019	.0008	.02	.00017	.0002	.30
π_{87}	.0001	.0011	.96	.0012	.0008	.14	.00008	.0002	.65
π_{88}	-.0001	.0007	.92	.0004	.0010	.69	-.00025	.0002	.30
π_{89}	.0020	.0010	.05	.0023	.0009	.01	.00006	.0002	.77
π_{90}	-.0011	0.0006	.07	-.0002	.0007	.72	.00029	.0001	.03
Estimation of equation (5.19) using the AB GMM estimator as									
described in Section 5.5.1. Standard errors are robust to heteroscedasticity.									

Table 5.26: The Demand for Skilled Labour in the High Growth Group and Declining Groups: Detailed Estimation Results for Single Equation Model

	High Growth Group			Medium Growth			Declining		
	coeff.	s.e.	pr.	coeff.	s.e.	pr.	coeff.	s.e.	pr.
π_1	.403	.071	.00	.252	.158	.11	.143	.044	.00
π_2	.193	.063	.00	-.045	.126	.72	-.180	.108	.10
π_{lk0}				.025	.053	.63	-.454	.166	.01
π_{lk1}				-.053	.035	.13	.103	.108	.34
π_{lk2}				.090	.077	.24	-.197	.158	.21
π_{lk0d}				.037	.047	.43	-.073	.078	.35
π_{lk1d}				.044	.040	.28	-.035	.059	.55
π_{lk2d}				.046	.044	.30	.199	.095	.04
π_{ln0}	.068	.036	.06	-.079	.182	.66	.260	.316	.41
π_{ln1}	-.032	.056	.56	-.083	.155	.59	-.036	.261	.89
π_{ln2}	-.029	.026	.27	.371	.201	.06	.291	.361	.42
π_{lq0}	-.107	.011	.00	-.452	.134	.00	-.181	.126	.15
π_{lq1}	.043	.020	.03	-.027	.179	.88	.371	.129	.00
π_{lq2}	.052	.021	.01	.404	.215	.06	-.056	.221	.80
π_{82}	-.001	.002	.49				-.002	.001	.04
π_{83}	.0012	.0023	.60				.0016	.0015	.27
π_{84}	.0013	.0023	.57				.0028	.0013	.03
π_{85}	.0029	.0018	.11				.0005	.0009	.55
π_{86}	.0012	.0015	.39				.0027	.0012	.03
π_{87}	.0005	.0021	.81				-.0009	.0008	.25
π_{88}	.0010	.0019	.61				.0014	.0011	.20
π_{89}	-.0004	.0021	.85				.0029	.0013	.02
π_{90}	.0031	.0020	.12				.0014	.0011	.20

Estimation of equation (5.19) using the AB GMM estimator as described in Section 5.5.1 .Standard errors are robust to heteroscedasticity The table also shows significance levels [pr.].

Table 5.27: The Demand for Aggregated Labour in Each Group: Detailed Estimation Results for Single Equation Model

5.8.2 Graphs

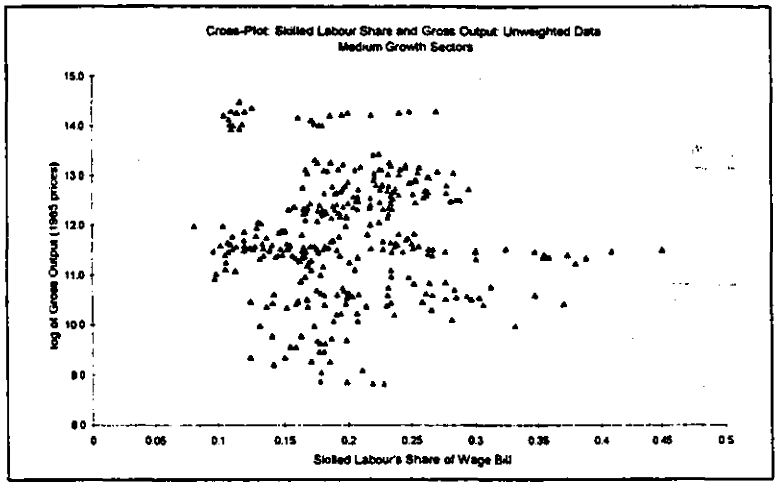

Figure 5.2: Cross-Plot of Skilled Labour Share of Wage Bill and Gross Output for Medium Growth Sectors: Unweighted Data

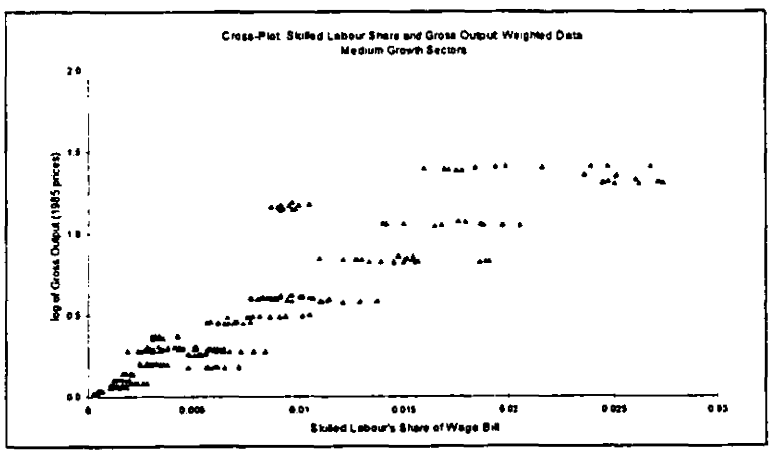

Figure 5.3: Cross-Plot of Skilled Labour Share of Wage Bill and Gross Output for Medium Growth Sectors: Weighted Data

Chapter 6

Estimating the Long Run Demand For Skilled Labour, Unskilled Labour, Clerical Labour and Capital Services Using a Systems Estimator

6.1 Introduction

In the previous chapter we estimated the demand for skilled labour relative to unskilled labour for three groups of sectors. The estimation was based on a set of highly restrictive *a priori* assumptions about the relationship between factors. In this chapter we relax these restrictions, and estimate a system of equations to model the joint determination of skilled labour, unskilled labour, clerical labour and capital services.

The factor demand system consists of four equations with cross-equation restrictions. Along with relative factor price terms, each equation includes period-specific time dummies, the number of firms per sector and output as additional regressors. Two lags are included on all variables in each equation to allow for short-run deviations from long-run behaviour. Taken together, this results in a highly parameterised set of equations for estimation.

We use nonlinear least squares and FIML estimators to estimate the system. Our results have to be viewed with caution since there are unresolved issues in relation to the small-sample properties of these estimators and because there is some evidence of misspecification in estimation. Nevertheless, they do represent the first attempt to estimate the substitution possibilities between different types of labour in the Irish manufacturing sector and as such represent an important contribution towards our understanding of the demand for different types of labour in the Irish labour market.

6.2 Issues in Estimation

6.2.1 The System of Equations for Estimation

A systems analogue of equation (5.11) in the previous chapter can be written in matrix form as

$$\Delta S_{st} = B\Delta S_{st-1} + D_0 \Delta X^{*}_{st} + D_1 \Delta X^{*}_{st-1} - \Lambda(S_{st-2} - \Gamma X_{st-2}) \tag{6.1}$$

where S_{st} is a vector of the factor shares S_{ist}, X_{st} is a vector of the explanatory variables [1, P_{js}, Q_s, NO_s]' and X^{*}_{st} is the same vector with the first element deleted. This gives a system of dynamic factor demand equations with the long-run factor share equations, equivalent to (5.9), included as the error correction terms in brackets. Since the elements of S_{st} sum to unity for each t (and the elements of ΔS_{st} sum to zero) this system of equations is singular. Anderson and Blundell (1982) have developed an empirically tractable method of estimating this system. They point out that the full set of parameters in (6.1) cannot be identified. Because the covariance matrix is singular it is necessary, as in the static case, to eliminate one of the share equations within the brackets. This redundant variable problem extends to the vector of lagged dependent variables where one element is also eliminated, while the full set of short-run adjustment parameters on the explanatory variables D_0 and D_1 can be estimated.

Denote a matrix with the K^{th} row deleted with a subscript K and with the K^{th} column deleted with a superscript K then (6.1) becomes:

$$\Delta S_{st} = B^K \Delta S_{K,st-1} + D_0 \Delta X^{*}_{st} + D_1 \Delta X^{*}_{st-1} - \Lambda^K (S_{K,st-2} - \Gamma_K X_{st-2}) \tag{6.2}$$

The parameters of the K^{th} long-run factor share equation which is eliminated from estimation can be identified via the adding-up condition (5.4). Similarly the short-run parameters in B^K and Λ^K are identified by making each column of B^K and Λ^K sum to zero, however we cannot fully identify the parameters in B and Λ in equations (6.1). Anderson and Blundell (1982, p1566) point out, however, that "the lack of identification on the lag structure of the dependent variable does not hamper the identification of the parameters associated with economic theory." Since our primary interest is in estimating the long-run factor share equations, about which economic theory has something to say, this lack of identification is of secondary importance[1].

[1]More recently, Allen and Urga (1999) have shown that by specifying a dynamic translog cost function, and estimating this jointly with the factor demand equations, full identification of the short run parameters is possible.

In our data set we have four separate factors, skilled labour denoted h, unskilled labour denoted l, clerical labour denoted c and capital services denoted k. The full set of equations for estimation from (6.2) is

$$
\begin{bmatrix} \Delta S_{hst} \\ \Delta S_{lst} \\ \Delta S_{cst} \\ \Delta S_{kst} \end{bmatrix}
=
\begin{bmatrix} \beta_{hh} & \beta_{hl} & \beta_{hc} \\ \beta_{lh} & \beta_{ll} & \beta_{lc} \\ \beta_{ch} & \beta_{cl} & \beta_{cc} \\ \beta_{kh} & \beta_{kl} & \beta_{kc} \end{bmatrix}
\begin{bmatrix} \Delta S_{hst-1} \\ \Delta S_{lst-1} \\ \Delta S_{cst-1} \end{bmatrix}
+
\begin{bmatrix} \delta_{hh0} & \delta_{hl0} & \delta_{hc0} & \delta_{hk0} & \delta_{hq0} & \delta_{hn0} \\ \delta_{lh0} & \delta_{ll0} & \delta_{lc0} & \delta_{lk0} & \delta_{lq0} & \delta_{ln0} \\ \delta_{ch0} & \delta_{cl0} & \delta_{cc0} & \delta_{ck0} & \delta_{cq0} & \delta_{cn0} \\ \delta_{kh0} & \delta_{kl0} & \delta_{kc0} & \delta_{kk0} & \delta_{kq0} & \delta_{kn0} \end{bmatrix}
\begin{bmatrix} \Delta \ln P_{hst} \\ \Delta \ln P_{lst} \\ \Delta \ln P_{cst} \\ \Delta \ln P_{kst} \\ \Delta \ln Q_{st} \\ \Delta \ln NO_{st} \end{bmatrix}
$$

$$
+
\begin{bmatrix} \delta_{hh1} & \delta_{hl1} & \delta_{hc1} & \delta_{hk1} & \delta_{hq1} & \delta_{hn1} \\ \delta_{lh1} & \delta_{ll1} & \delta_{lc1} & \delta_{lk1} & \delta_{lq1} & \delta_{ln1} \\ \delta_{ch1} & \delta_{cl1} & \delta_{cc1} & \delta_{ck1} & \delta_{cq1} & \delta_{cn1} \\ \delta_{kh1} & \delta_{kl1} & \delta_{kc1} & \delta_{kk1} & \delta_{kq1} & \delta_{kn1} \end{bmatrix}
\begin{bmatrix} \Delta \ln P_{hst-1} \\ \Delta \ln P_{lst-1} \\ \Delta \ln P_{cst-1} \\ \Delta \ln P_{kst-1} \\ \Delta \ln Q_{st-1} \\ \Delta \ln NO_{st-1} \end{bmatrix}
-
\begin{bmatrix} \lambda_{hh} & \lambda_{hl} & \lambda_{hc} \\ \lambda_{lh} & \lambda_{ll} & \lambda_{lc} \\ \lambda_{ch} & \lambda_{cl} & \lambda_{cc} \\ \lambda_{kh} & \lambda_{kl} & \lambda_{kc} \end{bmatrix}
$$

$$
\left(
\begin{bmatrix} S_{hst-2} \\ S_{lst-2} \\ S_{cst-2} \end{bmatrix}
-
\begin{bmatrix} \alpha_{hs} & \gamma_{hh} & \gamma_{hl} & \gamma_{hc} & \gamma_{hk} & \gamma_{hq} & \gamma_{hn} \\ \alpha_{ls} & \gamma_{lh} & \gamma_{ll} & \gamma_{lc} & \gamma_{lk} & \gamma_{lq} & \gamma_{ln} \\ \alpha_{cs} & \gamma_{ch} & \gamma_{cl} & \gamma_{cc} & \gamma_{ck} & \gamma_{cq} & \gamma_{cn} \end{bmatrix}
\begin{bmatrix} 1 \\ \ln P_{hst-2} \\ \ln P_{lst-2} \\ \ln P_{cst-2} \\ \ln P_{kst-2} \\ \ln Q_{st-2} \\ \ln NO_{st-2} \end{bmatrix}
\right)
\qquad (6.3)
$$

The (six) short-run adding-up restrictions needed for identification are:

$\beta_{kh} = -(\beta_{hh} + \beta_{lh} + \beta_{ch})$	$\beta_{kl} = -(\beta_{hl} + \beta_{ll} + \beta_{cl})$	$\beta_{kc} = -(\beta_{hc} + \beta_{lc} + \beta_{cc})$
$\lambda_{kh} = -(\lambda_{hh} + \lambda_{lh} + \lambda_{ch})$	$\lambda_{kl} = -(\lambda_{hl} + \lambda_{ll} + \lambda_{cl})$	$\lambda_{kc} = -(\lambda_{hc} + \lambda_{lc} + \lambda_{cc})$

The four dynamic factor share equations, with these restrictions imposed, are written out in full in Section 6.6. The typical equation for factor i (assuming these adding up restrictions are applied to the equation for factor $j \neq i$) is:

$$\Delta S_{ist} \;=\; \beta_{ih}\Delta S_{hst-1} + \beta_{il}\Delta S_{lst-1} + \beta_{ic}\Delta S_{cst-1} + \delta_{ih0}\Delta \ln P_{hst} + \delta_{il0}\Delta \ln P_{lst}$$

$$
\begin{aligned}
&+\delta_{ic0}\Delta\ln P_{cst}+\delta_{ik0}\Delta\ln P_{kst}+\delta_{iq0}\Delta\ln Q_{st}+\delta_{in0}\Delta\ln NO_{st}\\
&+\delta_{ih1}\Delta\ln P_{hst-1}+\delta_{il1}\Delta\ln P_{lst-1}+\delta_{ic1}\Delta\ln P_{cst-1}+\delta_{ik1}\Delta\ln P_{kst-1} \qquad (6.4)\\
&+\delta_{iq1}\Delta\ln Q_{st-1}+\delta_{in1}\Delta\ln NO_{st-1}-\lambda_{ih}ecm_{hst-2}-\lambda_{il}ecm_{lst-2}-\lambda_{ic}ecm_{cst-2}
\end{aligned}
$$

where ecm_{ist} is the long-run factor share equation for factor i in sector s in year t based on (5.9). These long-run steady state equations are given as

$$
\begin{aligned}
ecm_{hst} &= S_{hst}-\alpha_{hs}-\gamma_{hh}\ln P_{hst}-\gamma_{hl}\ln P_{lst}-\gamma_{hc}\ln P_{cst}-\gamma_{hk}\ln P_{kst}-\gamma_{hq}\ln Q_{st}-\gamma_{hn}\ln NO_{st}\\
ecm_{lst} &= S_{lst}-\alpha_{ls}-\gamma_{lh}\ln P_{hst}-\gamma_{ll}\ln P_{lst}-\gamma_{lc}\ln P_{cst}-\gamma_{lk}\ln P_{kst}-\gamma_{lq}\ln Q_{st}-\gamma_{ln}\ln NO_{st}\\
ecm_{cst} &= S_{cst}-\alpha_{cs}-\gamma_{ch}\ln P_{hst}-\gamma_{cl}\ln P_{lst}-\gamma_{cc}\ln P_{cst}-\gamma_{ck}\ln P_{kst}-\gamma_{cq}\ln Q_{st}-\gamma_{cn}\ln NO_{st}
\end{aligned}
$$

The adding-up condition then identifies the parameters of the long run capital share equation as follows:

Recovering Parameters for Factor Capital:		$\alpha_{ks}=1-(\alpha_{hs}+\alpha_{ls}+\alpha_{cs})$
$\gamma_{kh}=-(\gamma_{hh}+\gamma_{lh}+\gamma_{ch})$	$\gamma_{kl}=-(\gamma_{hl}+\gamma_{ll}+\gamma_{cl})$	$\gamma_{kc}=-(\gamma_{hc}+\gamma_{lc}+\gamma_{cc})$
$\gamma_{kk}=-(\gamma_{hk}+\gamma_{lk}+\gamma_{ck})$	$\gamma_{kq}=-(\gamma_{hq}+\gamma_{lq}+\gamma_{cq})$	$\gamma_{kn}=-(\gamma_{hn}+\gamma_{ln}+\gamma_{cn})$

Price homogeneity and symmetry conditions imply six further testable restrictions on the estimated long-run parameters together with three symmetry conditions which further identify parameters of the capital services equation. Testing these restrictions is equivalent to testing the hypothesis of cost-minimisation behaviour. Such tests are widely used to evaluate the theoretical coherence of empirical models (Anderson and Blundell, 1982).

Price Homogeneity:		
$\gamma_{hh}=-(\gamma_{hl}+\gamma_{hc}+\gamma_{hk})$	$\gamma_{ll}=-(\gamma_{lh}+\gamma_{lc}+\gamma_{lk})$	$\gamma_{cc}=-(\gamma_{ch}+\gamma_{cl}+\gamma_{ck})$
Symmetry:		
$\gamma_{hl}=\gamma_{lh}$	$\gamma_{hc}=\gamma_{ch}$	$\gamma_{lc}=\gamma_{cl}$
Symmetry identifies parameters of Capital Services Equation:		
$\gamma_{kh}=\gamma_{hk}$	$\gamma_{kl}=\gamma_{lk}$	$\gamma_{kc}=\gamma_{ck}$

6.2.2 Systems Estimators With Panel Data

In the system of dynamic equations all slope coefficients are assumed common across sectors but the intercept terms are sector-specific reflecting unobserved differences between individual sector's factor shares. To eliminate this unobserved effect, these equations are estimated in first differences where the typical equation for factor i (assuming adding up restrictions are applied to the equation for factor $j \neq i$) is given as:

$$\begin{aligned}
\Delta S_{ist} = \; & \pi_{iH1}\Delta S_{hst-1} + \pi_{iH2}\Delta S_{hst-2} + \pi_{iL1}\Delta S_{lst-1} + \pi_{iL2}\Delta S_{lst-2} \\
& \pi_{iC1}\Delta S_{cst-1} + \pi_{iC2}\Delta S_{cst-2} + \pi_{il0}\Delta \ln P_{lst} + \pi_{il1}\Delta \ln P_{lst-1} \\
& + \pi_{il2}\Delta \ln P_{lst-2} + \pi_{ih0}\Delta \ln P_{hst} + \pi_{ih1}\Delta \ln P_{hst-1} + \pi_{ih2}\Delta \ln P_{lst-2} \\
& + \pi_{ic0}\Delta \ln P_{cst} + \pi_{ic1}\Delta \ln P_{cst-1} + \pi_{ic2}\Delta \ln P_{cst-2} \\
& + \pi_{ik0}\Delta \ln P_{kst} + \pi_{ik1}\Delta \ln P_{kst-1} + \pi_{ik2}\Delta \ln P_{kst-2} \\
& + \pi_{iq0}\Delta \ln \frac{Q_{st}}{NO_{st}} + \pi_{iq1}\Delta \ln \frac{Q_{st-1}}{NO_{st-1}} + \pi_{iq2}\Delta \ln \frac{Q_{st-2}}{NO_{st-2}} \\
& + \pi_{in0}\Delta \ln NO_{st} + \pi_{in1}\Delta \ln NO_{st-1} + \pi_{in2}\Delta \ln NO_{st-2}
\end{aligned} \tag{6.5}$$

Because of possible collinearity between gross output per sector and the number of firms per sector as regressors, these are reparameterised in (6.5) in more orthogonal form as $\frac{Q}{NO}$ and Q respectively. In all there are twelve possible restrictions on the estimated system in first differences. In Section 6.6 the implications of these restrictions for the relationship between the estimated π parameters from (6.5) and the underlying short-run and long-run behavioural parameters in $B^n, D_0, D_1, \Lambda^n, \Gamma_n$ from the equations in (6.2) are fully specified.

The issue of fixed effects and its implications for dynamic single equation estimation with short panels discussed in the previous chapter applies also to estimation of a system of simultaneous equations with panel data. Krishnakumar (1992) provides an overview of the properties of estimators of simultaneous equations using panel data (specifically two-stage and three stage least squares with and without instrumental variables, also full information maximum likelihood (FIML) estimators) however he does not discuss the properties of these estimators when there are lagged endogenous variables within the system. Holtz-Eakin, Newey and Rosen (1988) develop a technique for estimation of vector autoregression models with panel data. They express the equation in quasi-differences, thereby dealing with the fixed effects, and use instrumental variables to tackle correlation with the quasi-differenced error term. The instrumental variables they use are different in different time periods analogous to (5.18) above.

To date most applied work estimating systems of factor demand equations with panel data has used either full information maximum likelihood (FIML) estimators (see Lindquist, 1995), instrumental variables estimators (Morrison, 1997) or iterative SURE/ML (Allen and Urga, 1999). In estimation we tested several different estimators[2]: non-linear least squares, non-linear two stage least squares with instrumental variables, non-linear three stage least

[2] All systems estimation was done using the TSP package.

squares with instrumental variables, FIML and GMM estimators. In all but the FIML case these included heteroscedastic-robust estimation of the covariance matrix.

It was difficult to evaluate the relative performance of each estimator. First differences eliminate fixed effects but will introduce correlation between the lagged endogenous variable and the error term in each equation. For this reason we estimated (6.5) using both two stage and three stage least squares with instrumental variables. The instrument set included the second and third lags of each endogenous variable together with the differenced $\frac{Q}{NO}$ and NO variables (lags zero to two). The factor price variables were omitted from the instrument set because of their definitional relationship with the endogenous variables used as instruments. All equations which included time dummies had equivalent time dummies included in the instrument set. This instrument set differs for each cross-section equation because the set of instruments is different in different time periods analogous to the Z instrument matrix for the AB GMM estimator described above. We also performed GMM estimation, allowing for heteroscedasticity and an MA(1) error term, of (6.5) with this same instrument set.

In all cases the IV and GMM estimators were very unstable, with a failure to converge[3] and high estimated covariance terms. By contrast least squares results did converge with sensible coefficient estimates which agreed with the single equation model estimates. Therefore, despite unresolved issues relating to the small-sample properties of these estimators (see Krishnakumar (1992) p.149), we used nonlinear least squares estimates for the high growth and declining groups and FIML[4] estimates for the medium growth group.

We report the results of estimating the full set of interrelated factor demand equations as set out in Section 6.6. Estimation is done for each of our three groups of sectors for four factors: skilled labour, unskilled labour, clerical labour and capital. Based on the empirical results of the single equation estimation we include second-order lags in all equations, in addition to both firm turnover and scale effects and a full set of time dummies.

6.2.3 Preliminary Overview of Sectors

Table 6.1 gives the average shares of each factor in total value added. This gives an indication of the different mix of factors in each group. The very high share of capital in total value added in the high-growth group, almost 80%, is an indication of the distortion which transfer pricing introduces into the data for these sectors (see Chapter 4, Section 4.3.2). By contrast

[3]Where convergence refers to minimising a criterion function, (e.g. the sum of squared residuals or minus the log of the likelihood function) through an iterative process of "squeezing" the parameter vector. When the iterative process fails to improve convergence, iteration ceases. All systems estimation was done using the TSP package.

[4]Initial values for FIML estimates were taken from multivariate least squares estimates.

	Skilled	*Unskilled*	*Clerical*	*Capital*
High Growth	0.05	0.13	0.02	0.80
Medium Growth	0.10	0.38	0.05	0.47
Declining	0.10	0.50	0.05	0.34

Table 6.1: Average Shares for Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services in Total Value Added

	Skilled			Unskilled			Clerical		
	No.	Within	Between	No.	Within	Between	No.	Within	Between
	High Growth								
1979	3,210	12.0%	13.7%	21,058	78.7%	11.5%	2,494	9.3%	12.2%
1990	8,321	18.25%	33.7%	31,681	69.4%	21.4%	5,625	12.3%	26.9%
	Medium Growth								
1979	13,238	11.2%	56.7%	92,991	78.9%	50.9%	11,659	9.9%	57.3%
1990	11,808	11.8%	47.8%	76,556	76.7%	51.7%	11,434	11.5%	54.65
	Declining								
1979	6,904	8.5%	29.6%	68,545	83.9%	37.5%	6,198	7.6%	30.5%
1990	4,572	9.5%	18.5%	39,724	82.5%	26.8%	3,866	8.05	18.5%
No. = Numbers Employed; Within = Percentage of Within Group (Row) Total									
Between = Percentage of Between Groups (Column) Total									

Table 6.2: Within and Between Groups Shares of Total Skilled, Unskilled and Clerical Employment

over 50% of total value-added is accounted for by the unskilled wage bill in the declining group.

Table 6.2 shows the levels of employment in each group for skilled labour, unskilled labour and clerical labour in 1979 and 1990 together with the within group and between group shares. The within group shares measure the share of each type of labour in total employment within each group. The between group shares measure the share of each group in total employment for each type of labour.

Looking first at the within group shares we can see that the composition of labour input for the high-growth group shifted towards a higher share of skilled labour (from 12% to 18.25%) and clerical labour (from 9.3% to 12.3%). There was comparatively little change in the medium-growth and declining groups labour mix over the period, although in both there was a gradual decline in the unskilled labour share.

Turning now to the between group shares we see that the high-growth group's share of total skilled employment increased by twenty percentage points over this period, its share of unskilled employment by ten percentage points and its share of clerical employment by fourteen percentage points. This group recorded an increase in total employment of over 18,800. In the declining group total employment fell by approximately 33,500, with over 28,800 of this decline in unskilled employment. The most stable share is in the medium-growth group which employs approximately half of all unskilled labour in the sample both at the beginning and end of the period and accounts for just over 50% of total employment both in 1979 and 1990.

6.3 Estimation Results

6.3.1 Medium Growth Sectors

Table 6.3 gives the results of several (Wald) tests applied to the estimated system. They test the following (joint) hypotheses:

1. H_1 : Long Run Price Homogeneity
2. H_2 : Long Run Symmetry
3. H_3 : Long Run Price Homogeneity and Symmetry
4. H_4 : Time Dummies Insignificant where $D_t = 1$ if $t = T$, 0 otherwise.
5. H_5 : Cobb-Douglas Technology (All long-run price coefficients jointly insignificant)
6. H_6 : Long Run Homotheticity (Scale Effects Insignificant)
7. H_7 : Firm Turnover Effects Insignificant
8. H_8 : Cobb-Douglas Technology With No Scale or Firm Turnover Effects (All long-run coefficients jointly insignificant)
9. H_9 : Second Lag Insignificant

In addition the table shows the last value of the squared average error in the parameters prior to convergence ($CRIT$).

In Table 6.3 specification (1) is the most general specification, which includes time dummies and imposes no behavioural restrictions. The restrictions imposed by price homogeneity

		(1)	(2)	(3)
$H_1 : \sum_j \gamma_{ij} = 0; i = h,l,c$	$\chi_2(3)$	0.042(.99)		
$H_2 : \gamma_{ij} = \gamma_{ji}, \forall i,j; j \neq i$	$\chi_2(3)$	0.12(.99)		
$H_3 : H_1 \cap H_2$	$\chi_2(6)$	0.58(1.00)		
$H_4 : D_t = 0 \; \forall t$	$\chi_2(36)$	7.46(1.00)	8.89(1.00)	
$H_5 : \gamma_{ij} = 0, i, j; j = 1...K$	$\chi_2(6)$	0.84(.99)	9.15(.16)	14.86(.02)
$H_6 : \gamma_{iq} = 0, i = h,l,c$	$\chi_2(3)$	0.15(.98)	0.23(.97)	0.57(.90)
$H_7 : \gamma_{in} = 0, i = h,l,c$	$\chi_2(3)$	0.53(.91)	2.50(.47)	8.58(.03)
$H_8 : \gamma_{ij} = 0, \forall i,j$	$\chi_2(12)$	9.61(.65)	15.9(.20)	23.93(.02)
$H_9 : \pi_{ij2} = 0, \forall i,j$	$\chi_2(36)$	74.33(.00)	124.55(.00)	220.04(.00)
$\ln L$		6077.7	6071.1	6054.3
$N * T$		261	261	261
		1982-1990	1982-1990	1982-1990
$CRIT$		0.0001	0.0011	0.0002
(1) General Specification; (2) With Long-run Homotheticity and Symmetry				
(3) With Long-Run Homotheticity and Symmetry, no time dummies				

Table 6.3: Specification Testing of Four Equation Factor Demand System for Medium Growth Sectors: Based on FIML Estimation of (6.5)

and symmetry are not rejected by this specification. Time dummies are insignificant, as found in the single equation models. Re-estimation with price homogeneity and symmetry imposed (specification (2)) also finds the time dummies insignificant. Our preferred specification (3), which imposes both long-run price homogeneity and symmetry, omits these time dummies. In this preferred specification the long-run coefficients in the factor demand equations are found to be jointly significant. While the long-run scale coefficients are jointly insignificant in this specification (H_6) we found that dropping these led to behaviourally implausible elasticity signs (positive own elasticity of demand for clerical labour and capital). Therefore we retained these long-run scale effects in our preferred specification.

Figures 6.2, 6.3, 6.4 and 6.5 plot the residuals from each of the four equations. Normality tests confirm what is visually clear from these graphs - the estimated residuals are not normally distributed. This is also clearly illustrated in Figure 6.6 which plots the distribution of the residuals. The full set of coefficients and standard errors for this specification are given in Section 6.7.1.

Table 6.4 gives the elasticities of substitution and demand between skilled labour, unskilled labour, clerical labour and capital for the medium-growth group as estimated from the long run parameters. These elasticities are evaluated using the period average factor

Allen Elasticity of Substitution, σ_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	*-4.99	*0.67	2.43	0.19
Unskilled		**-1.16	*-4.31	**1.30
Clerical			-6.57	3.75
Capital				-1.53
Constant-Output Elasticity of Demand, ε_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	*-0.48	*0.25	0.13	0.09
Unskilled	*0.06	**-0.44	-0.24	**0.61
Clerical	0.23	*-1.64	-0.36	1.76
Capital	0.02	**0.49	0.21	-0.72
Morishima Elasticity of Substitution, μ_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled		0.69	0.49	0.81
Unskilled	0.54		0.12	1.33
Clerical	0.71	-1.20		2.48
Capital	0.49	0.93	0.56	

Table 6.4: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: Medium Growth Sectors

shares. Figure 6.1 gives the associated 90% and 95% confidence intervals for these elasticities which are computed based on the formulae in Anderson and Thursby (1986). Section 6.7.2 gives full details of how these confidence intervals are computed. These are indicated in the table where * indicates significance at the 10% level and ** indicates significance at the 5% level. Note that because the demand for capital equation is not estimated we do not have a confidence interval for the own elasticity of capital.

The Allen own and cross elasticity of substitution is computed using the product of the relevant factor shares as the denominator (see equation (5.6)). From this it can be seen that as we divide the labour input into smaller subpopulations, the elasticity of substitution rises. This partly explains why the *magnitude* of the own and cross elasticities of substitution for clerical labour (share= 0.05) and skilled labour (share= 0.10) are so high.

The signs of the Allen elasticities of substitution rank the pairwise substitutability between different factors as ranging from very high substitutability for clerical-capital, clerical-skilled and capital-unskilled, to limited substitutability between skilled and unskilled, to almost zero substitutability between skilled and capital, to a very high degree of complementarity between clerical and unskilled.

The constant-output elasticities of demand indicate a series of distinctive technical and economic relationships between factors:

1. The own price elasticities of demand are low and of a similar order of magnitude for all three categories of labour, ranging from -0.36 for clerical labour to -0.48 for skilled labour. The own elasticity of demand for capital, while slightly higher at -0.72, is also relatively inelastic. The own price elasticity for clerical labour is not significantly different from zero at the 10% level.

2. Both skilled labour and capital are most sensitive to changes in their own price with limited response to changes in other factor prices.

3. Skilled labour has a limited substitution response to changes in the price of unskilled labour.

4. Clerical labour is a strong complement to unskilled labour. A 1% fall in the price of unskilled labour has a larger proportionate positive effect on clerical employment (1.64%) than on unskilled employment (0.44%).

5. Unskilled labour and capital are limited substitutes.

What do these elasticities imply for the evolution of employment in response to changes in both general and relative wage levels? Given different partial elasticities of substitution for the different categories of labour, the effect of an increase in general wage levels will differ across labour type. Shadman-Meta and Sneesens (1995), in a study of the demand for skilled and unskilled labour in France over the period 1962-1989, found significantly different effects of an increase in general wage levels on the demand for skilled and unskilled labour (an elasticity of -0.25 for unskilled labour and -0.15 for skilled labour).

The implied *elasticity of total employment with respect to wages* is the response to a 1% overall increase in wages with no change in relative wages or output. This is the simple sum of the elasticities of demand with respect to each wage, i.e. $\sum_j \varepsilon_{ij}$ for $j = s, u, c$. For the medium-growth group of sectors this is -0.1 for skilled labour, -0.62 for unskilled labour and -1.77 for clerical labour. Clearly a general increase in wage levels has a large differential effect on the demand for skilled, unskilled and clerical labour.

Point estimates of firm turnover and scale effects reported in Section 6.7.1 are not significant for the medium-growth group. Firm turnover effects are jointly significant and are all biased against labour suggesting that net new firms are more capital-intensive than the average, while scale effects are both individually and jointly insignificant.

6.3.2 High-Growth Sectors

		(1)	(2)
$H_1 : \sum_j \gamma_{ij} = 0; i = h, l, c$	$\chi_2(3)$	1.38(.71)	
$H_2 : \gamma_{ij} = \gamma_{ji}, \forall i, j; j \neq i$	$\chi_2(3)$	5.54(.14)	
$H_3 : H_1 \cap H_2$	$\chi_2(6)$	7.96(.24)	
$H_4 : D_t = 0 \forall t$	$\chi_2(36)$	56.85(.01)	57.71(.01)
$H_5 : \gamma_{ij} = 0, \forall i, j; j = 1...K$	$\chi_2(12)$	56.90(.00)	93.05(.00)
$H_6 : \gamma_{iq} = 0, i = h, l, c$	$\chi_2(3)$	2.28(.51)	7.40(.06)
$H_7 : \gamma_{in} = 0, i = h, l, c$	$\chi_2(3)$	14.39(.00)	21.12(.00)
$H_8 : \gamma_{ij} = 0, \forall i, j$	$\chi_2(12)$	73.74(.00)	143.69(.00)
$H_9 : \pi_{ij2} = 0, \forall i, j$	$\chi_2(36)$	378.4(.00)	329.61(.00)
$\ln L$		2303.1	2301.8
$N * T$		99	99
		1982-1990	1982.1990
$CRIT$	0.0012	0.0009	0.0007
(1) General Specification;			
(2) With Long-run Homotheticity and Symmetry			

Table 6.5: Specification Testing of Four Equation Factor Demand System for Medium Growth Sectors: Based on Multivariate Least Squares Estimation of 6.5

Estimation was done using nonlinear least squares with standard errors robust to heteroscedasticity. The reported results in Table 6.5 indicate that homotheticity and symmetry were not rejected by the general specification (1) based on estimating equations (6.5). Re-estimation with homogeneity and symmetry imposed - specification (2) - indicated that all other long-run variables are significant, in addition the time dummies are significant.

Figures 6.7, 6.8, 6.9 and 6.10 plot the residuals from each of the four equations. Normality tests indicated that the estimated residuals are not normally distributed, as illustrated in Figure 6.11 which plots the distribution of the residuals. The full set of coefficients and standard errors for this specification are given in Section 6.7.1.

Table 6.6 gives the estimated elasticities of substitution and demand for the high-growth group. The own elasticities of substitution and demand for skilled labour is positive violating standard economic theory. However they are not significantly different from zero at the 10% level.

The signs of the Allen elasticities rank the pairwise substitutability between different factors as ranging from high substitutability for skilled-unskilled, unskilled-clerical, to limited

Allen Elasticity of Substitution, σ_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	0.95	**2.27	-3.76	*-0.31
Unskilled		**-4.71	*2.12	**0.53
Clerical			**-26.30	**0.69
Capital				-0.08
Constant-Output Elasticity of Demand, ε_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	0.05	**0.29	-0.09	*-0.25
Unskilled	**0.12	**-0.59	*0.05	**0.43
Clerical	-0.19	*0.27	**-0.62	**0.55
Capital	*-0.02	**0.07	**0.02	-0.07
Morishima Elasticity of Substitution, μ_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled		0.88	0.53	-0.18
Unskilled	0.07		0.67	0.49
Clerical	-0.24	0.86		0.62
Capital	-0.06	0.66	0.64	

Table 6.6: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: High Growth Sectors

substitutability between unskilled and capital and clerical-capital, to limited complementarity between skilled and capital, to high complementarity between skilled and clerical.

The following technical and economic relationships are implied by the elasticity of demand estimates:

1. The own elasticity of demand for skilled labour is positive but insignificantly different from zero. The own elasticity of demand for capital is also very close to zero (-0.07). The own price elasticity of demand for unskilled (-0.59) and clerical labour (-0.62) are very similar and both indicate inelastic demand.

2. Skilled labour and capital are weak complements, while unskilled labour and clerical labour are both limited substitutes for capital.

3. Skilled labour and unskilled labour and clerical and unskilled labour are substitutes. This latter contrasts directly with the results for the medium-growth group where clerical labour and unskilled labour were complements.

4. The demand for capital is estimated to have almost zero sensitivity to changes in wages.

The implied elasticity of total employment with respect to wages for the high-growth sectors is +0.25 for skilled labour, -0.42 for unskilled and -0.54 for clerical.

The point estimates in Section 6.7.1 show that long-run firm turnover effects are negative and significant for skilled labour while long-run scale effects are significant and positive for both skilled and clerical labour. Net new firms are more capital-intensive than the average while an expansion of production, controlling for sectoral firm turnover, reduces capital-intensity. There are no significant firm turnover or scale effects for unskilled labour.

Overall these results suggest that the demand for capital is highly inelastic and the demand for skilled labour marginally less so. The capital-skill complementarity hypothesis is supported while skilled and unskilled labour, and clerical and unskilled labour are substitutes in production.

6.3.3 Declining Sectors

The estimation of a full set of dynamic factor demand equations for the declining group of sectors proved extremely difficult. The general specification (6.5) of the four factor demand equations failed to converge in estimation[5] as can be seen in Table 6.7. No long-run relations were found to be significant, in addition the full set of time dummies was found to be insignificant. Specification (3) which excludes all long-run coefficients was the only estimation which achieved convergence as can be seen from the values of $CRIT$ in Table 6.7.

This specification implies a Cobb-Douglas technology with all cross-elasticities of substitution equal to one. All cross price elasticity of demand terms are equal to the factor share. The dynamic equations for the declining group are shown in Section 6.7.1. Each equation shows dynamic adjustment to the level of each factor share rather than to a set of error correction terms. There is evidence of strong short-run decreasing returns to firm turnover for unskilled labour and strong increasing returns for capital. There is also evidence of short-run increasing returns to scale for capital. We ignore the results for the declining group in further analysis.

6.3.4 Do Relative Factor Prices Explain Changes in Employment?

Table 6.9 shows the cumulative change in relative factor prices in the three sectors between 1979 and 1990. We use the estimated elasticities of demand and the change in other factor

[5]All estimation was carried out using multivariate least squares with heteroscedastic-consistent standard errors.

		(1)	(2)	(3)
$H_4 : D_t = 0 \forall t$	$\chi_2(36)$	20.2(.98)		
$H_5 : \gamma_{ij} = 0, \forall i, jj = 1...K$	$\chi_2(6)$	0.04(1.00)	0.06(1.00)	
$H_6 : \gamma_{iq} = 0, i = h, l, c$	$\chi_2(3)$	0.0001(1.00)	0.00005(1.00)	
$H_7 : \gamma_{in} = 0, i = h, l, c$	$\chi_2(3)$	0.0001(1.00)	0.00005(1.00)	
$H_8 : \gamma_{ij} = 0, \forall i, j$	$\chi_2(12)$	0.04(1.00)	0.06(1.00)	
$H_9 : \pi_{ij2} = 0, \forall i, j$	$\chi_2(36)$	124.73(.00)	54.83(.02)	323.7(.00)
$\ln L$		2665.1	2761.6	5692.4
$N * T$		261	261	261
		1982-1990	1982-1990	1982-1990
$CRIT$		6.06	874.7	0.0011
(1) With Long-Run Homotheticity and Symmetry				
(2) With Long-Run Homotheticity and Symmetry, no time dummies				
(3) Cobb-Douglas, no time dummies, no Long-Run Scale or Firm Turnover Effects				

Table 6.7: Specification Testing of Four Equation Factor Demand System for Declining Sectors: Based on Multivariate Least Squares Estimation of (6.5)

prices *relative to that factor's own price* to estimate the implied level of employment in 1990. Table 6.10 gives the resulting "guesstimates" of the change in skilled, unskilled and clerical employment between 1979 and 1990. By comparing these with the actual change we can assess how much of the total change in employment is accounted for by changes in other factor prices.

In the M group the estimates suggest that almost one-fifth of the total change in employment is attributable to movements in relative factor prices. The predicted increase in skilled employment is the wrong sign, but very small, while the predicted fall in clerical employment is greatly overestimated. The fall in unskilled employment at over 3,000 is equivalent to almost one-fifth of the total fall in unskilled employment. Clearly movements in relative factor prices did matter in the M group, particularly for unskilled labour.

By contrast in the high-growth group none of the change in employment can be attributed to movements in relative factor prices. Arguably in this group the very rapid growth in output and the number of firms, at over 340% and 80% respectively in 10 years, accounts for the large increase in employment in all categories of labour and dominates any effects due to changes in relative factor prices.

Constant-Output Elasticity of Demand, ε_{ij}				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	-0.90	0.50	0.05	0.34
Unskilled	0.10	-0.50	0.05	0.34
Clerical	0.10	0.50	-0.95	0.34
Capital	0.10	0.50	0.05	-0.66

Table 6.8: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: Declining Sectors

		High	**Medium**
Skilled/Unskilled	P_h/P_l	-6.33	2.29
Skilled/Clerical	P_h/P_l	2.67	-9.72
Unskilled/Clerical	P_h/P_l	9.61	-11.74
Skilled/Capital	P_h/P_k	-3.45	2.81
Unskilled/Capital	P_h/P_k	3.08	0.51
Clerical/Capital	P_h/P_k	-5.96	13.88
Number of Firms	NO	80.02	4.33
Gross Output	Q	342.20	35.84

Table 6.9: Cumulative Percentage Change in Relative Factor Prices, Number of Firms and Gross Output 1979-1990 (Weighted Data)

6.4 Discussion of Results

The estimation results for the medium-growth group of sectors provide a profile of the group as follows. The M group is characterised by a stable production technology where skilled labour, unskilled labour and capital are all limited substitutes in production and there is no evidence of factor-biased technical change. This group numbered over half of all manufacturing employment throughout the period under study.

The results for the high-growth group were less theoretically robust, in particular the estimated elasticity of demand for skilled labour, although insignificant, was positive. The results suggest that the H group has all the features of the production technology described in modern growth theory: skilled labour and capital are complements in production, there is strong evidence of factor-biased technology shocks and the skill-intensity of labour input is increasing over time.

The estimates of the relationship between unskilled and clerical labour are interesting. Clerical labour is a complement to unskilled labour in the M group, while it is a substitute

	Actual	Guess	%
High Growth:			
Skilled	5,111	41	1%
Unskilled	10,623	-517	-2%
Clerical	3,131	138	6%
Total	18,865	-338	-1%
Medium Growth:			
Skilled	-1,430	81	-6%
Unskilled	-16,435	-3,072	19%
Clerical	-225	-529	235%
Total	-18,090	-3,520	19%

Table 6.10: Estimates of Change in Employment Between 1979 and 1990 Using Estimated Cross Price Elasticities

for unskilled labour in the H group. In this context recall two hypotheses put forward in Chapter 4. Firstly we suggested that the outward shift in the demand curve for clerical labour reflected the positive effects of computerisation in increasing the skills of clerical labour. This is consistent with clerical labour replacing unskilled labour in the H group.

Secondly we suggested that unskilled labour in the M group has a higher level of embodied skills than in the H group, so that unskilled labour is more similar to clerical labour in this group. This is consistent with unskilled labour and clerical labour being complements in production in the M group.

In a recent paper Garcia Cervero (1997) argued that the degree of substitutability between skilled and unskilled labour is negatively related to the rate of technological progress in an industry or group of industries. Industries with relatively new technologies, where the rate of technological progress is rapid, will have very low substitutability between skilled and unskilled labour. These industries will have skill-capital complementarity in production and a higher than average share of skilled labour. By contrast industries with mature technologies, where the rate of technological progress is low, will have installed processes with more user-friendly capital which will increase the possibility of substituting (cheaper) unskilled labour for skilled labour. Skill-capital complementarity is no longer necessary and the share of skilled labour is lower than in the new technology industries.

This profile of new technology and mature technology industries can be applied to the high growth and medium-growth groups of sectors. The high growth group is concentrated in industries where the pace of technological change is very rapid, these have a higher skilled labour share than the average and there is evidence of skill-capital complementarity in production. Conversely the medium-growth group has more fixed input production processes, they have a lower skilled labour share than the average and the evidence suggests that the skilled-capital ratio is fixed in production.

Is the elasticity of substitution lower in the high growth industries? The Allen partial elasticity of substitution would suggest not, in contrast to the Garcia Cervero hypothesis. However the Morishima elasticity of substitution in response to a change in the *skilled wage* is much lower in H than M, while the Morishima elasticity of substitution in response to a change in the *unskilled wage* is higher in H than M. Therefore the hypothesis is supported if relative factor prices shift due to a change in the skilled wage but rejected if they shift due to a change in the unskilled wage.

6.5 Conclusions

In this chapter we estimated the long-run demand for three categories of labour, skilled, unskilled and clerical, jointly with the demand for capital for three groups. There were unresolved issues in estimation which means we have to approach interpretation of the results with care. Overall we found a plausible set of results for the M group of sectors, consistent with results from earlier chapters and with the general profile of the group. The results for the H group were not as good, and the results for the D group were very poor.

6.6 Specification of Dynamic Equations and Relationship with Estimated Coefficients

The following four equations are the behavioural equations from (6.2) with short-run adding up restrictions imposed:

$$\begin{aligned}\Delta S_{hst} = {} & \beta_{hh}\Delta S_{hst-1} + \beta_{hl}\Delta S_{lst-1} + \beta_{hc}\Delta S_{cst-1} + \delta_{hh0}\Delta\ln P_{hst} + \delta_{hl0}\Delta\ln P_{lst} \\ & +\delta_{hc0}\Delta\ln P_{cst} + \delta_{hk0}\Delta\ln P_{kst} + \delta_{hq0}\Delta\ln Q_{st} + \delta_{hn0}\Delta\ln NO_{st} \\ & +\delta_{hh1}\Delta\ln P_{hst-1} + \delta_{hl1}\Delta\ln P_{lst-1} + \delta_{hc1}\Delta\ln P_{cst-1} + \delta_{hk1}\Delta\ln P_{kst-1} \\ & +\delta_{hq1}\Delta\ln Q_{st-1} + \delta_{hn1}\Delta\ln NO_{st-1} \\ & -\lambda_{hh}ecm_{hst-2} - \lambda_{hl}ecm_{lst-2} - \lambda_{hc}ecm_{cst-2}\end{aligned} \tag{6.6}$$

$$\begin{aligned}\Delta S_{lst} = {} & \beta_{lh}\Delta S_{hst-1} + \beta_{ll}\Delta S_{lst-1} + \beta_{lc}\Delta S_{cst-1} + \delta_{lh0}\Delta\ln P_{hst} + \delta_{ll0}\Delta\ln P_{lst} \\ & +\delta_{lc0}\Delta\ln P_{cst} + \delta_{lk0}\Delta\ln P_{kst} + \delta_{lq0}\Delta\ln Q_{st} + \delta_{ln0}\Delta\ln NO_{st} \\ & +\delta_{lh1}\Delta\ln P_{hst-1} + \delta_{ll1}\Delta\ln P_{lst-1} + \delta_{lc1}\Delta\ln P_{cst-1} + \delta_{lk1}\Delta\ln P_{kst-1} \\ & +\delta_{lq1}\Delta\ln Q_{st-1} + \delta_{ln1}\Delta\ln NO_{st-1} \\ & -\lambda_{lh}ecm_{hst-2} - \lambda_{ll}ecm_{lst-2} - \lambda_{lc}ecm_{cst-2}\end{aligned} \tag{6.7}$$

$$\begin{aligned}\Delta S_{cst} = {} & \beta_{ch}\Delta S_{hst-1} + \beta_{cl}\Delta S_{lst-1} + \beta_{cc}\Delta S_{cst-1} + \delta_{ch0}\Delta\ln P_{hst} + \delta_{cl0}\Delta\ln P_{lst} \\ & +\delta_{cc0}\Delta\ln P_{cst} + \delta_{ck0}\Delta\ln P_{kst} + \delta_{cq0}\Delta\ln Q_{st} + \delta_{cn0}\Delta\ln NO_{st} \\ & +\delta_{ch1}\Delta\ln P_{hst-1} + \delta_{cl1}\Delta\ln P_{lst-1} + \delta_{cc1}\Delta\ln P_{cst-1} + \delta_{ck1}\Delta\ln P_{kst-1} \\ & +\delta_{cq1}\Delta\ln Q_{st-1} + \delta_{cn1}\Delta\ln NO_{st-1} \\ & -\lambda_{ch}ecm_{hst-2} - \lambda_{cl}ecm_{lst-2} - \lambda_{cc}ecm_{cst-2}\end{aligned} \tag{6.8}$$

$$\begin{aligned}\Delta S_{kst} = {} & -(\beta_{hh} + \beta_{lh} + \beta_{ch})\Delta S_{hst-1} - (\beta_{hl} + \beta_{ll} + \beta_{cl})\Delta S_{lst-1} \\ & -(\beta_{hc} + \beta_{lc} + \beta_{cc})\Delta S_{cst-1} + \delta_{kh0}\Delta\ln P_{hst} + \delta_{kl0}\Delta\ln P_{lst} \\ & +\delta_{kc0}\Delta\ln P_{cst} + \delta_{kk0}\Delta\ln P_{kst} + \delta_{kq0}\Delta\ln Q_{st} + \delta_{kn0}\Delta\ln NO_{st} \\ & +\delta_{kh1}\Delta\ln P_{hst-1} + \delta_{kl1}\Delta\ln P_{lst-1} + \delta_{kc1}\Delta\ln P_{cst-1} + \delta_{kk1}\Delta\ln P_{kst-1} \\ & +\delta_{kq1}\Delta\ln Q_{st-1} + \delta_{kn1}\Delta\ln NO_{st-1} \\ & +(\lambda_{hh} + \lambda_{lh} + \lambda_{ch})ecm_{hst-2} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl})ecm_{lst-2} \\ & +(\lambda_{hc} + \lambda_{lc} + \lambda_{cc})ecm_{cst-2}\end{aligned} \tag{6.9}$$

6.6.1 The Short-Run Adjustment Coefficients

The π coefficients which are estimated using the set of first difference equations (6.5) identify the short-run adjustment coefficients as follows:

Factor h: Short-Run Adjustment Coefficients:	
$\pi_{hH1} = 1 + \beta_{hh}$	$\pi_{hH2} = -\beta_{hh} - \lambda_{hh}$
$\pi_{hL1} = \beta_{hl}$	$\pi_{hL2} = -\beta_{hl} - \lambda_{hl}$
$\pi_{hC1} = \beta_{hc}$	$\pi_{hC2} = -\beta_{hc} - \lambda_{hc}$
$\pi_{hh0} = \delta_{hh0}$	$\pi_{hh1} = \delta_{hh1} - \delta_{hh0}$
$\pi_{hl0} = \delta_{hl0}$	$\pi_{hl1} = \delta_{hl1} - \delta_{hl0}$
$\pi_{hc0} = \delta_{hc0}$	$\pi_{hc1} = \delta_{hc1} - \delta_{hc0}$
$\pi_{hk0} = \delta_{hk0}$	$\pi_{hk1} = \delta_{hk1} - \delta_{hk0}$
$\pi_{hq0} = \delta_{hq0}$	$\pi_{hq1} = \delta_{hq1} - \delta_{hq0}$
$\pi_{hn0} = \delta_{hn0} - \delta_{hq0}$	$\pi_{hn1} = (\delta_{hn1} - \delta_{hn0}) - (\delta_{hq1} - \delta_{hq0})$

Factor l: Short-Run Adjustment Coefficients:	
$\pi_{lH1} = \beta_{lh}$	$\pi_{lH2} = -\beta_{lh} - \lambda_{lh}$
$\pi_{lL1} = 1 + \beta_{ll}$	$\pi_{lL2} = -\beta_{ll} - \lambda_{ll}$
$\pi_{lC1} = \beta_{lc}$	$\pi_{lC2} = -\beta_{lc} - \lambda_{lc}$
$\pi_{lh0} = \delta_{lh0}$	$\pi_{lh1} = \delta_{lh1} - \delta_{lh0}$
$\pi_{ll0} = \delta_{ll0}$	$\pi_{ll1} = \delta_{ll1} - \delta_{ll0}$
$\pi_{lc0} = \delta_{lc0}$	$\pi_{lc1} = \delta_{lc1} - \delta_{lc0}$
$\pi_{lk0} = \delta_{lk0}$	$\pi_{lk1} = \delta_{lk1} - \delta_{lk0}$
$\pi_{lq0} = \delta_{lq0}$	$\pi_{lq1} = \delta_{lq1} - \delta_{lq0}$
$\pi_{ln0} = \delta_{ln0} - \delta_{lq0}$	$\pi_{ln1} = (\delta_{ln1} - \delta_{ln0}) - (\delta_{lq1} - \delta_{lq0})$

Factor c: Short-Run Adjustment Coefficients:	
$\pi_{cH1} = \beta_{ch}$	$\pi_{cH2} = -\beta_{ch} - \lambda_{ch}$
$\pi_{cL1} = \beta_{cl}$	$\pi_{cL2} = -\beta_{cl} - \lambda_{cl}$
$\pi_{cC1} = 1 + \beta_{cc}$	$\pi_{cC2} = -\beta_{cc} - \lambda_{cc}$
$\pi_{ch0} = \delta_{ch0}$	$\pi_{ch1} = \delta_{ch1} - \delta_{ch0}$
$\pi_{cl0} = \delta_{cl0}$	$\pi_{cl1} = \delta_{cl1} - \delta_{cl0}$
$\pi_{cc0} = \delta_{cc0}$	$\pi_{cc1} = \delta_{cc1} - \delta_{cc0}$
$\pi_{ck0} = \delta_{ck0}$	$\pi_{ck1} = \delta_{ck1} - \delta_{ck0}$
$\pi_{cq0} = \delta_{cq0}$	$\pi_{cq1} = \delta_{cq1} - \delta_{cq0}$
$\pi_{cn0} = \delta_{cn0} - \delta_{cq0}$	$\pi_{cn1} = (\delta_{cn1} - \delta_{cn0}) - (\delta_{cq1} - \delta_{cq0})$

Factor k: Short-Run Adjustment Coefficients:

$$\begin{array}{ll}
\pi_{kH1} = -(\beta_{hh} + \beta_{lh} + \beta_{ch}) & \pi_{kH2} = -(\beta_{hh} + \beta_{lh} + \beta_{ch}) - (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \\
\pi_{kL1} = -(\beta_{hl} + \beta_{ll} + \beta_{hl}) & \pi_{kL2} = -(\beta_{hl} + \beta_{ll} + \beta_{hl}) - (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \\
\pi_{kC1} = -(\beta_{hc} + \beta_{lc} + \beta_{cc}) & \pi_{kC2} = -(\beta_{hc} + \beta_{lc} + \beta_{cc}) - (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \\
\pi_{kh0} = \delta_{kh0} & \pi_{kh1} = \delta_{kh1} - \delta_{kh0} \\
\pi_{kl0} = \delta_{kl0} & \pi_{kl1} = \delta_{kl1} - \delta_{kl0} \\
\pi_{kc0} = \delta_{kc0} & \pi_{kc1} = \delta_{kc1} - \delta_{kc0} \\
\pi_{kk0} = \delta_{kk0} & \pi_{kk1} = \delta_{kk1} - \delta_{kk0} \\
\pi_{kq0} = \delta_{kq0} & \pi_{kq1} = \delta_{kq1} - \delta_{kq0} \\
\pi_{kn0} = \delta_{kn0} - \delta_{kq0} & \pi_{kn1} = (\delta_{kn1} - \delta_{kn0}) - (\delta_{kq1} - \delta_{kq0})
\end{array}$$

Using these estimated coefficients (which include the adding up restrictions on the short-run coefficients used for identification)) the parameters of B^n, D_0, D_1 and Λ_n in equation (6.2) can be recovered:

$$\begin{bmatrix} \beta_{hh} & \beta_{hl} & \beta_{hc} \\ \beta_{lh} & \beta_{ll} & \beta_{lc} \\ \beta_{ch} & \beta_{cl} & \beta_{cc} \\ \beta_{kh} & \beta_{kl} & \beta_{kc} \end{bmatrix} = \begin{bmatrix} \pi_{hH1} - 1 & \pi_{hL1} & \pi_{hC1} \\ \pi_{lH1} & \pi_{lL1} - 1 & \pi_{lC1} \\ \pi_{cH1} & \pi_{cL1} & \pi_{cC1} - 1 \\ 1 - \pi_{hH1} - \pi_{lH1} - \pi_{cH1} & 1 - \pi_{hL1} - \pi_{lL1} - \pi_{cL1} & 1 - \pi_{hC1} - \pi_{lC1} - \pi_{cC1} \end{bmatrix}$$

This matrix of twelve coefficients is estimated with nine free parameters and three adding-up restrictions.

$$\begin{bmatrix} \delta_{hh0} & \delta_{hl0} & \delta_{hc0} & \delta_{hk0} & \delta_{hq0} & \delta_{hn0} \\ \delta_{lh0} & \delta_{ll0} & \delta_{lc0} & \delta_{lk0} & \delta_{lq0} & \delta_{ln0} \\ \delta_{ch0} & \delta_{cl0} & \delta_{cc0} & \delta_{ck0} & \delta_{cq0} & \delta_{cn0} \\ \delta_{kh0} & \delta_{kl0} & \delta_{kc0} & \delta_{kk0} & \delta_{kq0} & \delta_{kn0} \end{bmatrix} = \begin{bmatrix} \pi_{hh0} & \pi_{hl0} & \pi_{hc0} & \pi_{hk0} & \pi_{hq0} & \pi_{hn0} + \pi_{hq0} \\ \pi_{lh0} & \pi_{ll0} & \pi_{lc0} & \pi_{lk0} & \pi_{lq0} & \pi_{ln0} + \pi_{lq0} \\ \pi_{ch0} & \pi_{cl0} & \pi_{cc0} & \pi_{ck0} & \pi_{cq0} & \pi_{cn0} + \pi_{cq0} \\ \pi_{kh0} & \pi_{kl0} & \pi_{kc0} & \pi_{kk0} & \pi_{kq0} & \pi_{kn0} + \pi_{kq0} \end{bmatrix}$$

This matrix of twenty-four coefficients is estimated without restrictions.

$$\begin{bmatrix} \delta_{hh1} & \delta_{hl1} & \delta_{hc1} & \delta_{hk1} & \delta_{hq1} & \delta_{hn1} \\ \delta_{lh1} & \delta_{ll1} & \delta_{lc1} & \delta_{lk1} & \delta_{lq1} & \delta_{ln1} \\ \delta_{ch1} & \delta_{cl1} & \delta_{cc1} & \delta_{ck1} & \delta_{cq1} & \delta_{cn1} \\ \delta_{kh1} & \delta_{kl1} & \delta_{kc1} & \delta_{kk1} & \delta_{kq1} & \delta_{kn1} \end{bmatrix}$$

$$= \begin{bmatrix} \pi_{hh1} + \pi_{hh0} & \pi_{hl1} + \pi_{hl0} & \pi_{hc1} + \pi_{hc0} & \pi_{hk1} + \pi_{hk0} & \pi_{hq1} + \pi_{hq0} & \pi_{hn1} + \pi_{hq1} + \pi_{hn0} + \pi_{hq0} \\ \pi_{lh1} + \pi_{lh0} & \pi_{ll1} + \pi_{ll0} & \pi_{lc1} + \pi_{lc0} & \pi_{lk1} + \pi_{lk0} & \pi_{lq1} + \pi_{lq0} & \pi_{ln1} + \pi_{lq1} + \pi_{ln0} + \pi_{lq0} \\ \pi_{ch1} + \pi_{ch0} & \pi_{cl1} + \pi_{cl0} & \pi_{cc1} + \pi_{cc0} & \pi_{ck1} + \pi_{ck0} & \pi_{cq1} + \pi_{cq0} & \pi_{cn1} + \pi_{cq1} + \pi_{cn0} + \pi_{cq0} \\ \pi_{kh1} + \pi_{kh0} & \pi_{kl1} + \pi_{kl0} & \pi_{kc1} + \pi_{kc0} & \pi_{kk1} + \pi_{kk0} & \pi_{kq1} + \pi_{kq0} & \pi_{kn1} + \pi_{kq1} + \pi_{kn0} + \pi_{kq0} \end{bmatrix}$$

This matrix of twenty-four coefficients is estimated without restrictions.

$$\begin{bmatrix} \lambda_{hh} & \lambda_{hl} & \lambda_{hc} \\ \lambda_{lh} & \lambda_{ll} & \lambda_{lc} \\ \lambda_{ch} & \lambda_{cl} & \lambda_{cc} \\ \lambda_{kh} & \lambda_{kl} & \lambda_{kc} \end{bmatrix} = \begin{bmatrix} 1 - \pi_{hH1} - \pi_{hH2} & -\pi_{hL2} - \pi_{hL1} & -\pi_{hC1} - \pi_{hC2} \\ -\pi_{lH1} - \pi_{lH2} & 1 - \pi_{lL2} - \pi_{lL1} & -\pi_{lC1} - \pi_{lC2} \\ -\pi_{cH1} - \pi_{cH2} & -\pi_{cL2} - \pi_{cL1} & 1 - \pi_{cC1} - \pi_{cC2} \\ \sum_{t=1,2}\sum_{i=h,l,c}\pi_{iHt} - 1 & \sum_{t=1,2}\sum_{i=h,l,c}\pi_{iLt} - 1 & \sum_{t=1,2}\sum_{i=h,l,c}\pi_{iCt} - 1 \end{bmatrix}$$

This matrix of twelve coefficients is estimated with nine free parameters and three adding-up restrictions.

6.6.2 The Long-Run Parameters

Factor h: Long-Run Parameters:

$\pi_{hh2} = \lambda_{hh} \cdot \gamma_{hh} + \lambda_{hl} \cdot \gamma_{lh} + \lambda_{hc} \cdot \gamma_{ch} - \delta_{hh1}$

$\pi_{hl2} = \lambda_{hh} \cdot \gamma_{hl} + \lambda_{hl} \cdot \gamma_{ll} + \lambda_{hc} \cdot \gamma_{cl} - \delta_{hl1}$

$\pi_{hc2} = \lambda_{hh} \cdot \gamma_{hc} + \lambda_{hl} \cdot \gamma_{lc} + \lambda_{hc} \cdot \gamma_{cc} - \delta_{hc1}$

$\pi_{hk2} = \lambda_{hh} \cdot \gamma_{hk} + \lambda_{hl} \cdot \gamma_{lk} + \lambda_{hc} \cdot \gamma_{ck} - \delta_{hk1}$

$\pi_{hq2} = \lambda_{hh} \cdot \gamma_{hq} + \lambda_{hl} \cdot \gamma_{lq} + \lambda_{hc} \cdot \gamma_{cq} - \delta_{hq1}$

$\pi_{hn2} = \lambda_{hh} \cdot (\gamma_{hn} - \gamma_{hq}) + \lambda_{hl} \cdot (\gamma_{ln} - \gamma_{lq}) + \lambda_{hc} \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{hn1} - \delta_{hq1})$

Factor l: Long-Run Parameters:

$\pi_{lh2} = \lambda_{lh} \cdot \gamma_{hh} + \lambda_{ll} \cdot \gamma_{lh} + \lambda_{lc} \cdot \gamma_{ch} - \delta_{lh1}$

$\pi_{ll2} = \lambda_{lh} \cdot \gamma_{hl} + \lambda_{ll} \cdot \gamma_{ll} + \lambda_{lc} \cdot \gamma_{cl} - \delta_{ll1}$

$\pi_{lc2} = \lambda_{lh} \cdot \gamma_{hc} + \lambda_{ll} \cdot \gamma_{lc} - \lambda_{lc} \cdot \gamma_{cc} - \delta_{lc1}$

$\pi_{lk2} = \lambda_{lh} \cdot \gamma_{hk} + \lambda_{ll} \cdot \gamma_{lk} + \lambda_{lc} \cdot \gamma_{ck} - \delta_{lk1}$

$\pi_{lq2} = \lambda_{lh} \cdot \gamma_{hq} + \lambda_{ll} \cdot \gamma_{lq} + \lambda_{lc} \cdot \gamma_{cq} - \delta_{lq1}$

$\pi_{ln2} = \lambda_{lh} \cdot (\gamma_{hn} - \gamma_{hq}) + \lambda_{ll} \cdot (\gamma_{ln} - \gamma_{lq}) + \lambda_{lc} \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{ln1} - \delta_{lq1}$

Factor c: Long-Run Parameters:

$\pi_{ch2} = \lambda_{ch} \cdot \gamma_{hh} + \lambda_{cl} \cdot \gamma_{lh} + \lambda_{cc} \cdot \gamma_{ch} - \delta_{ch1}$
$\pi_{cl2} = \lambda_{ch} \cdot \gamma_{hl} + \lambda_{cl} \cdot \gamma_{ll} + \lambda_{cc} \cdot \gamma_{cl} - \delta_{cl1}$
$\pi_{cc2} = \lambda_{ch} \cdot \gamma_{hc} + \lambda_{cl} \cdot \gamma_{lc} + \lambda_{cc} \cdot \gamma_{cc} - \delta_{cc1}$
$\pi_{ck2} = \lambda_{ch} \cdot \gamma_{hk} + \lambda_{cl} \cdot \gamma_{lk} + \lambda_{cc} \cdot \gamma_{ck} - \delta_{ck1}$
$\pi_{cq2} = \lambda_{ch} \cdot \gamma_{hq} + \lambda_{cl} \cdot \gamma_{lq} + \lambda_{cc} \cdot \gamma_{cq} - \delta_{cq1}$
$\pi_{cn2} = \lambda_{ch} \cdot (\gamma_{hn} - \gamma_{hq}) + \lambda_{cl} \cdot (\gamma_{ln} - \gamma_{lq}) + \lambda_{cc} \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{cn1} - \delta_{cq1})$

Factor k: Long-Run Parameters:

$\pi_{kh2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hh} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{lh} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{ch} - \delta_{kh1}$
$\pi_{kl2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hl} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{ll} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{cl} - \delta_{kl1}$
$\pi_{kc2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hc} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{lc} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{cc} - \delta_{kc1}$
$\pi_{kk2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hk} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{lk} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{ck} - \delta_{kk1}$
$\pi_{kq2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hq} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{lq} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{cq} - \delta_{kq1}$
$\pi_{kn2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot (\gamma_{hn} - \gamma_{hq}) + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot (\gamma_{ln} - \gamma_{lq})$
$\quad +(\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{kn1} - \delta_{kq1})$

The behavioural parameters of interest can be recovered from the estimated parameters as follows:

$$\Gamma_n = \begin{bmatrix} \gamma_{hh} & \gamma_{hl} & \gamma_{hc} & \gamma_{hk} & \gamma_{hq} & \gamma_{hn} \\ \gamma_{lh} & \gamma_{ll} & \gamma_{lc} & \gamma_{lk} & \gamma_{lq} & \gamma_{ln} \\ \gamma_{ch} & \gamma_{cl} & \gamma_{cc} & \gamma_{ck} & \gamma_{cq} & \gamma_{cn} \end{bmatrix} = \begin{bmatrix} 1 - \pi_{hH1} - \pi_{hH2} & -\pi_{hL2} - \pi_{hL1} & -\pi_{hC1} - \pi_{hC2} \\ -\pi_{lH1} - \pi_{lH2} & 1 - \pi_{lL2} - \pi_{lL1} & -\pi_{lC1} - \pi_{lC2} \\ -\pi_{cH1} - \pi_{cH2} & -\pi_{cL2} - \pi_{cL1} & 1 - \pi_{cC1} - \pi_{cC2} \end{bmatrix}^{-1}$$
$$\cdot \begin{bmatrix} \sum_{t=0,1,2} \pi_{hht} & \sum_{t=0,1,2} \pi_{hlt} & \sum_{t=0,1,2} \pi_{hct} & \sum_{t=0,1,2} \pi_{hkt} & \sum_{t=0,1,2} \pi_{hqt} & \sum_{t=0,1,2}(\pi_{hnt} + \pi_{hqt}) \\ \sum_{t=0,1,2} \pi_{lht} & \sum_{t=0,1,2} \pi_{llt} & \sum_{t=0,1,2} \pi_{lct} & \sum_{t=0,1,2} \pi_{lkt} & \sum_{t=0,1,2} \pi_{lqt} & \sum_{t=0,1,2}(\pi_{lnt} + \pi_{lqt}) \\ \sum_{t=0,1,2} \pi_{cht} & \sum_{t=0,1,2} \pi_{clt} & \sum_{t=0,1,2} \pi_{cct} & \sum_{t=0,1,2} \pi_{ckt} & \sum_{t=0,1,2} \pi_{cqt} & \sum_{t=0,1,2}(\pi_{cnt} + \pi_{cqt}) \end{bmatrix}$$

Note that the linear dependent coefficients in the capital services equation are excluded so that each matrix here is of full rank. The long-run parameters of the capital services equation are derived as an identity given the adding-up condition:

Parameters for Factor Capital:		
$\gamma_{kh} = -(\gamma_{hh} + \gamma_{lh} + \gamma_{ch})$	$\gamma_{kl} = -(\gamma_{hl} + \gamma_{ll} + \gamma_{cl})$	$\gamma_{kc} = -(\gamma_{hc} + \gamma_{lc} + \gamma_{cc})$
$\gamma_{kk} = -(\gamma_{hk} + \gamma_{lk} + \gamma_{ck})$	$\gamma_{kq} = -(\gamma_{hq} + \gamma_{lq} + \gamma_{cq})$	$\gamma_{kn} = -(\gamma_{hn} + \gamma_{ln} + \gamma_{cn})$

Finally the theoretical restrictions of price homogeneity and symmetry can be tested using the following relations:

Price Homogeneity:		
$\gamma_{hh} = -(\gamma_{hl} + \gamma_{hc} + \gamma_{hk})$	$\gamma_{ll} = -(\gamma_{lh} + \gamma_{lc} + \gamma_{lk})$	$\gamma_{cc} = -(\gamma_{ch} + \gamma_{cl} + \gamma_{ck})$
Symmetry:		
$\gamma_{hl} = \gamma_{lh}$	$\gamma_{hc} = \gamma_{ch}$	$\gamma_{lc} = \gamma_{cl}$
Symmetry applied to Capital Services Equation:		
$\gamma_{kh} = \gamma_{hk}$	$\gamma_{kl} = \gamma_{lk}$	$\gamma_{kc} = \gamma_{ck}$

6.7 The Empirical Results in More Detail

6.7.1 The Estimated Equations

Medium Growth Sectors:

Equation for Skilled Labour

$$\begin{aligned}\Delta S_{hst} = & - \underset{(.22)}{1.34}\,\Delta S_{hst-1} - \underset{(.16)}{0.12}\,\Delta S_{lst-1} - \underset{(.29)}{0.42}\,\Delta S_{cst-1} + \underset{(.03)}{0.10}\,\Delta \ln P_{hst} - \underset{(.05)}{0.03}\,\Delta \ln P_{lst} \\ & - \underset{(.02)}{0.02}\,\Delta \ln P_{cst} - \underset{(.01)}{0.02}\,\Delta \ln P_{kst} - \underset{(.05)}{0.05}\,\Delta \ln Q_{st} - \underset{(.03)}{0.03}\,\Delta \ln NO_{st} \\ & + \underset{(.03)}{0.09}\,\Delta \ln P_{hst-1} - \underset{(.04)}{0.03}\,\Delta \ln P_{lst-1} + \underset{(.03)}{.002}\,\Delta \ln P_{cst-1} - \underset{(.01)}{0.02}\,\Delta \ln P_{kst-1} \\ & - \underset{(.07)}{0.10}\,\Delta \ln Q_{st-1} - \underset{(.03)}{0.10}\,\Delta \ln NO_{st-1} \\ & - \underset{(.37)}{1.59}\,ecm_{hst-2} - \underset{(.15)}{0.16}\,ecm_{lst-2} - \underset{(.39)}{0.40}\,ecm_{cst-2}\end{aligned}$$

Equation for Unskilled Labour

$$\begin{aligned}\Delta S_{lst} = & - \underset{(..50)}{0.34}\,\Delta S_{hst-1} - \underset{(.33)}{0.56}\,\Delta S_{lst-1} + \underset{(.58)}{0.15}\,\Delta S_{cst-1} + \underset{(.07)}{0.06}\,\Delta \ln P_{hst} + \underset{(.08)}{0.12}\,\Delta \ln P_{lst} \\ & + \underset{(.05)}{0.000003}\,\Delta \ln P_{cst} - \underset{(.03)}{0.004}\,\Delta \ln P_{kst} - \underset{(.13)}{0.26}\,\Delta \ln Q_{st} - \underset{(.09)}{0.26}\,\Delta \ln NO_{st} \\ & - \underset{(.09)}{0.05}\,\Delta \ln P_{hst-1} + \underset{(.09)}{0.02}\,\Delta \ln P_{lst-1} - \underset{(.05)}{0.06}\,\Delta \ln P_{cst-1} - \underset{(.02)}{0.01}\,\Delta \ln P_{kst-1} \\ & - \underset{(.13)}{0.02}\,\Delta \ln Q_{st-1} - \underset{(.07)}{0.14}\,\Delta \ln NO_{st-1} \\ & + \underset{(.65)}{0.007}\,ecm_{hst-2} - \underset{(.36)}{0.79}\,ecm_{lst-2} + \underset{(.68)}{0.36}\,ecm_{cst-2}\end{aligned}$$

Equation for Clerical Labour

$$\Delta S_{cst} = \underset{(.24)}{0.27}\,\Delta S_{hst-1} + \underset{(.20)}{0.37}\,\Delta S_{lst-1} - \underset{(.21)}{0.61}\,\Delta S_{cst-1} - \underset{(.03)}{0.04}\,\Delta \ln P_{hst} - \underset{(.05)}{0.07}\,\Delta \ln P_{lst}$$
$$+ \underset{(.03)}{0.06}\,\Delta \ln P_{cst} + \underset{(.01)}{0.008}\,\Delta \ln P_{kst} - \underset{(.07)}{0.12}\,\Delta \ln Q_{st} - \underset{(.04)}{0.09}\,\Delta \ln NO_{st}$$
$$- \underset{(.04)}{0.07}\,\Delta \ln P_{hst-1} - \underset{(.06)}{0.13}\,\Delta \ln P_{lst-1} + \underset{(.03)}{0.04}\,\Delta \ln P_{cst-1} + \underset{(.02)}{0.02}\,\Delta \ln P_{kst-1}$$
$$+ \underset{(.10)}{0.08}\,\Delta \ln Q_{st-1} + \underset{(.05)}{0.04}\,\Delta \ln NO_{st-1}$$
$$+ \underset{(.44)}{0.52}\,ecm_{hst-2} + \underset{(.16)}{0.27}\,ecm_{lst-2} - \underset{(.49)}{0.41}\,ecm_{cst-2}$$

Equation for Capital

$$\Delta S_{kst} = 1.41\Delta S_{hst-1} - 0.31\Delta S_{lst-1} + 0.87\Delta S_{cst-1} - \underset{(.11)}{0.20}\,\Delta \ln P_{hst} - \underset{(.14)}{0.12}\,\Delta \ln P_{lst}$$
$$- \underset{(.05)}{0.02}\,\Delta \ln P_{cst} + \underset{(.03)}{0.04}\,\Delta \ln P_{kst} + \underset{(.14)}{0.30}\,\Delta \ln Q_{st} - \underset{(.10)}{0.16}\,\Delta \ln NO_{st}$$
$$- \underset{(.11)}{0.09}\,\Delta \ln P_{hst-1} - \underset{(.11)}{0.09}\,\Delta \ln P_{lst-1} - \underset{(.07)}{0.04}\,\Delta \ln P_{cst-1} + \underset{(.04)}{0.05}\,\Delta \ln P_{kst-1}$$
$$+ \underset{(.14)}{0.37}\,\Delta \ln Q_{st-1} - \underset{(.16)}{0.008}\,\Delta \ln NO_{st-1}$$
$$+1.06 ecm_{hst-2} + 0.67 ecm_{lst-2} + 0.45 ecm_{cst-2}$$

Error Correction Terms

$$ecm_{hst} =$$
$$S_{hst} - \alpha_{hs} - \underset{(.023)}{.041}\ln P_{hst} - \underset{(.013)}{.012}\ln P_{lst} + \underset{(.042)}{.007}\ln P_{cst} - \underset{(.036)}{.036}\ln P_{kst} - \underset{(.157)}{.112}\ln Q_{st} - \underset{(.049)}{.051}\ln NO_{st}$$
$$ecm_{lst} =$$
$$S_{lst} - \alpha_{ls} - \underset{(.013)}{.012}\ln P_{hst} - \underset{(.069)}{.068}\ln P_{lst} - \underset{(.061)}{.110}\ln P_{cst} + \underset{(.101)}{.054}\ln P_{kst} + \underset{(.359)}{.234}\ln Q_{st} - \underset{(.149)}{.074}\ln NO_{st}$$
$$ecm_{cst} =$$
$$S_{cst} - \alpha_{cs} + \underset{(.042)}{.007}\ln P_{hst} - \underset{(.061)}{.110}\ln P_{lst} - \underset{(.095)}{.032}\ln P_{cst} + \underset{(.103)}{.071}\ln P_{kst} + \underset{(.366)}{.193}\ln Q_{st} - \underset{(.126)}{.010}\,\gamma_{cn}\ln NO_{st}$$

High Growth Sectors

Equation for Skilled Labour

$$\Delta S_{hst} = -\underset{(.10)}{0.72}\,\Delta S_{hst-1} + \underset{(.05)}{0.21}\,\Delta S_{lst-1} + \underset{(.23)}{0.08}\,\Delta S_{cst-1} + \underset{(.01)}{0.04}\,\Delta \ln P_{hst} + \underset{(.01)}{0.03}\,\Delta \ln P_{lst}$$
$$- \underset{(.003)}{0.005}\,\Delta \ln P_{cst} - \underset{(.006)}{0.02}\,\Delta \ln P_{kst} - \underset{(.01)}{0.006}\,\Delta \ln Q_{st} - \underset{(.01)}{0.04}\,\Delta \ln NO_{st}$$
$$+ \underset{(.01)}{0.03}\,\Delta \ln P_{hst-1} - \underset{(.018)}{0.024}\,\Delta \ln P_{lst-1} - \underset{(.006)}{0.01}\,\Delta \ln P_{cst-1} - \underset{(.008)}{0.02}\,\Delta \ln P_{kst-1}$$
$$+ \underset{(.01)}{0.0005}\,\Delta \ln Q_{st-1} - \underset{(.01)}{0.01}\,\Delta \ln NO_{st-1} - \underset{(.09)}{0.75}\,ecm_{hst-2} + \underset{(.05)}{0.14}\,ecm_{lst-2} + \underset{(.25)}{0.20}\,ecm_{cst-2}$$
$$+ \underset{(.0003)}{.0003}\,D_{h82} - \underset{(.0003)}{.0002}\,D_{h83} - \underset{(.0002)}{.0002}\,D_{h84} - \underset{(.0004)}{.0006}\,D_{h85}$$
$$- \underset{(.0002)}{.0001}\,D_{h86} + \underset{(.0003)}{.0004}\,D_{h87} + \underset{(.0001)}{.00003}\,D_{h88} + \underset{(.0002)}{.00002}\,D_{h89} - \underset{(.0004)}{.0004}\,D_{h90}$$

Equation for Unskilled Labour

$$\Delta S_{lst} = \underset{(.21)}{1.05}\,\Delta S_{hst-1} + \underset{(.12)}{0.32}\,\Delta S_{lst-1} + \underset{(.51)}{1.78}\,\Delta S_{cst-1} + \underset{(.06)}{0.03}\,\Delta \ln P_{hst} + \underset{(.07)}{0.19}\,\Delta \ln P_{lst}$$
$$+ \underset{(.01)}{0.002}\,\Delta \ln P_{cst} + \underset{(.03)}{0.06}\,\Delta \ln P_{kst} - \underset{(.07)}{0.05}\,\Delta \ln Q_{st} - \underset{(.05)}{0.11}\,\Delta \ln NO_{st}$$
$$+ \underset{(.06)}{0.02}\,\Delta \ln P_{hst-1} - \underset{(.07)}{0.08}\,\Delta \ln P_{lst-1} - \underset{(.02)}{0.05}\,\Delta \ln P_{cst-1} + \underset{(.03)}{0.03}\,\Delta \ln P_{kst-1}$$
$$+ \underset{(.04)}{0.07}\,\Delta \ln Q_{st-1} + \underset{(.04)}{0.09}\,\Delta \ln NO_{st-1} + \underset{(.26)}{1.39}\,ecm_{hst-2} + \underset{(.14)}{0.33}\,ecm_{lst-2} + \underset{(.54)}{1.46}\,ecm_{cst-2}$$
$$+ \underset{(.001)}{.0005}\,D_{h82} - \underset{(.001)}{.0013}\,D_{h83} - \underset{(.001)}{.0015}\,D_{h84} - \underset{(.001)}{.0037}\,D_{h85}$$
$$+ \underset{(.001)}{.0011}\,D_{h86} + \underset{(.001)}{.0004}\,D_{h87} - \underset{(.001)}{.00002}\,D_{h88} - \underset{(.001)}{0.0002}\,D_{h89} - \underset{(.001)}{.0024}\,D_{h90}$$

Equation for Clerical Labour

$$\Delta S_{cst} = \underset{(.07)}{0.25}\,\Delta S_{hst-1} + \underset{(.03)}{0.26}\,\Delta S_{lst-1} - \underset{(.10)}{1.29}\,\Delta S_{cst-1} + \underset{(.01)}{0.003}\,\Delta \ln P_{hst} + \underset{(.01)}{0.03}\,\Delta \ln P_{lst}$$
$$+ \underset{(.003)}{0.01}\,\Delta \ln P_{cst} + \underset{(.006)}{0.008}\,\Delta \ln P_{kst} - \underset{(.01)}{0.01}\,\Delta \ln Q_{st} - \underset{(.01)}{0.02}\,\Delta \ln NO_{st}$$
$$- \underset{(.01)}{0.01}\,\Delta \ln P_{hst-1} - \underset{(.01)}{0.01}\,\Delta \ln P_{lst-1} + \underset{(.006)}{0.008}\,\Delta \ln P_{cst-1} + \underset{(.006)}{0.006}\,\Delta \ln P_{kst-1}$$
$$+ \underset{(.01)}{0.014}\,\Delta \ln Q_{st-1} + \underset{(.008)}{0.02}\,\Delta \ln NO_{st-1} + \underset{(.09)}{0.33}\,ecm_{hst-2} + \underset{(.04)}{0.26}\,ecm_{lst-2} - \underset{(.16)}{1.49}\,ecm_{cst-2}$$
$$- \underset{(.0002)}{.0001}\,D_{h82} - \underset{(.0002)}{.0002}\,D_{h83} - \underset{(.0002)}{.0004}\,D_{h84} - \underset{(.0003)}{.0006}\,D_{h85}$$
$$+ \underset{(.0002)}{.0001}\,D_{h86} + \underset{(.0002)}{.0001}\,D_{h87} + \underset{(.0001)}{.00004}\,D_{h88} - \underset{(.0002)}{.00007}\,D_{h89} - \underset{(.0003)}{.0004}\,D_{h90}$$

Equation for Capital

$$\Delta S_{kst} = -0.58\Delta S_{hst-1} - 0.79\Delta S_{lst-1} - 0.57\Delta S_{cst-1} - \underset{(.05)}{0.05}\,\Delta \ln P_{hst} - \underset{(.05)}{0.15}\,\Delta \ln P_{lst}$$
$$- \underset{(.01)}{0.02}\,\Delta \ln P_{cst} + \underset{(.02)}{0.04}\,\Delta \ln P_{kst} + \underset{(.05)}{0.03}\,\Delta \ln Q_{st} + \underset{(.04)}{0.12}\,\Delta \ln NO_{st}$$
$$- \underset{(.05)}{0.09}\,\Delta \ln P_{hst-1} + \underset{(.07)}{0.05}\,\Delta \ln P_{lst-1} + \underset{(.01)}{0.02}\,\Delta \ln P_{cst-1} + \underset{(.03)}{0.06}\,\Delta \ln P_{kst-1}$$
$$- \underset{(.03)}{0.04}\,\Delta \ln Q_{st-1} + \underset{(.04)}{0.006}\,\Delta \ln NO_{st-1} - 0.98ecm_{hst-2} - 0.72ecm_{lst-2} - 0.17ecm_{cst-2}$$
$$- \underset{(.001)}{.001}\,D_{h82} + \underset{(.001)}{.001}\,D_{h83} + \underset{(.0008)}{.0001}\,D_{h84} + \underset{(.0013)}{.0024}\,D_{h85}$$
$$+ \underset{(.001)}{.00006}\,D_{h86} - \underset{(.0009)}{.0013}\,D_{h87} - \underset{(.0006)}{.00006}\,D_{h88} - \underset{(.001)}{.0003}\,D_{h89} + \underset{(.0012)}{.0017}\,D_{h90}$$

Error Correction Terms:

$$ecm_{hst} = S_{hst} - \alpha_{hs} - \underset{(.01)}{.051}\ln P_{hst} + \underset{(.007)}{.008}\ln P_{lst} - \underset{(.004)}{.006}\ln P_{cst} - \underset{(.009)}{.054}\ln P_{kst} + \underset{(.006)}{.012}\ln Q_{st} - \underset{(.005)}{.023}\ln NC$$

$$ecm_{lst} = S_{lst} - \alpha_{ls} + \underset{(.007)}{.008}\ln P_{hst} - \underset{(.018)}{.035}\ln P_{lst} + \underset{(.004)}{.003}\ln P_{cst} - \underset{(.023)}{.047}\ln P_{kst} + \underset{(.018)}{.011}\ln Q_{st} - \underset{(.038)}{.014}\ln NO$$

$$ecm_{cst} = S_{cst} - \alpha_{cs} - \underset{(.004)}{.006}\ln P_{hst} + \underset{(.004)}{.003}\ln P_{lst} - \underset{(.095)}{.032}\ln P_{cst} - \underset{(.003)}{.008}\ln P_{kst} + \underset{(.003)}{.009}\ln Q_{st} - \underset{(.005)}{.003}\gamma_{cn}\ln N$$

Declining Sectors

Equation for Skilled Labour

$$\begin{aligned}\Delta S_{hst} = &- \underset{(.11)}{1.06}\,\Delta S_{hst-1} + \underset{(..3)}{.12}\,\Delta S_{lst-1} + \underset{(.12)}{0.29}\,\Delta S_{cst-1} + \underset{(.01)}{0.06}\,\Delta\ln P_{hst} + \underset{(.02)}{0.001}\,\Delta\ln P_{lst} \\ &- \underset{(.01)}{0.01}\,\Delta\ln P_{cst} - \underset{(.006)}{0.006}\,\Delta\ln P_{kst} - \underset{(.02)}{0.007}\,\Delta\ln Q_{st} - \underset{(.01)}{0.03}\,\Delta\ln NO_{st} \\ &+ \underset{(.01)}{0.02}\,\Delta\ln P_{hst-1} - \underset{(.02)}{0.03}\,\Delta\ln P_{lst-1} - \underset{(.01)}{0.03}\,\Delta\ln P_{cst-1} - \underset{(.007)}{0.0004}\,\Delta\ln P_{kst-1} \\ &+ \underset{(.02)}{0.02}\,\Delta\ln Q_{st-1} + \underset{(.01)}{0.004}\,\Delta\ln NO_{st-1} \\ &- \underset{(.18)}{1.04}\,S_{hst-2} + \underset{(.04)}{0.21}\,S_{lst-2} - \underset{(.15)}{0.31}\,S_{cst-2}\end{aligned}$$

Equation for Unskilled Labour

$$\begin{aligned}\Delta S_{lst} = &\underset{(.40)}{0.34}\,\Delta S_{hst-1} - \underset{(.13)}{0.80}\,\Delta S_{lst-1} + \underset{(.64)}{1.83}\,\Delta S_{cst-1} + \underset{(.06)}{0.07}\,\Delta\ln P_{hst} + \underset{(.07)}{0.37}\,\Delta\ln P_{lst} \\ &- \underset{(.05)}{0.02}\,\Delta\ln P_{cst} - \underset{(.03)}{0.004}\,\Delta\ln P_{kst} - \underset{(.08)}{0.11}\,\Delta\ln Q_{st} - \underset{(.07)}{0.19}\,\Delta\ln NO_{st} \\ &- \underset{(.05)}{0.02}\,\Delta\ln P_{hst-1} + \underset{(.07)}{0.06}\,\Delta\ln P_{lst-1} - \underset{(.05)}{0.07}\,\Delta\ln P_{cst-1} - \underset{(.03)}{0.02}\,\Delta\ln P_{kst-1} \\ &- \underset{(.08)}{0.05}\,\Delta\ln Q_{st-1} + \underset{(.06)}{0.04}\,\Delta\ln NO_{st-1} \\ &+ \underset{(.52)}{0.50}\,S_{hst-2} - \underset{(.16)}{0.57}\,S_{lst-2} + \underset{(.55)}{0.64}\,S_{cst-2}\end{aligned}$$

Equation for Clerical Labour

$$\begin{aligned}\Delta S_{cst} = &- \underset{(.07)}{0.005}\,\Delta S_{hst-1} - \underset{(.03)}{0.07}\,\Delta S_{lst-1} - \underset{(.11)}{0.64}\,\Delta S_{cst-1} + \underset{(.01)}{0.008}\,\Delta\ln P_{hst} + \underset{(.01)}{0.04}\,\Delta\ln P_{lst} \\ &+ \underset{(.008)}{0.05}\,\Delta\ln P_{cst} - \underset{(.004)}{0.0007}\,\Delta\ln P_{kst} - \underset{(.01)}{0.04}\,\Delta\ln Q_{st} - \underset{(.008)}{0.03}\,\Delta\ln NO_{st} \\ &+ \underset{(.008)}{0.0005}\,\Delta\ln P_{hst-1} + \underset{(.01)}{0.02}\,\Delta\ln P_{lst-1} + \underset{(.007)}{0.014}\,\Delta\ln P_{cst-1} - \underset{(.004)}{0.004}\,\Delta\ln P_{kst-1} \\ &- \underset{(.01)}{0.03}\,\Delta\ln Q_{st-1} - \underset{(.008)}{0.01}\,\Delta\ln NO_{st-1} \\ &+ \underset{(.11)}{0.02}\,S_{hst-2} - \underset{(.04)}{0.08}\,S_{lst-2} - \underset{(.16)}{0.58}\,S_{cst-2}\end{aligned}$$

Equation for Capital

$$\begin{aligned}\Delta S_{kst} = &-0.72\Delta S_{hst-1} - 0.75\Delta S_{lst-1} + 1.48\Delta S_{cst-1} - \underset{(.07)}{0.09}\,\Delta\ln P_{hst} - \underset{(.09)}{0.33}\,\Delta\ln P_{lst} \\ &- \underset{(.05)}{0.11}\,\Delta\ln P_{cst} + \underset{(.03)}{0.004}\,\Delta\ln P_{kst} + \underset{(.06)}{0.09}\,\Delta\ln Q_{st} + \underset{(.08)}{0.15}\,\Delta\ln NO_{st} \\ &- \underset{(.06)}{0.05}\,\Delta\ln P_{hst-1} - \underset{(.10)}{0.29}\,\Delta\ln P_{lst-1} - \underset{(.05)}{0.08}\,\Delta\ln P_{cst-1} + \underset{(.03)}{0.02}\,\Delta\ln P_{kst-1} \\ &+ \underset{(.08)}{0.16}\,\Delta\ln Q_{st-1} + \underset{(.06)}{0.15}\,\Delta\ln NO_{st-1} \\ &+0.53S_{hst-2} + 0.45S_{lst-2} + 0.25S_{cst-2}\end{aligned}$$

6.7.2 Confidence Intervals for The Elasticity Estimates

The translog estimates of the Allen elasticity of substitution, $\hat{\sigma}_{ij}$, and the gross price elasticity of demand, $\hat{\varepsilon}_{ij}$, are functions of both the estimated parameters and the factor cost shares:

$$\begin{aligned} \hat{\sigma}_{ij} &= 1 + \hat{\gamma}_{ij} \;/\; S_i \; S_j, \\ \hat{\varepsilon}_{ij} &= \hat{\sigma}_{ij} \; S_j \end{aligned}$$

Anderson and Thursby (1986) examine the statistical properties of these elasticity estimators. In a Monte Carlo study they found that a normal distribution is appropriate if the elasticity estimator is computed using the mean of the actual factor shares. In addition they found that the estimators of the gross price elasticities of demand were

> "more likely to be robust with respect to departures from the assumed distributions [...either the normal or ratio-of-normals...], and policy conclusions drawn from price elasticity estimates are more easily judged (statistically) than those drawn from AES [Allen Elasticity of Substitution] estimates alone." [p.652]

We estimate confidence intervals for the translog elasticity estimates using the formulae presented in Anderson and Thursby (1986). The confidence interval estimator for the AES in the normal distribution case is

$$\hat{\sigma}_{ij} \pm \frac{A}{B}$$

and the confidence interval estimator for the price elasticity of demand is

$$\hat{\varepsilon}_{ij} \;\pm\; z_\alpha \; \overline{S_i}^{-1} \; \left[T^{-1} \; \hat{\varepsilon}_{ij}^2 \; s_i^2 - 2 \; r_2 \hat{\varepsilon}_{ij} \; s_i \; \left(T^{-1} \; \left(s_\gamma^2 + v^2 \right) \right)^{\frac{1}{2}} + s_\gamma^2 + v^2 \right]^{\frac{1}{2}}$$

where

$$\begin{aligned} A &= z_\alpha \; (v^2 \; \hat{\gamma}_{ij}^2 - 2 \; v \; s_\gamma \; r_1 \; \hat{\gamma}_{ij} + s_\gamma^2)^{\frac{1}{2}} \\ B &= \overline{S_i} \; \overline{S_j} + r_{ij} \; s_i \; s_j / T \\ v^2 &= (\overline{S_i}^2 \; s_j^2 + \overline{S_j}^2 \; s_i^2 + 2 \; \overline{S_i} \; \overline{S_j} \; s_i \; s_j \; r_{ij} + (1 + r_{ij}) \; s_j^2 \; s_j^2)/T \\ r_2 &= T^{-3} \left[\sum_{s=1}^{N} \sum_{t=1}^{T} \left(\left(S_{ist} - \overline{S_i} \right) \left(S_{ist} S_{jst} - \hat{m}_{ij} \right) + T(T-1) \overline{S_i} s_i \left(s_i + r_{ij} s_j \right) \right) \right] \\ \hat{m}_{ij} &= \overline{S_i} \; \overline{S_j} + r_{ij} \; s_i \; s_j \end{aligned}$$

z_α is the critical value from the standard normal distribution;

$\overline{S_j}$ is the sample mean of the cost share for factor j;
s_j is the standard deviation of the cost share for factor j;
s_γ is the estimated standard error of the coefficient $\hat{\gamma}_{ij}$;
r_1 is the sample correlation between $\hat{\alpha}_{ij}$ and $\overline{S_i}\,\overline{S_j}$;
r_{ij} is the sample correlation between S_i and S_j and $T*$ is the sample size.

6.7.3 Graphs

	Medium Growth Sectors					High Growth Sectors				
Confidence Intervals for Allen Elasticity of Substitution Estimates										
		95% Interval		90% Interval			95% Interval		90% Interval	
	Estimate	Upper	Lower	Upper	Lower	Estimate	Upper	Lower	Upper	Lower
Skilled, Skilled	-4.99	0.04	-10.02	-1.71	-8.28	0.95	8.25	-6.34	5.72	-3.81
Skilled, Unskilled	0.67	1.40	-0.06	1.14	0.19	2.27	4.42	0.12	3.67	0.87
Skilled, Clerical	2.43	18.03	-13.17	12.62	-7.76	-3.76	2.04	-9.56	0.02	-7.55
Skilled, Capital	0.19	1.77	-1.39	1.23	-0.84	-0.31	0.13	-0.74	-0.02	-0.59
Unskilled, Unskilled	-1.16	-0.22	-2.10	-0.55	-1.77	-4.71	-2.43	-7.00	-3.22	-6.21
Unskilled, Clerical	-4.31	1.40	-10.03	-0.58	-8.05	2.12	4.93	-0.70	3.96	0.28
Unskilled, Capital	1.30	2.41	0.20	2.02	0.58	0.54	0.99	0.08	0.83	0.24
Clerical, Clerical	-6.57	55.42	-68.56	33.92	-47.05	-26.30	-15.60	-36.99	-19.31	-33.28
Clerical, Capital	3.76	11.64	-4.13	8.91	-1.40	0.69	1.16	0.22	1.00	0.38
Confidence Intervals for Gross Elasticity of Demand Estimates										
Skilled, Skilled	-0.48	0.00	-0.96	-0.16	-0.79	0.05	0.42	-0.33	0.29	-0.20
Skilled, Unskilled	0.25	0.53	-0.02	0.43	0.07	0.29	0.56	0.02	0.46	0.11
Skilled, Clerical	0.13	0.99	-0.72	0.69	-0.42	-0.09	0.05	-0.23	0.00	-0.18
Skilled, Capital	0.09	0.83	-0.65	0.58	-0.40	-0.25	0.10	-0.59	-0.02	-0.47
Unskilled, Skilled	0.06	0.13	-0.01	0.11	0.02	0.12	0.23	0.01	0.19	0.04
Unskilled, Unskilled	-0.44	-0.08	-0.80	-0.21	-0.67	-0.59	-0.31	-0.88	-0.41	-0.78
Unskilled, Clerical	-0.24	0.08	-0.55	-0.03	-0.44	0.05	0.12	-0.02	0.09	0.01
Unskilled, Capital	0.61	1.13	0.09	0.95	0.27	0.43	0.79	0.06	0.66	0.19
Clerical, Skilled	0.23	1.72	-1.26	1.21	-0.74	-0.19	0.10	-0.49	0.00	-0.39
Clerical, Unskilled	-1.64	0.53	-3.81	-0.22	-3.06	0.27	0.62	-0.09	0.50	0.04
Clerical, Clerical	-0.36	3.03	-3.75	1.86	-2.57	-0.62	-0.37	-0.88	-0.46	-0.79
Clerical, Capital	1.77	5.47	-1.94	4.19	-0.66	0.55	0.93	0.17	0.80	0.30
Capital, Skilled	0.02	0.17	-0.13	0.12	-0.08	-0.02	0.01	-0.04	0.00	-0.03
Capital, Unskilled	0.49	0.91	0.07	0.77	0.22	0.07	0.12	0.01	0.10	0.03
Capital, Clerical	0.21	0.64	-0.23	0.49	-0.08	0.02	0.03	0.01	0.02	0.01

Figure 6.1: 90% and 95% Confidence Intervals For Elasticity Estimates From Multi-Equation System

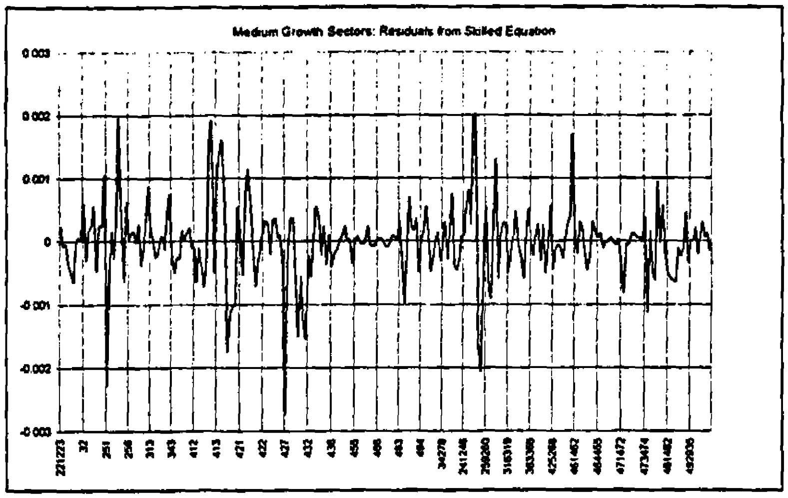

Figure 6.2: Residuals of Skilled Equation for Medium Growth Group: 1982-1990 by Labelled Sector

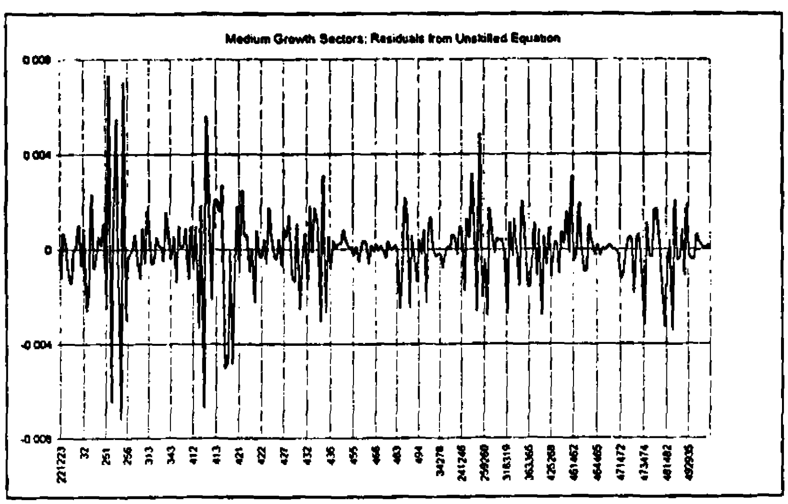

Figure 6.3: Residuals of Unskilled Equation for Medium Growth Group: 1982-1990 by Labelled Sector

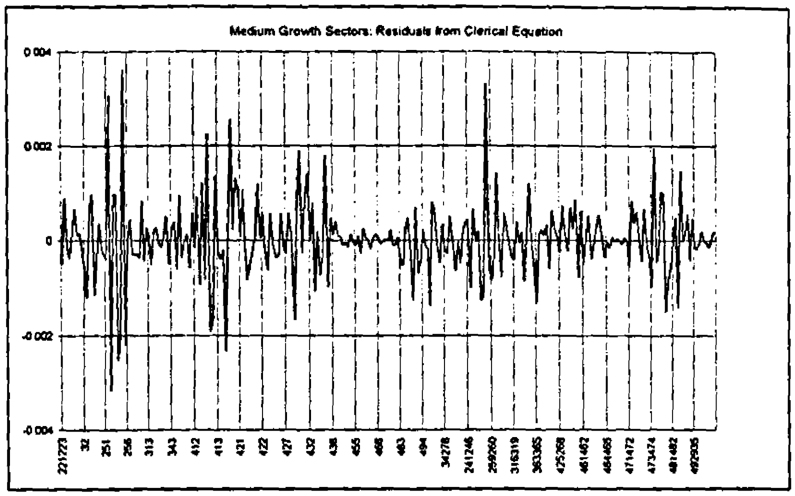

Figure 6.4: Residuals of Clerical Equation for Medium Growth Group: 1982-1990 by Labelled Sector

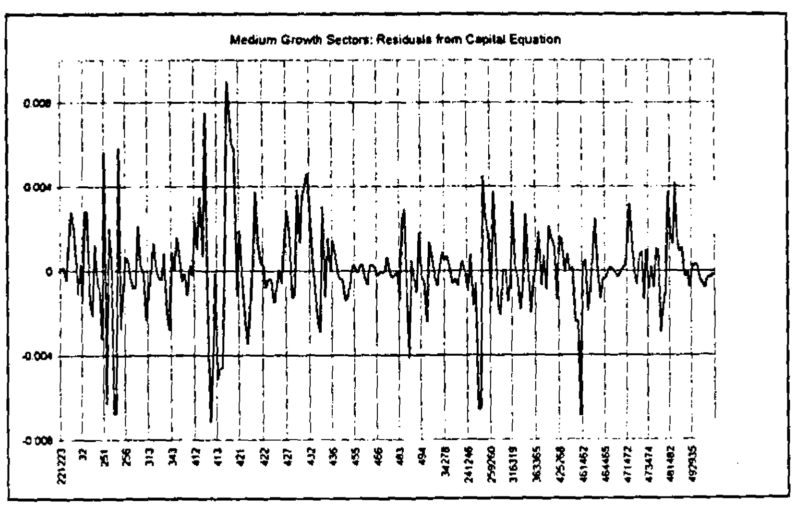

Figure 6.5: Residuals of Capital Equation for Medium Growth Group: 1982-1990 by Labelled Sector

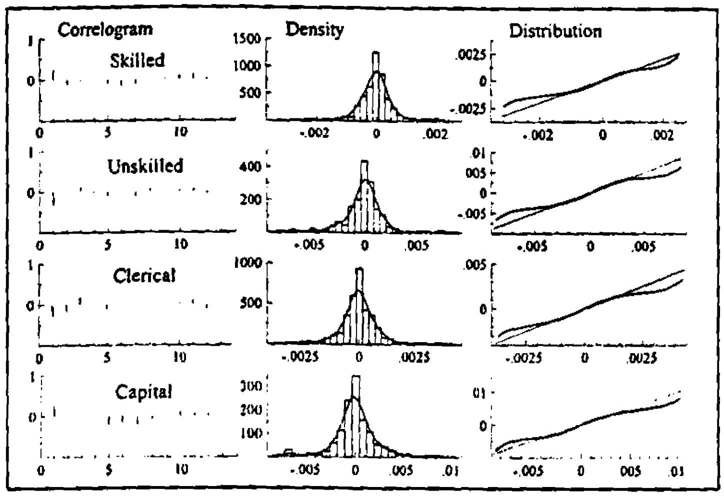

Figure 6.6: Diagnostics on Residuals from Systems Estimation: Medium Growth Group

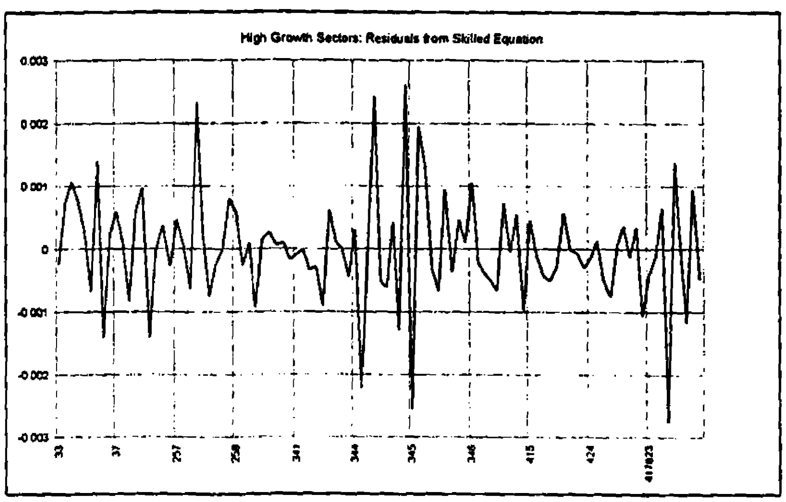

Figure 6.7: Residuals of Skilled Equation for High Growth Group: 1982-1990 by Labelled Sector

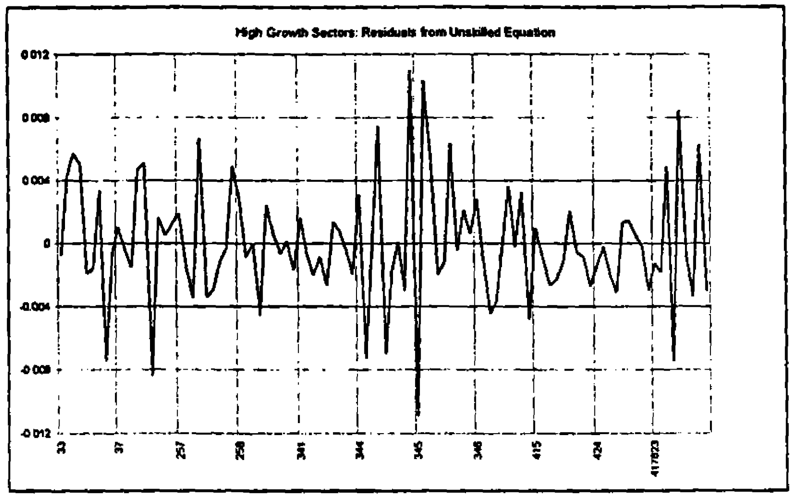

Figure 6.8: Residuals of Unskilled Equation for High Growth Group: 1982-1990 by Labelled Sector

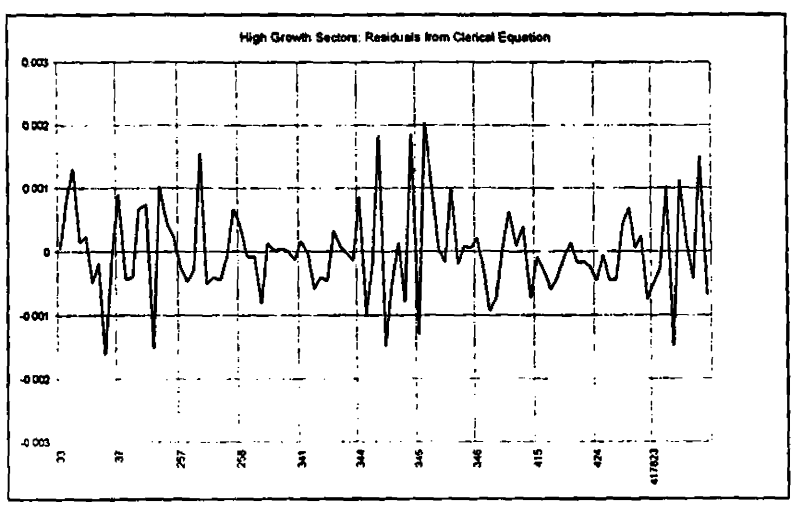

Figure 6.9: Residuals of Clerical Equation for High Growth Group: 1982-1990 by Labelled Sector

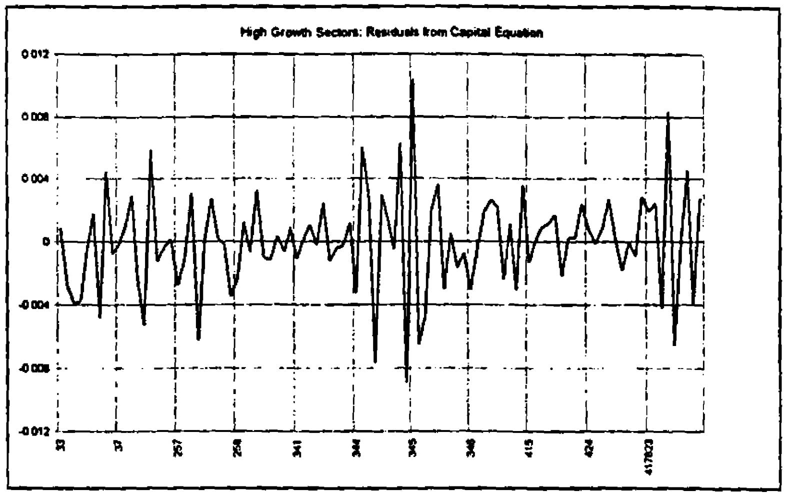

Figure 6.10: Residuals of Capital Equation for High Growth Group: 1982-1990 by Labelled Sector

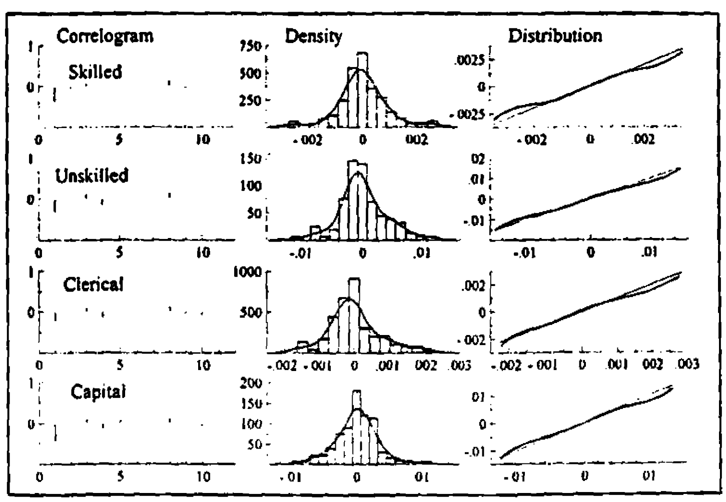

Figure 6.11: Diagnostics on Residuals from Systems Estimation: High Growth Group

Part III

Conclusions

Chapter 7

Conclusions

7.1 Summary

The central question addressed in this thesis is whether relative factor prices matter in the demand for labour in the Irish manufacturing sector. To answer this question we estimated the demand for labour in Irish manufacturing. To do so effectively, it was important to recognise the degree of heterogeneity both in production and employment.

The sectoral composition of output in the manufacturing sector during the 1980s switched from low-productivity (declining sectors) to high-productivity (high-growth sectors) industry. Because of this heterogeneity in production we disaggregated manufacturing into three groups of sectors with similar output markets. Approximately half of all manufacturing employment occurred in medium-growth sectors. Alongside this group there was a smaller, rapidly expanding group of high growth sectors, predominantly foreign-owned and export-oriented and with very low labour share of value added. The growing importance of this group led to a continued decline in labour's share of value added in manufacturing. The third group was predominantly indigenous, operating in traditional industries and declining in importance over time.

This sectoral switch in production also led to an increase in the demand for skilled labour and in the skill-intensity of a unit of labour employed in manufacturing. There was a persistent trend toward the employment of relatively more skilled labour in manufacturing during the 1980s. Because of this heterogeneity of employment in Part II we disaggregated labour into three types; skilled, unskilled and clerical labour.

7.1.1 Methodology (Chapter 2)

The methodology adopted to address the central question centred on three issues; theoretical specification, econometric methodology and data availability.

The basic theory of the demand for labour is simple. An increase in the wage will, *ceteris paribus,* reduce the demand for labour through both substitution and output effects. We chose to estimate the substitution effect alone, which is sufficient to answer our central question. To measure output effects, it would have been necessary to model the market for output. This is complex for Ireland where the manufacturing sector is closely linked to developments in the world economy, and would have involved making a set of assumptions about the workings of the output market. However it was straightforward to estimate the substitution effect alone based on the relatively uncontroversial assumption that all firms minimise costs. We used the translog cost function to specify a functional form for the factor demand equations. We focused throughout on the theoretical long run demand for labour, where all factors are variable, while empirically we estimated the statistical "long run" estimates of our underlying theoretical parameters.

In terms of econometric methodology, our preference was to adopt a general-to-specific strategy in estimation. In Part I we used the "encompassing-the-VAR" methodology to estimate a long-run demand for labour equation. This approach begins with a *general* VAR specification among the variables of interest, and tests whether this specification is congruent with the data before testing whether the *specific* theoretical relationship of interest encompasses the VAR.

In Part II, where we disaggregated labour into three types, we were unable to apply the encompassing-the-VAR methodology, for two reasons. Firstly the time-span of the data available - 12 annual observations - was far too short. Secondly, and more importantly, with three types of labour the dimensions of the factor demand system were far too high for the encompassing-the-VAR approach which is only feasible with a small number of variables. Instead we pooled cross-sectional sectoral data across time to create a panel data set, and began estimation with a fully parameterised set of equations. We estimated the most general specification possible given data restrictions and tested the validity of alternative reductions of this "general specification".

7.1.2 The Demand for Labour (Chapter 3)

In Chapter 3 we tackled the heterogeneity within manufacturing by estimating separate demand for labour functions for three different sectors, namely Metal Articles, Pharmaceuticals and Wool, chosen as representative of medium-growth (M), high growth (H) and declining (D) sectors respectively. The estimates for the H and D sectors showed evidence of misspecification. We concluded that we had failed to identify long run demand for labour functions for those sectors. We further concluded that disaggregation is critical in studies of labour demand in Ireland, since the empirical results were only robust for Metal Articles, a sector which has undergone relatively little change over the estimation period.

The results for the M sector suggested that movements in relative factor prices do matter in driving the demand for labour and that the two major EU events which occurred over the estimation period, namely joining the EMS in 1979 and the completion of the single market in 1992, had significant permanent effects in shifting the demand for labour curve outwards.

7.1.3 Compositional Shifts in Labour (Chapter 4)

The data analysis in Chapter 4 indicated that there was a persistent trend toward the employment of relatively more skilled labour in manufacturing during the 1980s. This is consistent with trends in manufacturing employment in most developed economies. However the data also highlighted the extent to which skill usage varies across sectors, high growth sectors had the most skill-intensive production processes, these were also the sectors where skill-intensity was increasing fastest, while low-growth or declining sectors had the lowest.

We separately identified clerical labour where both employment and wages grew in the 1980s. We argued that this reflects the positive effect of computerisation on the demand for clerical labour.

7.1.4 The Demand for Skilled and Unskilled Labour (Chapters 5 & 6)

In Chapters 5 and 6 we pooled cross-section and time-series data into three groups of sectors, high-growth (H), medium-growth (M) and declining (D) sectors. The H group, with only 11 sectors, was small and this had consequences in estimation since it reduced the degrees of freedom available. The M and D sectors contained 29 sectors each.

In Chapter 5 we estimated the demand for skilled and unskilled labour by estimating two separate equations. The first estimated the demand for skilled labour relative to unskilled labour holding total labour constant, the second estimated the demand for aggregate labour relative to capital. Under a number of highly restrictive behavioural assumptions these were combined to provide first estimates of the elasticity of demand for skilled and unskilled labour.

1. The results for the D and H groups showed evidence of misspecification, as did the results for aggregate labour for the M group.

2. The results for the demand for skilled labour, holding total labour constant, for the M group were robust and plausible. These suggested that substitution between skilled and unskilled labour was low. Net new firms were found to be more skill-intensive and capital-intensive than the average, an expansion in scale was unskilled-intensive, and there were no significant skill-biased technology effects.

In Chapter 6 we relaxed these restrictive behavioural assumptions and estimated a factor demand system for four factors, skilled labour, unskilled labour, clerical labour and capital services.

1. The results for the M group were plausible. They suggested that movements in relative factor prices did matter. Skilled labour and capital were substitutes for unskilled labour in production while clerical labour and unskilled labour were complements and there was zero skill-capital complementarity. Net new firms were more capital-intensive than average and there were no significant scale or technological bias effects.

2. The results for the H group were less theoretically robust but also plausible. They suggested a positive own elasticity of demand for skilled labour, violating economic theory, however this was insignificantly different from zero at the 10% level. The results suggested that skilled labour and clerical labour were both substitutes for unskilled labour in production and there was skill-capital complementarity. Net new firms were found to be more capital-intensive than the average, while scale effects were in general biased in favour of skilled and clerical labour.

3. The results for the D group showed evidence of misspecification.

7.2 Discussion of Results

7.2.1 Comparison with International Stylised Facts

How do our results compare with international evidence on the demand for labour? As outlined in Chapter 1, Hamermesh (1993, Chapter 3) surveyed a wide range of empirical literature on the parameters characterising labour demand and summarised the main findings from this research into seven stylised facts (p.135). Four of these are relevant to our study here:

1 *'We know the absolute value of the constant elasticity of demand for homogenous labor for a typical firm, and for the aggregate economy in the long run, is*

		M	H	D
VAR, Ch 3	Aggregate Labour	#-1.00	##	-##
System, Ch 6	Skilled Labour	#-0.48	0.05	##
	Unskilled Labour	#-0.44	#-0.59	##
	Clerical Labour	0.36	#-0.62	##

indicates non-robust results; # indicates significant results.

Table 7.1: Estimated Own Elasticities of Demand for Aggregate Labour

above 0 and below 1. Its value is probably bracketed by the interval [0.15, 0.75], with 0.30 being a good "best guess." '

Table 7.1 shows the estimated own elasticity of demand for aggregate labour. A ## is used to indicate results which were not robust (i.e. misspecified). The table also shows the own elasticity of demand for skilled labour, unskilled labour and clerical labour, estimated in Chapter 6. Due to unresolved issues in estimation these estimates are tentative in nature, the # indicates significance but not necessarily robustness.

These estimates suggest that the demand for homogeneous labour in the M sector has a unitary elasticity, which is very high and outside the "probable" range suggested by Hamermesh.

2 *'We are fairly sure that the own-wage demand elasticity decreases as the skill embodied in a group of workers increases.'*

As can be seen in Table 7.1, in the M group the unskilled elasticity is marginally lower than the skilled elasticity (-0.44 against -0.48) contrary to this stylised fact. For the H group this stylised fact is accepted, the own-wage elasticity for skilled labour is not significantly different from zero while for unskilled labour it is -0.59.

3 *'We are fairly sure than capital and skill are p-complements[1].'*

Table 7.2 reports the estimated cross-elasticities between skilled, unskilled and clerical labour from the system estimates in Chapter 6. The results for the D group were very poor and are not included.

[1]If elasticities are derived from the cost function where price (p) changes exogenously and the quantity response is measured then the relationship between factors is defined as p-substitutes or p- complements. This is the formulation we have been using throughout. Q-complements refer to elasticities derived from the production fucntion where quantities (q) change exogenously and the price response is measured.

Medium-Growth Group				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	*-0.48	*0.25	0.13	0.09
Unskilled	*0.06	**-0.44	-0.24	**0.61
Clerical	0.23	*-1.64	-0.36	1.76
Capital	0.02	**0.49	0.21	-0.72
High-Growth Group				
	Skilled	*Unskilled*	*Clerical*	*Capital*
Skilled	0.05	**0.29	-0.09	*-0.25
Unskilled	**0.12	**-0.59	*0.05	**0.43
Clerical	-0.19	*0.27	**-0.62	**0.55
Capital	*-0.02	**0.07	**0.02	-0.07

Table 7.2: Estimated Cross-Elasticities of Demand for Labour and Capital

This stylised fact is not rejected by the results for the M group and is supported by the results for the H group. For the M group, there is zero skill-capital substitution while there is significant substitution between capital and unskilled labour. The results for the H group point to significant skill-capital complementarity.

4 *'We are fairly sure that workers and hours are both p-substitutes for capital.'*

This stylised fact is supported by our results. In both the M and H groups the estimated elasticities between unskilled labour and capital are positive (suggesting substitutes) and significant.

7.2.2 How plausible are these results for Ireland?

How do our results compare with previous studies of the demand for labour in Ireland? We can compare them with two studies which also directly estimated constant-output labour demand elasticities. The first was done on pre-1973 data, pertaining to a very different period when Ireland was not a member of the EU. Boyle and Sloane (1982) estimated systems of factor demand equations for three factors, wage-earners, salaried earners and the capital stock over the period 1953-1973 using annual data on 40 manufacturing sectors. In general they found the elasticity of substitution between production workers (unskilled labour) and capital was greater than the corresponding elasticity for non-production workers (skilled labour) and capital. Our results confirm this finding for the post-accession period, with evidence of skill-capital complementarity in the emerging H group of sectors. Boyle and Sloane also found that the demand for non-production workers (skilled labour) was more inelastic than for production workers (unskilled labour). Our results for the H group support this finding for the post-accession period, however our results for the M group suggested that the own-wage elasticity for skilled labour and unskilled labour were not significantly different.

The second study was done using aggregate labour for the period 1970-1987, and is therefore not directly comparable with our results. Bradley et al. (1993) estimated a KLEM factor demand system in Irish manufacturing for two separate sectors, the 'modern' sector (similar to our high-growth group) and the 'traditional' sector (similar to our medium-growth and declining groups combined). Their estimated own-wage elasticities for labour and capital were less than one, ranging from -0.5 and -0.7 for the modern sector to -0.15 and -0.6 in the traditional sector. These are similar orders of magnitude to our estimates. Furthermore they found that labour and capital were substitutes in the modern sector but complements in the traditional sector, this is in direct contrast to our findings.

Our results do not contradict the results of the Boyle and Sloane study of the pre-accession period, but they do suggest that there has been some evolution in the skill-capital relationships in the manufacturing sector, since we find significant evidence of skill-capital complementarity in the H group and zero skill-capital substitutability in the M group in the post-accession period. Our results do differ from those in the Bradley et al. study, however these are not directly comparable since labour is treated as a single aggregate factor in their study. In relation to their finding of labour-capital complementarity in the traditional sector, they argue that when conditioned on value-added, capital and labour are substitutes in this sector[2] which is consistent with our results for the M group. With regard to their finding of labour-capital substitution in the modern sector, our findings (and those of Boyle and Sloane for an earlier time period) would suggest that disaggregation of labour by skill would reveal substitution between unskilled labour and capital but skill-capital complementarity.

7.2.3 Do Relative Factor Prices Matter?

In economic theory, the demand for labour is driven by changes in relative factor prices and changes in output. In this thesis we asked the question whether the first of these is important in the demand for labour in the Irish manufacturing sector. The simple answer to this is yes. Our evidence suggested that movements in relative factor prices accounted for almost one fifth of the changes in employment that occurred in the M group of sectors in the 1980s. In the more high-technology industries, the effect of movements in relative factor prices was

[2]The argument is that since most of material and energy inputs in the traditional sector are imported, any rise in domestic costs (labour or capital) will cause substitution of value-added for imported inputs and this effect dominates giving rise to labour-capital complementarity.

	M	H
Skilled Labour	-0.10	+0.25
Unskilled Labour	-0.62	-0.42

These elasticities of demand
from Chapter 6,
measure the response to a
1% uniform increase in all wages.

Table 7.3: Estimated Total Employment Elasticities of Demand for Disaggregated Labour

dominated by the very rapid expansion in output and the number of firms which increased the demand for all categories of labour.

Furthermore, movements in wages matter more for the demand for unskilled labour than the demand for skilled labour. Table 7.3 shows the estimated total employment elasticity for skilled and unskilled labour. These estimates suggest that any policy which increases all wages uniformly (e.g. centrally agreed wage increases) will have a larger negative effect on the demand for unskilled labour than on the demand for skilled labour.

7.3 Concluding Remarks

I made a deliberate decision at the outset of this thesis to separate out those sectors involved in the large-scale restructuring of Irish manufacturing that took place in the 1980s. The empirical results have confirmed that this disaggregation was important. We have only successfully estimated a labour demand function for the M sector in Chapter 3 and for the M group of sectors in Chapters 5 and 6, while we failed to estimate any plausible results for the D sector, and only estimated plausible results for the H sector in Chapter 6 at the 10% level of significance. This is not surprising since the "medium-growth" sector is by construction the stable core of Irish manufacturing in the 1980s which experienced neither rapid growth nor decline. Although separating out the high-growth sectors did impose a cost in restricting the degrees of freedom in estimation for the H group in Chapters 5 and 6, the results for the M and H groups in Chapter 6 confirmed that the two groups are very different.

But the success of this disaggregation strategy is demonstrated by the poor results for the D and H sectors. This is scant reward in a thesis devoted to applied econometric analysis of labour demand. In particular the failure to estimate any labour demand functions for the D sectors was something I had not anticipated at the outset. My prior had been that the

H sectors would be the most difficult given their very rapid introduction and growth within Irish manufacturing.

I do not believe that the problems encountered in this thesis should discourage further research on labour demand, for two reasons. The most obvious reason is that we need good quality estimates of labour demand to understand how the labour market works. Labour demand is already an under-researched area in Ireland, partly because of a lack of data availability, so that studies like this thesis are important in filling the many gaps that exist in our knowledge.

The second reason is the quality of the results themselves. We have plausible estimates for more than half of the Irish manufacturing sector (the M sectors). These give us a profile of labour demand, discussed above, which confirms that relative factor prices do matter. Furthermore they suggest that membership of the EU has had a significant effect in shifting the demand for labour outwards. We also have some plausible estimates for the H sectors. These point to a different type of labour demand in those firms which are now dominant in Irish manufacturing and have been identified as critical to the emergence of the "Celtic Tiger" in the 1990s.

Appendix A

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Part IV

The Data

Appendix B

The Data

The *Census of Industrial Production* is an extensive, under-utilised source of published time series data on Irish industry at a detailed sectoral level. We have used these data to construct two datasets on employment, wages and output in the Irish industrial sector. The first is a quarterly dataset of variables covering 31 manufacturing sectors. This dataset covers the period 1973Q1-1997Q2. The second dataset is based on annual data, 1979-1990, and covers 72 industrial sectors. Besides a greater level of sectoral detail the key distinguishing feature of this second dataset is that it provides data on wages and numbers employed for different categories of worker.

The data sources used to construct these datasets are described in Appendix B.1. Appendix B.2 describes the methods use to interpolate some missing sub-annual observations in the early years of the quarterly dataset. Finally Appendix B.3 details the theoretical framework used to construct the cost of capital variables.

B.1 Background Information on Data Availability and Coverage

This section catalogues the different sources of data on Irish industry and their sectoral and temporal coverage. In Section B.1.1 the NACE classification system for industrial sectors is defined. The following section B.1.2 lists the sources of official annual statistics on Irish industry used in this thesis. The quarterly and monthly industrial statistics available are defined in Section B.1.3. Section B.1.4 defines the annual data set and finally Section B.1.5 describes the quarterly data set put together using these short-term indicators.

B.1.1 NACE Sectoral Classification of Industrial Activity

The NACE (Nomenclature Générale des Activités Economiques dans les Communautés Européennes) sectoral classification system for industrial activity has been in use in Ireland since 1973.[1] This system classifies industries at three levels of disaggregation:

1. **major** industrial sector - disaggregates industry into 12 sectors.
2. **broad** industrial sector - disaggregates industry into 34 sectors.
3. **detailed** industrial sector - disaggregates industry into 75 sectors.

The sectoral definitions for each disaggregation level are given in Tables B.1, B.2, B.3 and B.4. A frequent point of confusion is the correct definition of "manufacturing" industry and its distinction from "transportable goods" industry and "total" industry. Transportable goods refers to all industrial activity with the exception of the so-called utilities "Electricity, Gas and Water", NACE 13,16,17. Manufacturing industry excludes both utilities *and* "Mining, Quarrying and Turf", NACE 11,21,23.

B.1.2 Annual Data Sources

The following list gives an overview of the different sources of annual data on Irish industry used in this thesis.

1. **Census of Industrial Production:**

   The Irish *Census of Industrial Production* (CIP) has been conducted on an annual basis since 1931. Between 1954 and 1973 the census classification scheme was based on the UN International Standard Industrial Classification (ISIC). Between 1973 and 1990 the classification was altered to accord with EC standards using the NACE classification system. The Central Statistics Office (CSO) has provided data on both the ISIC and NACE basis in the link 1973 year, there are substantial changes in the classifications especially at the detailed industrial sector level. Beginning in 1991 the NACE classification system has been extensively revised (from Rev. 70 to Rev. 1), this revision has again caused substantial changes in classification at a detailed sector level. Thus our annual data set is strictly limited to cover the period 1973-1990 for consistent time-series at a sectoral level.

[1] This is based on the 1970 edition of NACE classification - NACE 70. In 1991 the CSO changed to NACE Rev. 1 which is a special European extension of ISIC Rev. 3.

(a) **Census of Industrial Establishments:**

The *Census of Industrial Establishments* collects data on all industrial establishments with three or more persons engaged. It is estimated to cover roughly 90% of all industrial production. It provides data on the value of gross output, intermediate inputs, net output, persons engaged, wages and salaries and remainder of net output for the 75 detailed industrial sectors, the more aggregated 34 broad industrial sectors and the most highly aggregated 12 major industrial sectors. These data are used by the CSO to calculate sectoral volume of production index numbers. With the exception of the employment figures, all of these data are based on the financial accounting year nearest to the reference calendar year, in most cases (77% in 1990) this coincides with the calendar year.

(b) **Census of Industrial Enterprises**

A second, smaller annual inquiry was introduced in 1973 with the first results published for 1975 - the *Census of Industrial Enterprises.* This census covers all enterprises with 20 or more persons engaged and focuses on trading information of the firm (e.g. turnover, cost of non-industrial services, other labour costs). Although it has more limited coverage than the Census of Establishments, it is useful since it provides estimates of total labour costs including non-wage costs at the NACE detailed sector level.

2. **ESRI-Dept. of Finance Databank:**

This databank contains a comprehensive set of annual economic time series for Ireland which have been constructed based on current National Accounts definitions. The main source used to construct the databank is the *National Income and Expenditure* (NIE) data published annually by the CSO. In addition, other data sources were used to construct series at a more disaggregated level within a National Accounts framework. A full description of the databank is given in Bradley et al.(1990).

3. **Capital Stock and Investment Data:**

Henry (1989) constructs annual estimates of the capital stock for Ireland over the period 1950-84. Henry's capital stock data for total manufacturing is derived based on Gross Fixed Capital Formation (GFCH) data for different asset groups from NIE sources. The sectoral manufacturing investment data - "purchases less sales of assets" - are CIP estimates scaled up by a common factor to the National Accounts totals. The detailed backgound figures which Henry uses are based on unpublished data thus making them to some extent unreproducible. The CSO also provides (unpublished) annual estimates of GFCF from 1970 onwards at the sectoral level, these series are deflated using the aggregate manufacturing investment deflator since there are no sectoral investment price deflators.

B.1.3 Quarterly and Monthly Data Sources

1. **Quarterly Industrial Inquiry:**

   The inquiry provides estimates of employment, earnings and hours worked and covers about 85% of total industrial employment. The NACE classification system was introduced on a quarterly basis in 1980 and retrospectively to January 1977. The data are available for the 34 broad industrial sectors.

   (a) *Employment LQ:* These data are supplemented by data from the Monthly Inquiry and revised with reference to annual census results so they are directly comparable with the CIP Census of Establishments data.

   (b) *Index of Weekly Earnings 1985Q3=100 WQ:* The coverage for these data is not as good as for the employment indices since it does not incorporate the monthly results.

   (c) *Index of Hours Worked per Week 1985Q3=100 HQ:* These data begin in 1977Q1.

   (d) *Index of Hourly Earnings, 1985Q3=100 HW:* These data begin in 1977Q1.

2. **Monthly Industrial Inquiry:**

   This inquiry has been conducted on a monthly basis since 1975. It covers all industrial establishments with 20 or more persons engaged. The monthly data were first published in 1977 and were revised in 1980 to a NACE classification basis. The data are available for the 34 broad industrial sectors. Quarterly series based on these survey data are also published.

   (a) *Industrial Production Index 1985=100 QM:* These data measure movements in volume (constant-prices) output. They are revised with reference to the annual CIP volume index numbers.

   (b) *Industrial Turnover Index 1980=100 TV:* These data measure movements in monthly turnover. They are revised with reference to the annual CIP gross output estimates and are available from 1980 onwards.

B.1.4 The Annual Data Set

The annual data set includes data for the 75 detailed industrial sectors along with the more aggregated sectors. Data on output, employment and wages cover the period 1973-1990. Data on the disaggregation of employment and wages are only available from 1979 onwards.

1. **1973-1990: Output, Employment and Wages**

   Data on the following variables were taken from the CIP Census of Establishments. The data cover the period 1973-90 for 75 detailed industrial sectors.

   (a) *Gross Output QV:* This is the net selling value of all goods manufactured in the year whether sold or not. It includes subsidies but excludes excise duty and other taxes on products (VAT). This is not equal to sales.

   (b) *Persons Engaged L:* All persons engaged in the industrial activity in a particular week in September. This figure may be more underrepresented than the 90% production coverage would indicate because small establishments are not covered. These numbers exclude outside piece workers.

   (c) *Industrial Inputs MV:* This includes industrial materials, industrial services and fuel and power used in the production of output.

   (d) *Net Output YV:* This is the difference between gross output and industrial input. It is roughly comparable to value- added (the sum of factor payments, i.e. wages and salaries, rent, depreciation, profits) however there are important differences. Net output includes items such as expenditure on advertising and selling expenses so it will in general be higher than value added.

   (e) *Wages and Salaries LV:* This is the gross amount paid to employees before deduction of income tax, employees social security, etc. Overtime pay, bonuses, commissions, holiday pay and sick pay are included. However it excludes a wide range of non-wage labour costs, namely employer's contributions in respect of social welfare, superannuation, lump-sum redundancy payments, insurance premiums covering sickness and injury, benefits in kind, training costs, social expenditure, etc.

   (f) *Remainder of Net Output KV:* This is the fund from which dividends, depreciation, labour costs other than wages and salaries, interest and other financing charges, hire and leasing charges, taxes and all other expenses and overheads are paid.

(g) *Volume Index Numbers* I_Q: These index numbers are derived by the CSO from each year's census results. They are to the base 1985 = 100. These differ from the monthly survey-based series on Industrial Production because the census results are derived from returns for reporting years which are not always the calendar year while the indices for the short-term series are all based on the calendar year.

2. **1979-90: Disaggregation By Worker**

Unpublished data from the CIP Census of Establishments have been provided by the CSO for 75 detailed industrial sectors. These cover three variables:

(a) Number of firms in the sector.

(b) Persons Engaged disaggregated by worker.

(c) Wages and Salaries disaggregated by worker.

Both the employment and the wages and salaries data separately identify Industrial Workers (with a three-way breakdown into Supervisors, Operatives and Apprentices), Administrative and Technical Staff and Clerical Staff. In addition the employment data give the number of male and female workers in each worker category. The residuals for the employment and the wages data respectively are

(a) Number of Proprietors

$$= \text{Total Employment} - (\text{Industrial} + \text{Admin/Technical} + \text{Clerical})$$

(b) Wages of Outside Piece Workers

$$= \text{Total Wages \& Salaries} - (\text{Industrial} + \text{Admin/Technical} + \text{Clerical})$$

B.1.5 The Quarterly Data Set

The sectoral coverage of the quarterly data is much more limited than for the annual data, it does not disaggregate further than the NACE broad sector level. The turnover (TV) data only start in 1980, employment (LQ) and wages (WQ) in 1977 and output (QM) in 1975.

This quarterly data set covers the 34 broad NACE sectors. In our analysis in Chapter 3 we only use the 31 sectors relating to manufacturing activity (excluding Mineral Oil Refining, sector 14; Mining, Quarrying and Turf, sector 112123; Electricity, Gas and Water, sector 131617). These are listed in Table 3.6 which also gives the mnemonics used in references to these sectors.

Data Collation and Variable Construction

Four variables are constructed by combining and collating series from the quarterly and annual data sets - namely employment L, wages P_l, value added YV and volume production Q. All variables are calculated in annual amounts. This means that for example the quarterly wage data calculated is the annual level of the wage rate measured at quarterly intervals. This does not alter the behaviour of the measured variables, it simply means that (with the obvious exceptions of employment and output prices) they are scaled upwards by a multiple of four.

1. **Employment L**

   LQ: Quarterly Industrial Employment Numbers

   L: Annual Persons Engaged (calculated in mid-September) 1973-90

   The quarterly data and annual data correspond more or less exactly except for minor revisions. The annual data relate to quarter three of each year, specifically they are measured in the third week of September in each year.

2. **Cost of Labour P_l**

   WQ: Quarterly Index of Average Weekly Wages 1985Q3=100

   LV: Annual Wages and Salaries Bill 1973-90

   L: Annual Employment 1973-90

   The annual wage rate is calculated as

   $$WA_t = \frac{LV_t}{L_t}$$

   where t is an index of years. The within-year seasonal index is

   $$I_{WQ_t} = \left[\frac{WQ_{Q1t}}{WQ_{Q3t}}, \frac{WQ_{Q2t}}{WQ_{Q3t}}, 1, \frac{WQ_{Q4t}}{WQ_{Q3t}}\right]$$

   This rebases the quarterly data to $Q3 = 1$ within each calendar year. The collated quarterly wage data are calculated as

   $$W_t = WA_t.I_{WQ_t}$$

   where W_t is a (1×4) vector of quarterly wage rates which centres the annual data on $Q3$ in each year. For the period 1991-7 where there are no annual data I_{WQt} is calculated to base $I_{WQ,1990Q3} = 1$.

Non-Wage Labour Costs: These include other labour costs not included in the wage rate W. The *Census of Enterprises* (CoE) provides annual estimates of non-wage labour costs over the period 1979-90. Because the CoE and the Census of Establishments differ in coverage (see Appendix B.1.2) these data are not directly comparable with W_t. However the ratio $F_l = \frac{\text{Other Labour Costs}}{\text{Wages and Salaries}}$ from the CoE data provides an indicator of non-wage labour costs as a proportion of wages and salaries. These data cover the period 1979-90 and are available for all 31 sectors with the following approximations:

(a) In 1979 the data for sectors 2526, 251, 257 amd 255260 are approximated by data for the major NACE sector 25, 26.

(b) In 1980-90 the data for the sector 49 are approximated by data for the major NACE sector 14,48,49.

(c) In 1979-90 the data for the sectors 424428 and 429 are approximated by data for the major NACE sector 424-429.

For the period 1991-97 the data are approximated by the 1990 observation.

The *Labour Costs Survey* (LCS) data for the years 1974/5, 1978, 1981, 1984 and 1988 also provide estimates of F_L for all 33 sectors with the following approximations:

(a) For the year 1974/75 the data for sectors 412, 413, 416422, 419, 420421, 41*rem* and 424429 are approximated by data for the major NACE sector 41-42, the data for sectors 431, 436, 43*rem* by data for major NACE sector 43, the data for the sector 453456 by data for major NACE sector 45 and the data for sectors 471472 and 473474 by data for major NACE sector 47.

(b) For the years 1975 and 1978 the data for sector 112123 are approximated by data for the major NACE sector 11,23.

(c) For the years 1975, 1978 and 1981 the data for sectors 251, 257 and 255260 are approximated by data for the major NACE sector 25,26.

These data are used for F_l for the period 1973-78 with 1973 and 1974 set equal to the 1975 data, 1976 and 1977 set equal to the 1978 data.

The estimated F_l series are plotted in Figures B.1, B.2 and B.3. It can be seen that non-wage costs are increasing relative to wages and salaries over the time period. Figures B.4 through B.8 plot the ratio of CoE to LCS estimates of F_l in the overlap years 1981. 1984 and 1988. For certain sectors - 257 in 1981, 36 in 1984, 35 in 1981 and 1988 - the difference between the two measures exceeds 50% of the LCS measure. Almost 90% of the time the difference is between ±20% of the LCS measure.

The cost of labour P_l is calculated as

$$P_{l\,t} = (1 + F_l)_t . W_t$$

$P_{l\,t}$ is a (1×4) vector which scales up the wage data by the estimated ratio of non-wage labour costs to wage costs.

1. **Value-Added** YV:

   YV^A: Annual Net Output 1973-90

   TV: Quarterly Industrial Turnover Index 1980=100

   Define the vector $I_{TV\,t}$ as

   $$I_{TV\,t} = \frac{1}{\overline{TV}_t}[TV_{1t}\ ,\ TV_{2t}\ ,\ \ldots\ ,\ TV_{4t}] \quad \overline{TV}_t = \sum_{i=1}^{4} TV_{it}$$

   where t is an index of years and I_{TV} is a within-year seasonal index based to the annual average of the quarterly data within that year. Then the (1×4) vector of quarterly value added data is estimated as

   $$YV_t^E = YV_t^A . I_{TV\,t}$$

   This means that the annual average of the quarterly data YV^E exactly equals the annual data YV^A. For 1991-97 I_{TV} is set to the base 1990=1. Note that YV^E is only an estimate because the turnover index has a direct corrspondence with gross output but not with net output.

2. **Volume Production** Q

   QM: Quarterly Industrial Production Index 1985=100

   I_Q: Annual Volume Index Production Numbers 1973-90

   QV: Annual Gross Output 1973-90

   Define the vector $I_{QM\,t}$ as

   $$I_{QM\,t} = \frac{I_{Qt}}{\overline{QM}_t}[QM_{1t}\ ,\ QM_{2t}\ ,\ \ldots\ ,\ QM_{4t}] \quad \overline{QM}_t = \sum_{i=1}^{4} QM_{it}$$

   where t is an index of years. $I_{QM\,t}$ scales up the quarterly volume index numbers so that their annual average corresponds to the annual index number. Then

   $$Q_t = QV_{1985} . I_{QM\,t}$$

   estimates volume gross output data at 1985 constant prices.

B.2 Missing Observations

Most of the quarterly employment (LQ) and wages (WQ) data series used in constructing the quarterly databank begin in the first quarter of 1977, most of the monthly production series (QM) begin in July 1975 and most of the monthly turnover data series (TV) begin in January 1980. The corresponding annual data begin in 1973. This section describes a simple deterministic model used to "forecast"[2] the quarterly data to the beginning of 1973. The four variables employment L, wages W, volume output Q and value-added YV from the quarterly databank are needed to model the long-run demand for labour in a value-added framework (see Section 3.9.2). Therefore these four variables are forecast back to 1973, the year in which the annual data begin. The annual observations are used as an additional source of information which modifies the pure *ex ante* forecasts from the deterministic model.

B.2.1 A Multivariate Model With Deterministic Regressors

Given a $(p \times 1)$ vector x of p variables with observations available over the period $1 \dots n$, a simple deterministic model of x is

$$x_t = \alpha + \gamma s + \beta t \qquad t = 1 \dots n \tag{B.1}$$

where S_0 is an $(s \times 1)$ vector of centred seasonal dummies, s is the number of seasons in a given year ($s = 4$ with quarterly data), α and β are $p \times 1$ vectors of coefficients on the constant and trend, t is an index of time and γ is a $p \times s$ matrix of seasonal coefficients.

Defining the forecast period as $n+1 \dots N$ the *ex ante* forecasts from this model are

$$\hat{x}_t = \hat{\alpha} + \hat{\gamma} s + \hat{\beta} t \qquad t = n+1 \dots N \tag{B.2}$$

In matrix notation we can rewrite (B.1) and (B.2) as

$$X_1' = A + \gamma S_1 + \beta T_1 \tag{B.3}$$

where $X_1' = [x_1, \dots, x_n]$, $A = \alpha i_1'$, i_1' is a $1 \times n$ vector of ones, T_1 is a $1 \times n$ vector of time $= [1, \dots, n]$ and $S_1 = s i_1'$ and

$$\hat{X}_2' = \hat{A} + \hat{\gamma} S_2 + \hat{\beta} T_2 \tag{B.4}$$

$X_2' = [x_{n+1}, \dots, x_N]$, $A = \hat{\alpha} i_2'$, i_2' is $1 \times (N - (n+1))$ vector of ones, T_2 is $1 \times (N - (n+1))$ vector of time $[n+1, \dots, N]$, $S_2 = S_0 i_2'$, and

$$X' = [X_1', X_2'] \text{ is } p \times N \tag{B.5}$$

[2]The term "forecast" is used throughout this section even though the missing data occur at the beginning of the sample. This is because in each instance the incomplete data series is upended so that the beginning of each series, where the missing observations occur, is the end of the upended series. The missing data are then simply "forecast" from each estimated model.

B.2.2 Additional Annual Information

There are two categories of additional annual information. For the variable employment L and wages W observations relating to quarter three in each year of the forecast period are available. For the variables volume production Q and value added YV observations on the calendar year total are available. Thus the matrix X_2 which contains the data available over the forecast period is non-empty but incomplete. Annual totals are included in X_2 at the season in which they are calculated, annual observations made at a point in time are included at the season to which they relate, in all other seasons the data are set equal to zero.

1. **Observation for a Single Quarter, Z**

   Define the seasonal forward summations operator as

   $$S(F) = 1 + F + F^2 + ... + F^{s-1}$$

   and the seasonal backward summations operator as

   $$S(L) = 1 + L + L^2 + ... + L^{s-1}$$

   where L is the lag operator and F is the lead operator. Then the matrix Z of annual observations relating to a single point in time, quarter j, is

   $$Z = D_J X_2 \tag{B.6}$$

   where $D_J = D_j \otimes I_{\frac{N-(n+1)}{s}}$, D_j is an $(s \times s)$ matrix with diagonal element $(j, j) = 1$, all other elements equal to zero. The Z matrix is $(N - (n+1)) \times p$, it contains zeros for all seasons $s \neq j$ where there are no data. For each jth season it contains the observed data on x. For example if $N - (n+1) = 8$, 1973:1-1974:4 is the forecast horizon with $s = 4$, $j = 3$ is the quarter in which data are available over the forecast period and $p = 2$ is the number of variables to be modelled. Then

$$\underbrace{\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \otimes \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}}_{(=D_{j=3} \otimes I_{\frac{8}{4}})} = \begin{bmatrix} D_{j=3} & 0 \\ 0 & D_{j=3} \end{bmatrix} \Rightarrow Z = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ X_{1,1973:3} & X_{2,1973:3} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ X_{1,1974:3} & X_{2,1974:3} \\ 0 & 0 \end{bmatrix}$$

2. **Annual Totals Y or Annual Averages $\overline{Y}$**

The sum of observations over the period ending in t is

$$xtot = S(L)x_t = \begin{bmatrix} \sum_{i=0}^{s-1} x_{1,t-i} \\ \vdots \\ \sum_{i=0}^{s-1} x_{p,t-i} \end{bmatrix}$$

Then the matrix of observed annual totals, Y, is

$$Y = S(F)D_J S(L)X_2 \tag{B.7}$$

where D_J is defined as per above. This Y matrix is $N-(n+1)\times p$ where each column vector replicates the annual total calculated in season j in each of the $s-1$ seasons prior to j. Using the same example as previously with $j=4$ (calendar year totals) then Y is

$$Y = \begin{bmatrix} \sum_{i=1973:1}^{1973:4} x_{1,i} & \sum_{i=1973:1}^{1973:4} x_{2,i} \\ \sum_{i=1973:1}^{1973:4} x_{1,i} & \sum_{i=1973:1}^{1973:4} x_{2,i} \\ \sum_{i=1973:1}^{1973:4} x_{1,i} & \sum_{i=1973:1}^{1973:4} x_{2,i} \\ \sum_{i=1973:1}^{1973:4} x_{1,i} & \sum_{i=1973:1}^{1973:4} x_{2,i} \\ \sum_{i=1974:1}^{1974:4} x_{1,i} & \sum_{i=1974:1}^{1974:4} x_{2,i} \\ \sum_{i=1974:1}^{1974:4} x_{1,i} & \sum_{i=1974:1}^{1974:4} x_{2,i} \\ \sum_{i=1974:1}^{1974:4} x_{1,i} & \sum_{i=1974:1}^{1974:4} x_{2,i} \\ \sum_{i=1974:1}^{1974:4} x_{1,i} & \sum_{i=1974:1}^{1974:4} x_{2,i} \end{bmatrix}.$$

By analogy we can define

$$\overline{x}_t = \frac{1}{s} S(L)x_t \tag{B.8}$$

as the vector of annual averages of the observations over the year ending in t. The matrix $\overline{Y}$ is

$$\overline{Y} = S(F)D_J \frac{1}{s} S(L)X_2 \tag{B.9}$$

picks out the annual average calculated at season j and maps this into the $s-1$ seasons prior to j.

Over the forecast period annual totals for Q and YV relate to quarter 4. These totals are treated as annual averages because Q and YV are measured in annualised units. A comparison of (B.7) and (B.9) above shows this is purely a matter of scaling by s. It is important to remember in modifying the *ex ante* forecasts as shown in the next section.

B.2.3 Combining Ex Ante Forecasts and Additional Information

1. **Observation for a Single Quarter Z**

The constrained forecast with additional information Z is

$$\underbrace{\hat{X}_2|_Z}_{ex\ post} = \underbrace{\hat{X}_2}_{ex\ ante} + \underbrace{\hat{W}}_{additional\ information} \tag{B.10}$$

where

$$\hat{W} = W_1 F^{\frac{s}{2}} S(F) D_J(Z - \hat{X}_2) + W_2 L^{\frac{s}{2}} S(F) D_J * Z - \hat{X}_2) \tag{B.11}$$

$$W_1 = w_1 \otimes I_{\frac{N-(n+1)}{s}} \ , \quad W_2 = w_2 \otimes I_{\frac{N-(n+1)}{s}}$$

where w_1 and w_2 are $(s \times s)$ diagonal matrices with weights along the diagonal. Starting at season j the weights for w_1 are $\frac{1}{s}[s \ s-1 \ s-2 \ \ldots 1]$ and for w_2 are $\frac{1}{s}[0 \ 1 \ 2 \ \ldots s-2 \ s-1]$. At season j the forecast must equal the available observation so $(w_1)_{jj} = 1$ and $(w_2)_{jj} = 0$. For all other seasons there is no additional information. Therefore the adjustment at season j, $\left[S(F)D_J(Z - \hat{X}_2)\right]$, is interpolated for the other $s-1$ seasons using the weights w_1 and w_2. These weights are centred on the jth season and decline linearly between observations. So for example, using quarterly data with the observation available in the third quarter, $s = 4$, $j = 3$ we have:

$$w_1 = \begin{bmatrix} .5 & 0 & 0 & 0 \\ 0 & .25 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & .75 \\ \end{bmatrix} \quad \text{and} \quad w_2 = \begin{bmatrix} .5 & 0 & 0 & 0 \\ 0 & .75 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & .25 \\ \end{bmatrix}$$

Over the period 1973:1-1973:4 the *ex post* forecasts $\hat{X}|_Z$ are

$$\begin{bmatrix} \hat{x}_{1,1973:1}|_Z = & \hat{x}_{1,1973:1} + \frac{1}{2}(x_{1,1973:3} - \hat{x}_{1,1973:3}) + \frac{1}{2}(x_{1,1972:3} - \hat{x}_{1,1972:3}) \\ \hat{x}_{1,1973:2}|_Z = & \hat{x}_{1,1973:2} + \frac{3}{4}(x_{1,1973:3} - \hat{x}_{1,1973:3}) + \frac{1}{4}(x_{1,1972:3} - \hat{x}_{1,1972:3}) \\ \hat{x}_{1,1973:3}|_Z = & \hat{x}_{1,1973:3} + (x_{1,1973:3} - \hat{x}_{1,1973:3}) = x_{1,1973:3}) \\ \hat{x}_{1,1973:4}|_Z = & \hat{x}_{1,1973:4} + \frac{3}{4}(x_{1,1973:3} - \hat{x}_{1,1973:3}) + \frac{1}{4}(x_{1,1974:3} - \hat{x}_{1,1974:3}) \end{bmatrix}$$

The same adjustment applies if the model is in logarithms.

2. **Annual Averages $\overline{Y}$**

Define

$$\overline{\hat{X}}_2 = \frac{1}{s}S(L)\hat{X}_2$$

as the annual average of the *ex ante* forecasts $\hat{X}_2$. Given the additional information $\hat{Y}$ as defined in (B.9) above we have the following constraint on the *ex ante* forecasts

$$\overline{Y} = S(F)D_J\overline{\hat{X}}_2 \tag{B.12}$$

This states that the annual average of the *ex ante* forecasts must equal the observed annual average data available over the forecast period. Define $\overline{T}_2 = \frac{1}{s}S(L)T_2$ as the annual average of T_2, then

$$\overline{\hat{X}}_2 = \hat{A} + \hat{\beta}\overline{T}_2$$

where because the seasons are centred they average to zero. Substituting into the constraint in (B.12) we get an expression for the adjusted sample mean:

$$\hat{A}|_{\overline{Y}} = S(F)D_J\hat{A} = \overline{Y} - \hat{\beta}S(F)D_J\overline{T}_2 \tag{B.13}$$

The constrained forecast sample mean is the same <u>within</u> each year but differs <u>between</u> years. The *ex post* forecast is

$$\hat{X}_2|_{\overline{Y}} = \hat{A}|_{\overline{Y}} + \hat{\gamma}S_2 + \hat{\beta}T_2 \tag{B.14}$$

This can be rearranged as

$$\underbrace{\hat{X}_2|_{\overline{Y}}}_{ex\ post} = \underbrace{\hat{X}_2}_{ex\ ante} + \underbrace{\{\overline{Y} - \hat{A} - \hat{\beta}S(F)D_J\overline{T}_2\}}_{additional\ information} \tag{B.15}$$

Similarly with annual totals Y the *ex post* forecast is

$$\hat{X}_2|_Y = \hat{X}_2 + \{Y - \hat{A} - \hat{\beta}S(F)D_JS(L)T_2\} \tag{B.16}$$

The *ex post* adjustment is th same for all seasons within the year. It ensures that the forecast data will sum (average) exactly to the annual total (average) in season j.[3]

B.2.4 Empirical Results

The model in equation (B.3) was estimated in PC_FIML using FIML estimation techniques. Reductions (i.e. elimination of seasonals or trend term) of the model were made on the basis of likelihood ratio tests. For estimation purposes the 44 sectors were arranged into seven groups of sectors for each variable:

1. 251 257 255260
2. 22 31 32 33 34 35 36 37
3. 412 413 416422 419 420421
4. 424429 424428 429
5. 43 431 436
6. 4445 44451 453456
7. 47 471472 473474

For each of the seven groups of sector four different models were estimated, one each for L, Q, YV and W. The *ex ante* forecasts from estimation of these models were then adjusted, examples of the algorithms used for each of the four variables are given below:

[3]If x_t is modelled in (natural) logarithms then the annual average constraint in period t is

$$\overline{Y}_t = \frac{1}{s}\left[e^{\alpha+\gamma_0 s_0+\beta t} + e^{\alpha+\gamma_1 s_1+\beta(t-1)} + \ldots + e^{\alpha+\gamma_{s-1}s_{s-1}+\beta(t-s+1)}\right]$$

Rearranging and taking logs the *ex post* adjustment to the *ex ante* forecast is

$$\{\ln \overline{Y}_t + \ln s - \ln\{e^{\gamma_0 s_0} + e^{-\beta+\gamma_1 s_1} + \ldots + e^{-(s-1)\beta+\gamma_1 s_{s-1}}\} - \hat{\beta}t_j - \hat{\alpha} - \hat{\gamma}s\}$$

where t_j is the value of t at the jth season within each year.

1. **Example of algorithm for forecasting $L413$**

```
MODELS USED TO FORECAST EMPLOYMENT DATA
/* Estimated parameter values for variable X */
a=1.8728;b=0.0065815;s1=-0.063825; s2=-0.12238;s3=0.0;X=LLQ413;FX=FLLQ413;
/* Calculating the adjustment to the sample mean */
FIX=X-a*Constant-b*Trend-s1*CSeason-s2*lag(CSeason,1)-s3*lag(CSeason,2);
fix=FIX*lag(Seas,2);fix=lag(fix,-1); FIX=(fix==MISSING) ? 0:fix;
fix=FIX+lag(FIX,1)+lag(FIX,2)+lag(FIX,3); fix=(fix==MISSING) ? 0:fix;
FIXAV=Svar1*lag(fix,-2)+Svar2*lag(fix,2); FIXAV=(FIXAV==MISSING) ? fix: FI
/* ex post forecast */               X_F=FX+FIXAV;X_F=exp(X_F);
/* restricting to forecast period */ X_F=X_F*s18p2;X_S=Y*(!s18p2);
/* final variable */                 L413=X_S+X_F;
```

2. **Example of algorithm for forecasting $W35$**

```
MODELS USED TO FORECAST WAGE DATA
/* Estimated parameter values for variable X */
a=2.8361;b=-0.018838;s1=0.0;s2=0.0;s3=-0.027365; X=LWQ35;FX=FLWQ35;Y=WQ35;
/* Calculating the adjustment to the sample mean */
FIX=X-a*Constant-b*Trend-s1*CSeason-s2*lag(CSeason,1)-s3*lag(CSeason,2);
fix=FIX*lag(Seas,2);fix=lag(fix,-1);FIX=(fix==MISSING) ? 0:fix;
fix=FIX+lag(FIX,1)+lag(FIX,2)+lag(FIX,3);fix=(fix==MISSING) ? 0:fix;
FIXAV=Svar1*lag(fix,-2)+Svar2*lag(fix,2);FIXAV=(FIXAV==MISSING) ? fix: FIL
/* ex post forecast */               X_F=FX+FIXAV;X_F=exp(X_F);
/* restricting to forecast period */ X_F=X_F*s18p2;X_S=Y*(!s18p2);
/* final variable */                 W35=X_S+X_F;
```

3. **Example of algorithm for forecasting $YV35$**

```
MODELS USED TO FORECAST VALUE ADDED DATA
/* Estimated parameter values for variable X */
a=3.8636;b=0.0;X=LY35;FX=FLY35;Y=Y35;s0=0.0;s1=-0.15255;s2=0.0;
/* Calculating the adjustment to the sample mean */
```

```
T=Trend*Seas;T=(T==MISSING) ? 0:T;T1=T+lag(T,1)+lag(T,2)+lag(T,3);
T1=(T1==MISSING) ? 0:T1;
E=1+exp(b+s0*CSeason)+exp(2*b+s1*lag(CSeason,1))+exp(3*b+s2*lag(CSeason,2));
fix=X+log(4)-(a*Constant+b*T1+log(E));
/* ex post forecast */                 X_F=FX+fix;X_F=exp(X_F);
/* restricting to forecast period */  X_F=X_F*s15p1;X_S=Y*(!s15p1);
/* final variable */                   YV35=X_S+X_F;
```

4. **Example of algorithm for forecasting** $Q34$

```
MODELS USED TO FORECAST PRODUCTION DATA
/* Estimated parameter values for variable X */
a=8.0894;b=-0.033005;X=LQ34;FX=FLQ34;Y=Q34;s0=0.0;s1=-0.12586;s2=0.0;
/* Calculating the adjustment to the sample mean */
T=Trend*Seas;T=(T==MISSING) ? 0:T;T1=T+lag(T,1)+lag(T,2)+lag(T,3);
T1=(T1==MISSING) ? 0:T1;
E=1+exp(b+s0*CSeason)+exp(2*b+s1*lag(CSeason,1))+exp(3*b+s2*lag(CSeason,2));
fix=X+log(4)-(a*Constant+b*T1+log(E));
/* ex post forecast */                X_F=FX+fix;X_F=exp(X_F);
/* restricting to forecast period */ X_F=X_F*s19p3;X_S=Y*(!s19p3);
/* final variable */                  QQ34=X_S+X_F;
```

Note that the variable W was forecast prior to applying the non-wage labour costs adjustment F_L as described in Section B.1.5. Figures B.10, B.12, B.11 and B.9 plot the forecast against the actual data for each of the four variables for selected sectors.

B.3 The Price of the Factor "Capital"

The price of the factor 'capital', broadly defined, is a measure of the economic cost to a firm of it's usage of capital goods and services over a given time period, hence it is often referred to as the *user cost of capital.* Hicks described the capital measurement problem as "one of the nastiest jobs that economists have set to statisticians". This is because there are so many conceptual and empirical difficulties in defining and measuring both the factor capital and its price, which do not arise in relation to the other main factors of production, labour, energy and raw materials inputs. While it is easy to count employees or hours worked (although the measurement of work-intensity is not so easy) it is far more difficult to put a number on the total value of the capital stock, its usage in a given period and its cost to the firm over that period.

This section describes the cost of capital series estimated for Irish industry. Firstly we sketch the derivation of an expression for the user cost of capital which is based on neoclassical investment theory. Secondly we look at the impact of taxation policy which through its complex system of allowances and tax credits can significantly alter the cost of capital. Thirdly we review the methodology used in previous papers on the cost of capital to Irish industry. Finally we describe the data and methodology used to estimate cost of capital series for the 33 sectors in the quarterly databank.

B.3.1 Theoretical Framework

In the neoclassical theory of investment behaviour, as developed by Jorgensen(1963), optimising marginal productivity conditions for capital accumulation under a neoclassical technology yield a shadow price for capital which Jorgensen calls the *user cost of capital.* This "shadow price interpretation" of the cost of capital is presented in detail in Biorn(1989) and we follow his notation here.

Gross Capital Stock

Let $J(t)$ denote the quantity of capital invested at time t, and the function $B(s)$ the proportion of an investment made s periods ago which still exists as productive capital. This function is known as the *technical survival function* and has the following properties:

$$0 \leq B(s) \leq 1, \quad B'(s) \leq 0 \quad s \geq 0, B(0) = 1, \quad \lim_{s \to \infty} B(s) = 0.$$

Normalising such that one (efficiency) unit of capital produces one unit of capital services per unit of time, then the instantaneous flow of services produced at time t by capital of age s is

$$K(t,s) = B(s)J(t-s), \quad s \geq 0 \tag{B.17}$$

A basic assumption of neoclassical production theory is that capital units belonging to different vintages are perfect substitutes - the so-called putty-putty technology. Under this assumption the total volume of capital at time t is simply an aggregate across vintages

$$K(t) = \int_0^\infty K(t,s)ds = \int_0^\infty B(s)J(t-s)ds \tag{B.18}$$

Optimising Conditions for Capital Accumulation

Define the *restricted profit function* as

$$X(t) = F(K(t))$$

This measures profits for a given capital stock before deduction of the capital cost but after (partial) maximisation with respect to all other inputs. The marginal profit of capital is assumed to be positive and decreasing i.e. $F' > 0$ and $F'' < 0$. Then the net cash-flow at time t (in the absence of taxes) is defined as the gross operating surplus less the investment cost, i.e.

$$R(t) = X(t) - q(t)J(t)$$

where $q(t)$ is the price of one capital (efficiency) unit at time t. The objective of the firm is to maximise the present value of its net cash-flow $W = \int_0^\infty e^{-it}R(t)dt$ where i is the interest rate used in discounting future cash flows. By substitution we get

$$W = \int_0^\infty e^{-it}[F(K(t)) - q(t)J(t)]dt \tag{B.19}$$

which is maximised subject to the constraint imposed by the capital services equation (B.18) above. Solving for the necessary first order conditions (see Biorn, pp. 57-58) we get

$$\int_0^\infty e^{-is}F'[K(t+s)]B(s)ds = q(t) \tag{B.20}$$

This equation generates the optimal path of the planned gross capital stock for a given expected path of the investment price, a given nominal interest rate and a given survival function. The term $F'[K(t+s)]B(s)$ represents the increase in profit to be obtained at time $t+s$ by increasing capital at time t by one unit. The total present value of this marginal profit flow over the capital's life time, discounted at the nominal interest rate, must equal the initial investment price $q(t)$.

Differentiating (B.20) with respect to t and given the definition of the user cost of capital $c(t+s,t)$ as the shadow price of capital services $F'(K(t+s))$ then

$$c(t) = q(t)(i - \frac{\dot{q}(t)}{q(t)}) + \int_0^\infty e^{-is}F'(K(t+s))b(s)ds \tag{B.21}$$

where $b(s) = -B'(s)$ is the *relative retirement function.* The corresponding total retirement function is $D(t) = \int_0^\infty b(s)J(t-s)ds$ where $b(s)ds$ is the share of an initial investment of one unit which disappears from s to $s+ds$ years after installation.

The User Cost of Capital

Equation (B.21) states that the shadow price of increasing capital at time t by one unit is equal to the investment price times the real interest rate plus the present value of the loss of future profits from retirement of this marginal investment. Defining $\gamma = \gamma(t)$ as the constant expected inflation rate of investment prices, $\gamma = \frac{\dot{q}(t)}{q(t)}$, then equation (B.21) can be rewritten as

$$c(t) = \frac{q(t)(i-\gamma)}{1-\int_0^\infty e^{-(i-\gamma)s}b(s)ds} \tag{B.22}$$

Note that the per unit retirement flow $b(s)$ is discounted at the real interest rate $i-\gamma$. This derivation of the user cost of capital rests on the assumptions of a neoclassical technology with malleable capital and a perfect capital market. Now we further assume that the survival function declines exponentially at the constant rate δ, $B(s) = e^{-\delta s}$. This is the standard characterisation of the survival function in the empirical literature. The corresponding relative retirement function is $b(s) = \delta e^{-\delta s}$ which also declines at rate δ.[4] Equation (B.21) becomes

$$c(t) = q(t)(i-\gamma+\delta) \tag{B.23}$$

The expression $\int_0^\infty e^{-(i-\gamma)s}b(s)ds$ in equation (B.22) reduces to $\frac{\delta}{i-\gamma+\delta}$ for the exponential survival function. This is often referred to in the literature as the rate of *true economic depreciation* which measures the present value of the remaining retirement flow and is age invariant.

Equation (B.23) relates three variables,. the nominal interest rate i, the proportionate change in investment prices γ and the depreciation rate δ. The interest rate i measures the rate of discount at which a nominal payment at one point of time can be converted into payments at other points of time. Define $r = i - \pi$ as the real interest rate where π measures the inflation rate of output prices. Then equation B.23 can be rewritten as

$$c(t) = q(t)(r + \underbrace{[\pi-\gamma]}_{=\alpha} + \delta) \tag{B.24}$$

where the second term α measures the capital gain or loss from a real relative asset price change. If we assume that $\alpha = 0$, i.e. that the terms of trade between capital goods and

[4]When the survival function is exponential the dual counterpart for the quantity variables gross investment and gross capital stock is

$$J(t) = \dot{K}(t) + \delta K(t)$$

consumption goods do not change, then the cost of capital is the familiar text-book formula for the *market cost of capital*

$$c_0(t) = q(t)(r + \delta) \tag{B.25}$$

In this derivation of an expression for the user cost of capital we have ignored output prices $p(t)$ in the revenue function. This only alters the results insofar as $c_0(t)$ would be expressed in real terms $c_0(t) = \frac{q(t)}{p(t)}(r + \delta)$. The rate of increase of output prices π is assumed constant throughout.

Taxation and Sources of Financing

Equation (B.25) is the familiar formulation for the user cost of capital without allowing for the effects of taxation. However, the user cost of capital, unlike the gross capital stock, is not invariant to changes in the corporate income tax rate. In King and Fullerton (1984) an international comparison of marginal effective tax rates among four countries - Sweden, the UK, the US, and West Germany - for the year 1980 quantified "striking departures from horizontal equity in all four countries".

1. **Corporate Taxes**: Taxation of corporate earnings increases the cost of capital. Considering the effect of a corporate tax rate τ on the market cost of capital, the *pre-tax* cost of capital is

$$c_1(t) = q(t)\frac{(r + \delta)}{(1 - \tau)} \tag{B.26}$$

   This unambiguously increases the cost of capital: $c_1 > c_0$.

2. **Grants**: Investment grants reduce the cost of capital by reducing the proportion of the initial investment which must be financed. Let φ denote the capital grant rate

$$c_2(t) = q(t)(1 - \varphi)(r + \delta) \tag{B.27}$$

   then this unambiguously reduces the cost of capital $c_2 < c_0$.

3. **Tax Allowances**: Define x and v as the proportion of nominal interest payments and depreciation respectively which are allowable against taxation. Then

$$c_3(t) = q(t)\frac{((1 - x\tau)i - \pi + (1 - v\tau)\delta)}{(1 - \tau)} \tag{B.28}$$

   With full allowances $x = v = 1$ then $c_3 = c_0$ and the corporate tax system is non-distortionary with respect to capital, otherwise $c_0 < c_3 < c_1$ i.e. tax allowances reduce the pre-tax cost of capital.

Define z as the present value of the future stream of depreciation allowances and $\rho = \frac{(1-x\tau)}{1-\tau}i$ as the pre-tax rate of return. Note that if $x = 1$ then $\rho = i$, i.e. the pre-tax rate of return equals the market rate of return. Then the cost of capital can be written as

$$c_3'(t) = q(t)((1-\tau)\rho - \pi + \delta)\frac{(1-z\tau)}{(1-\tau)} \qquad \text{(B.29)}$$

If $z = \frac{\delta}{(1-\tau)\rho-\pi+\delta}$ (depreciation allowances set equal to the true rate of economic depreciation) then $c_3' = q(t)(\rho - \pi + \delta)$ which is higher than the market cost of capital c_0 but lower than the pre-tax cost of capital c_1. If there is full allowance of interest paid, $x = 1$ then $c_3' = c_0$ and the tax system is neutral with respect to capital.

4. **Initial Allowances** : Define an initial investment allowance (equivalent to a tax credit) θ as the proportion of an investment allowable against taxes. Then

$$c_4(t) = q(t)((r+\delta)\frac{(1-\theta\tau)}{(1-\tau)} \qquad \text{(B.30)}$$

This unambiguously reduces the pre-tax cost of capital $c_4 < c_1$.

In practice firms often face a combination of grants, allowances and tax bills on their investment expenditure. Combining all of these factors we get

$$c_5(t) = \frac{q(t)}{(1-\tau)}\underbrace{[(1-\tau)\rho - \pi + \delta]}_{<r+\delta}\underbrace{[1-\varphi-\theta\tau - z\tau(1-\theta)]}_{<1} \qquad \text{(B.31)}$$

This formulation assumes that depreciation is charged against the value of the investment less the amount deductable for tax purposes. Note that it is possible for c_5 to be lower than the market cost of capital ($c_5 < c_0$) even in the presence of corporation tax ($\tau > 0$) if $\theta = 1$ and $\varphi > 0$ or $\theta = 1, \varphi = 0$ and $x > 0$. Even with no investment grants, 100% investment allowances together with allowances against interest paid will reduce the cost of capital below market cost since the allowances exceed 100% of the cost of the investment. If $[\theta = 1, \varphi = 0, x = 0]$ or $[\theta = 0, z = \frac{\delta}{(1-\tau)\rho-\pi+\delta}, x = 1]$ then the tax system is neutral.

All the tax allowances and investment grants referred to here apply to fixed-asset capital. No such benefits apply to working capital (e.g. marketing expenditures) so for firms with a high ratio of working to fixed asset capital estimates of the cost of capital based on equation(B.31) are biased downwards.

Sources of Financing The derivation of the pre-tax user cost of capital c_5 in equation (B.31) assumes that the cost of investment is all debt-financed. However a major point of debate in the literature on the cost of capital is related to determining the sources of finance which firms use and should optimally use to fund their capital investments. Because of the differential tax treatment of equity financing rather than debt-financing, these different sources of finance have very different implications for the firm's final tax burden. The old view (see Sinn (1990)) was that a firm's investments are financed by either equity or debt. In the case of equity financing, the dividend payment required by the shareholder will exceed the market interest rate because of the double taxation of dividend income (at both corporate and personal level). In the case of debt financing, where interest payments are tax deductible, the cost of capital to the firm is lower than for equity financing. This is a clear case of a bias in the tax code in favour of debt financing. Debt financing is subject to tight constraints imposed by the banking system however and these hidden costs mean that in practice firms often have to use alternative sources of funds. The new view points to the frequent use of retained earnings i.e. withheld dividends, as a source of finance. This source avoids the problem of double taxation of dividend income although it is not available to new or immature firms. Another source of finance used is share repurchase schemes.

An alternative type of financing derives directly from the relative penalty imposed on firms who cannot fully exploit the full range of fiscal incentives available to them. In Ireland over the past thirty years the combination of a high level of initial grants and a low or zero tax rate on manufactured goods meant that some firms had unused allowances and had an incentive to enter leasing agreements with partners (typically banks) facing a higher rate of taxation. A further financial instrument in Ireland, so-called Section 84 loans, (finance loans whose interest payments are treated as untaxable dividends), give the lending institution another incentive to lend, where the reduced tax liability of the lender is shared between the borrower and the lender via the terms of the loan.

Limitations

The derivation of the pre-tax cost of capital expression in equation (B.31) is based on a stylised representation of the production process and the capital markets. Firstly the assumption that capital stocks of different vintages are perfect substitutes is dubious and has sometimes been replaced by a so-called putty-clay technology which allows for the substitution of labour (and/or other factors) for new capital but not for old capital. Actual technological processes are probably somewhere in between putty-putty and putty-clay(see Allen, Ch. 15). Secondly the assumption that both the interest rate and the inflation rate are constant (i.e. no uncertainty)was one which ran into difficulties in empirical work in the

1970s when the real interest rate was very far from constant, in some years the *ex ante* real interest rate was negative due to high and accelerating inflation.

Recently Dixit and Pindyck (1994) have proposed an alternative approach to modelling the investment process. They argue that three key features of the investment process have been ignored in the neoclassical formulation, namely that the investment, once made, is *irreversible*, that future rewards are *uncertain* and that the *timing* of the investment can be postponed. A firm with an opportunity to invest is effectively holding an "option" on that investment and therefore they propose that the corporate finance literature on option pricing be used to model the optimal investment path.

B.3.2 Previous Studies of the Irish Cost of Capital

Over the past twenty years several different authors have estimated the cost of capital to Irish industry. The first of these studies was by Geary, Walsh and Copeland (1975) updated by Geary and McDonnell (1979). They use the basic formulation of the market cost of capital as

$$c(t) = q_t(i + \delta - \dot{q}/q) \tag{B.32}$$

where $\delta = 0.10$, q is the price of investment goods and i is the redemption yield on new National Debt interest. They also estimate variants allowing for the impact of tax allowances and grants corresponding to c_3, c_3' and c_5 of the previous section with $\dot{q} = 0$ and $\varphi = 0$. In the original Jorgensen(1963) paper he assumes that $\dot{q} = 0$ because he argues that these price effects are 'transitory'. This preceded the era of high inflation in the 1970s. In their 1979 paper, Geary and McDonnell drop the assumption that $\dot{q} = 0$. In the years 1974 and 1975 their estimated cost of capital was negative because the rate of increase of q_t dominated $i+\delta$.

Their results indicated that the cost of capital, however measured, has risen less quickly than the cost of labour in the period 1953-75 in Ireland. The effect of goverment tax and grant policies was to raise the cost of labour relative to capital over the period.

FitzGerald (1983) uses the basic formula

$$c_t = \frac{q_t}{(1-T)}\Phi(r + \delta)[1 - T(z + y)] \tag{B.33}$$

where z and y are the present value of the tax shield on depreciation and interest paid respectively (these include the effects of initial allowances θ) and $\Phi = 1 - \varphi - T\theta$. He argues that the Geary et al.(1975) formulation (equation (B.32)) with $\dot{q} = 0$ leads to an upward bias in the estimated cost of capital because it includes the nominal rather than the real interest rate.

FitzGerald estimates separate cost of capital series for exporting manufacturing firms (who faced a zero corporate tax rate) and non-exporting firms (who faced a reduced 10% corporate tax rate) over the period 1957-80. The estimated results indicated that the cost of capital was higher for exporting firms because they could not exploit the full range of allowances available. But he points out that this result must be viewed with caution. Firstly tax incentives only apply to fixed assets and not to working capital so the tax shield is overestimated. Secondly, at the margin the tax saving on profits from a new investment due to the tax shield cannot exceed the tax savings from a zero tax rate. Thirdly the interest tax shield applies only to debt-financing. Finally, measured capital includes the factor 'enterprise' which unambiguously benefits from a zero tax rate.

Ruane and John(1984) provide an excellent synthesis of the range of cost of capital formulae applicable to firms facing different tax and financing options. Their basic market cost of capital formula is

$$c_t = q_t(r + \delta - \frac{\dot{q}}{q}) \tag{B.34}$$

where they define q as the real price of investment goods. They then define two costs of capital series, c_{min} and c_{max} which are given by the formulae for c_5 and c_2 respectively. c_{min} is the lower bound on the range of values for the cost of capital. It applies to firms who can exploit the full range of allowances and grants. c_{max} is the upper bound and applies to firms who pay no tax and therefore have no access to these tax benefits. In addition, they define formulae for the cost of capital under leasing c_{Lmin}, where $c_{min} < c_{Lmin} < c_{max}$, and for firms who sell their output on both the domestic and the export market, $c_x = s_x c_{max} + (1 - s_x)c_{min}$ where s_x is the share of output exported. Not surprisingly their results indicate that there is a wide range of variation in the marginal cost of capital bounded between c_{min} and c_{max} for different firms in the manufacturing sector. In all cases the net effect of the range of fiscal and financial incentives has been to subsidise capital rather than labour. They found that the fiscal incentives (tax-saving from interest-deductability and depreciation allowances) had a greater effect than financial incentives (industrial grants) on the cost of capital.

A more recent study of the cost of capital to Irish industry is Frain (1990). He defines the real cost of capital as

$$c_t = \frac{q_t}{p_t}(i + \delta - \frac{\dot{q}}{q})(\frac{(1 - \varphi - \tau(z + y))}{(1 - \tau)} \tag{B.35}$$

where z and y are as defined in equation (B.33). After 1986 the tax allowances on investment in Plant and Machinery were deductible net of grants (this was always the case for investment in Buildings) so that

$$c_{t1986} = \frac{q_t}{p_t}(i + \delta - \frac{\dot{q}}{q})(\frac{(1-\varphi)(1-\tau(z+y))}{(1-\tau)} \tag{B.36}$$

Frain estimates a set of different cost of capital series for investments with lives of five, ten, twenty and forty years over the period 1960-89. He found that a 1% rise in both nominal and real interest rates in 1989 caused the market cost of capital to rise by 0.9%. His stresses the importance of the system of capital grants as an investment incentive in reducing the cost of capital. Optimally the tax system should be designed to be neutral with respect to the investment decision while his estimates indicated that the cost of capital was negative in some years in the 1970s and 1980s for firms paying the full corporate tax rate. (In practice this includes very few firms since all manufacturing firms qualify for the 10% reduced rate of tax.) This was because the Irish tax system overcompensated by a combination of grants and interest and depreciation tax shields which was in excess of the tax liability.

B.3.3 Quarterly and Annual Estimates of the Cost of Capital

We define the *market cost of capital* using the shadow price equation (B.23) derived above as

$$c_{Kt} = p_{Kt}(i_t - \gamma_t + \delta) \tag{B.37}$$

where p_K is the price of investment goods, γ is the rate of change of investment goods prices, δ is the rate of economic depreciation, and i is the nominal rate of interest. The *pre-tax cost of capital* is

$$c_{Kt} = p_{Kt}\frac{(1-g_t)}{(1-\tau_t)}(i_t - \gamma_t + \delta) \tag{B.38}$$

where g is an average measure of the present value of tax allowances and investment grants and τ is the rate of corporation tax. This is an average approximation to the marginal shadow price concept where g serves as an average linear proxy for the present value of all allowances and grants.

We do not decompose our user cost of capital in terms of a real interest rate component and a capital gains or losses component. Recall that in equation (B.24) the components of the cost of capital were rearranged as

$$\underbrace{(i-\pi)}_{\text{Real Interest Rate}} + \underbrace{(\pi-\gamma)}_{\text{Capital Gain/Loss}} + \underbrace{\delta}_{\text{Depreciation Rate}} \tag{B.39}$$

In the literature the first term, which is a measure of the firm's real discount rate is sometimes adjusted to include a risk factor and the second term is often ignored under the assumption that $\gamma = \pi$. In our formulation we make no such assumption and include the nominal interest rate, the rate of change of investment prices and the physical depreciation rate seperately.

The data series used are

1. p_K: Wholesale Price Index of Capital Goods.

2. g: *Grants to Industry.* This measures the level of direct subsidies and capital grants to enterprises (Table 23, NIE). It includes grants by the IDA (Industrial Development Authority), SFADCo (Shannon Free Area Development Co.), IIRS (Institute for Industrial Research and Standards) and Udaras na Gaeltachta[5] to industrial enterprises. The grant rate is estimated as the ratio of these grants to total manufacturing investment in each year. We use this as a proxy for the present value of all allowances and grants. While this will underestimate the true value of all allowances for fixed-asset investment, and thus inflate the estimated cost of capital, it's inclusion will also bias downwards the true cost of investment in working capital which is subject to no such allowances. No attempt is made to allow for the different tax allowances related to different sources of finance.

3. τ: *Corporate Tax Rates.* This measures the rate of corporation or company taxation in the industrial sector. It includes the rate of income tax payable by companies. The data, taken from the ESRI databank, were originally sourced from the Revenue Commissioners Reports. *RCORP2* is the (reduced) rate for non-exporting manufacturing companies. *RCORP3* is the rate for manufactured exports which were zero-rated until 1981. For 1978-80 this rate was only applicable if employment increased by 3%.

4. i: *Interest Rate.* The interest rate used is the AAA category overdraft rate. This is the rate charged by commercial banks to Government, local authorities and large scale companies. Movements in this rate are broadly tracked in all short-term lending rates. From 1991 onwards, this interest rate is replaced by the Prime Rate. End-month data, averaged to quarterly, were taken from various issues of the Central Bank Quarterly Bulletin. In calculating the cost of capital we include the nominal interest rate as a four-quarter forward moving average.

5. γ: The quarter-on-quarter inflation rate of p_Kt. This is included as a four-quarter forward moving average.

6. δ: These are fixed depreciation rates for the 12 major industrial sectors calculated based on data from Henry (1989). Henry uses estimates of the average life of asset groups

[5] Development agency for Gaeltacht areas in the west of Ireland.

from a range of international studies and then applies linear depreciation over the average life of each major asset category. This methodology is based on an exponential survival function. Two asset groups are identified for the 12 major industrial sectors, namely, Plant, Machinery & Vehicles and Buildings & Land. We calculated weighted sectoral depreciation rates based on the average life of these two groups of assets as estimated by Henry, and under the assumption that in the final year the value of the asset is 5% or less of its original value.

$$a_n = a_0 * (1-\delta)^n \text{ with } \frac{a_n}{a_0} = 0.05$$

where a is the asset and n is the average life of the asset.

The estimated cost of capital series is a weighted average of the cost of capital calculated using τ_x and using τ_{nx}, where the weights used are from the 1985 input-output tables, exports as a percentage of total output. This weighting assumes that the profits earned from exports are proportional to the share of output exported.

The 33 sectoral series in the quarterly data set used in Part I do not differ very much, the only sector-specific components of the estimated cost of capital are the depreciation rate (differ over the 12 major industrial sectors) and the export weights (differ over the 33 broad industrial sectors). The measured real interest rate in the high-inflation years on the 1970s was negative. Over this period we set the real interest rate equal to an annualised rate of 2 per cent (lower than the measured real interest rate for the rest of the sample period). This can be thought of as some sort of "risk factor" adjustment making the real cost of borrowing positive in those years.

The corresponding annualised cost of capital series used in Part II, for the 72 detailed industrial sectors in the panel data set, 1979-1990 were mapped from broad to detailed sector so that the cost of capital series is the same for all detailed sectors included in a single broad sector.

B.4 Tables and Graphs for Part IV

CIP QUESTIONNAIRE

11. **Employment and gross earnings**	Persons engaged in week ended 15 September 1990			Gross earnings during year	
	Males	Females	Total	£	*3*
(a) Proprietors and members of family working in the business not paid a fixed wage or salary				Nil	*(1-15)*
(b) Managerial, technical and other salaried staff					*(16-40)*
(c) Clerical and other office staff *(incl. clerical supervisors)*					*(41-65)*
(d) Manual supervisory staff *(e.g. foremen, production supervisors)*					*(66-90)*
(e) Manual workers *except apprentices and outside piece-workers*					*(91-115)*
(f) Apprentices					*(116-140)*
(g) Outside piece-workers *(i.e. home workers)*					*(141-165)*
Total					*(166-190)*

SECTION 11: Earnings

These should be the gross amounts paid to all employees on the payroll in the year, before deduction of tax, PRSI etc

Include – overtime, service pay, shift and other allowances
- commissions and bonuses
- holiday and sick pay
- earnings of trainees (even if recouped in whole or in part from AnCO, etc.)

Exclude – redundancy payments, pensions to former employees
- payment of travelling expenses
- other labour costs not forming part of employee earnings (e.g. employer's PRSI and pension fund contributions, payments in kind, etc.).

NACE CODE	12 Major Industrial Sectors
11,21,23	Mining, Quarrying and Turf
13,16-17	Electricity, Gas and Water
24	Manufacture of Non-Metallic Mineral Products
25-26	Chemicals (incl. Man-made Fibres)
22,31-37	Metals and Engineering
411-423	Food
424-429	Drink and Tobacco
43	Textiles
44-45	Clothing, Footwear and Leather
46	Timber and Wooden Furniture Industries
47	Paper and Paper Products, Printing and Publishing
14,48-49	Miscellaneous Industries

Table B.1: NACE 12 Major Industrial Sectors

NACE CODE	34 Broad Industrial Sectors
11,21,23	Mining, Quarrying and Turf
13,16-17	Electricity, Gas and Water
24	Manufacture of Non-Metallic Mineral Products
251	Basic Industrial Chemicals
257	Pharmaceuticals
255-256, 258-260	Chemicals, Remainder (incl. Man-made Fibres)
22	Production and Preliminary Processing of Metals
31	Manufacture of metal articles
32	Mechanical engineering
33	Office and data processing
34	Electrical Engineering
35	Manuf and assembly of motor vehicles (incl. parts)
36	Manufacture of other means of transport
37	Instrument Engineering
412	Slaughtering, preparing and preserving of meat
413	Manufacture of dairy products
416,422	Grain Milling and Animal feeding Stuffs
419	Bread, biscuits and flour confectionery
420,421	Sugar, Cocoa, Chocolate and Sugar Confectionery
411,414-415, 417-418, 423	Other Food
424-428	Drink
429	Tobacco
431	Wool industry
436	Knitting industry
432-434,437-439	Other Textiles
44,451	Leather and Leather goods, Footwear
453-456	Clothing (incl. Furs and Household Textiles)
46	Timber and Wooden Furniture Industries
471-472	Paper and Paper Products
473-474	Printing and Publishing
14	Mineral oil refining
481-482	Manufacture of rubber products (incl. retreading of tyres)
483	Processing of plastics
49	Other manufacturing industries

Table B.2: NACE 34 Broad Industrial Sectors

NACE CODE	75 Detailed Industrial Sectors
111	Coal Mining
212	Extraction and preparation of non-ferrous metal ores
231-239	Extraction of non-metallic minerals (incl. turf)
132,162	Extraction and distribution of gas; gasworks
161	Generation and distribution of electric power
170	Water Supply
241-246	Non-metallic mineral products (excl. glass and ceramics)
247	Glass and glassware
248	Ceramic Goods
251	Basic Industrial Chemicals
255	Paints, varnishes and printing inks
256	Chemicals mainly for industrial and agricultural use
257	Pharmaceuticals
258	Soap, synthetic detergents, perfumes and toilet preparations
259-260	Other chemical products and man-made fibres
221-223	Iron and Steel
224	Non-ferrous metals
311	Foundries
312	Forging, pressing and stamping of metals
313	Secondary transformation, treatment and coating of metals
314	Manufacture of Structural metal products
315	Boilermaking, manufacture of tanks, etc.
316-319	Finished metal products and other metal workshop products
32	Mechanical engineering
33	Office and data processing
341	Insulated wires and cables
342,347-348	Electrical machinery and lighting equipment; assembly and installation of electrical equipment
343	Electrical apparatus for industrial use (incl. batteries)
344	Equipment for telecommunications, electronic recording etc.
345	Radio and television receivers, sound reproducing and recording equipment
346	Domestic electrical appliances
35	Manuf and assembly of motor vehicles (incl. parts)
361	Shipbuilding
362	Railway rolling stock
363-365	Cycles, motor cycles, aerospace and other means of transport
37	Instrument Engineering
411	Vegetable and animal oils and fats

Table B.3: NACE 75 Detailed Industrial Sectors I

NACE CODE	75 Detailed Industrial Sectors
412	Slaughtering, preparing and preserving of meat
413	Manufacture of dairy products
414	Processing and preserving of fruit and vegetables
415	Processing and preserving of edible fish and other seafood
416	Grain milling
417-418,423	Miscellaneous foodstuffs
419	Bread, biscuits and flour confectionery
420	Manufacture and refining of sugar
421	Cocoa, chocolate and sugar confectionery
422	Animal and poultry foods
424	Spirit distilling and compounding
425-426,428	Manufacture of wine, cider and soft drinks
427	Brewing and malting
429	Tobacco
431	Wool industry
432	Cotton industry
433-434	Silk and flax industries
436	Knitting industry
437,439	Textile finishing and miscellaneous textiles
438	Carpets and other floor coverings
44	Leather and leather goods
451	Footwear
453-454	Clothing and accessories (except knitwear)
455	Household and other textile goods
456	Furs and fur goods
461-462	Sawing and processing of wood; manuf. of semi-finished wood products
463	Carpentry and joinery components
464-465	Wooden containers and other wooden products (except furniture)
466	Articles of cork, straw etc; brushes and brooms
467	Wooden furniture
471-472	Paper and Paper Products
473-474	Printing and Publishing
14	Mineral oil refining
481-482	Manufacture of rubber products (incl. retreading of tyres)
483	Processing of plastics
491	Articles of jewellery
494	Toys and sports goods
492-493,495	Manufacturing industries n.i.e.

Table B.4: NACE 75 Detailed Industrial Sectors II

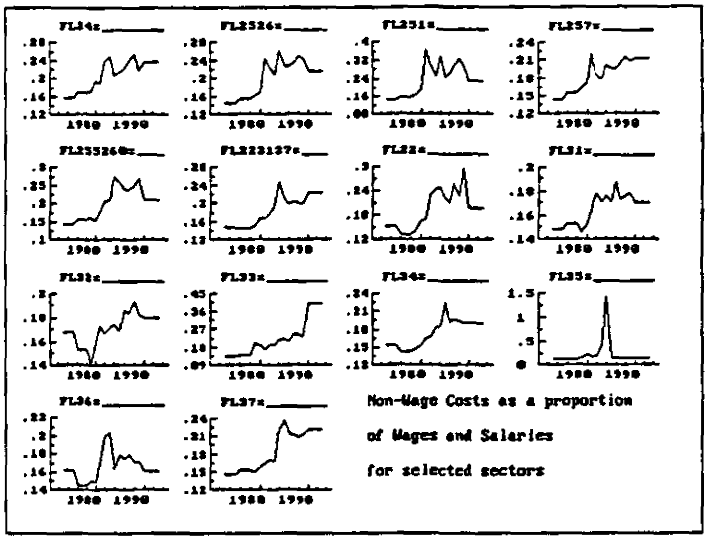

Figure B.1: Non-Wage Costs as a proportion of Wages and Salaries I

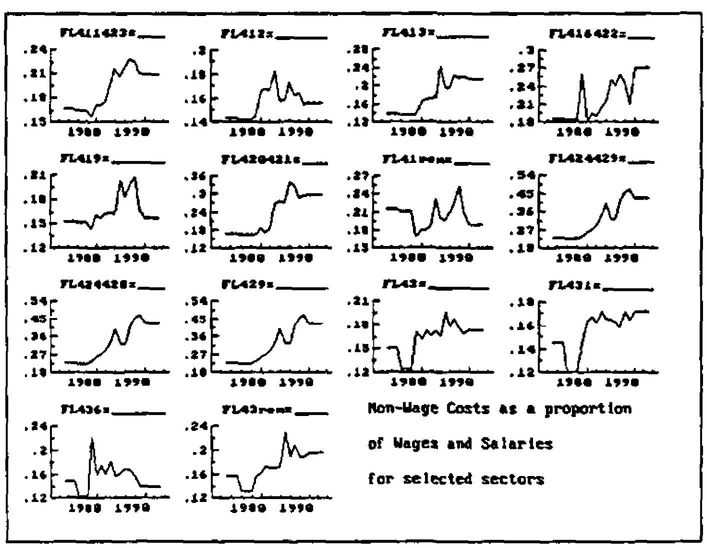

Figure B.2: Non-wage Costs as a proportion of Wages and Salaries II

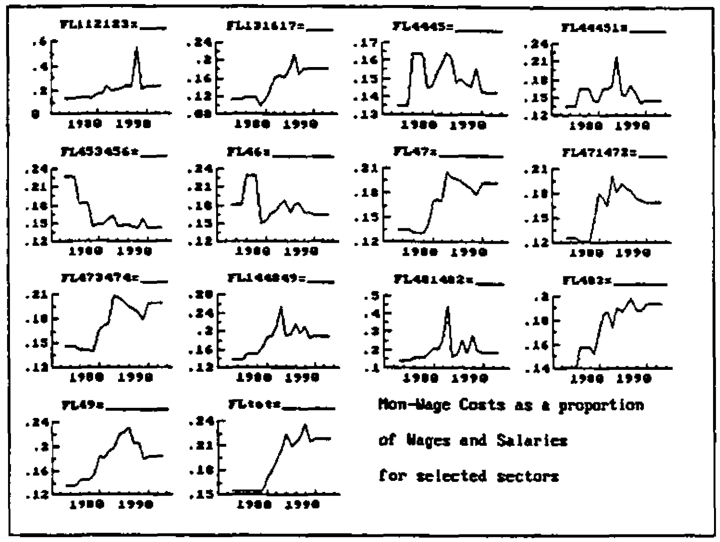

Figure B.3: Non-wage costs as a proportion of Wages and Salaries III

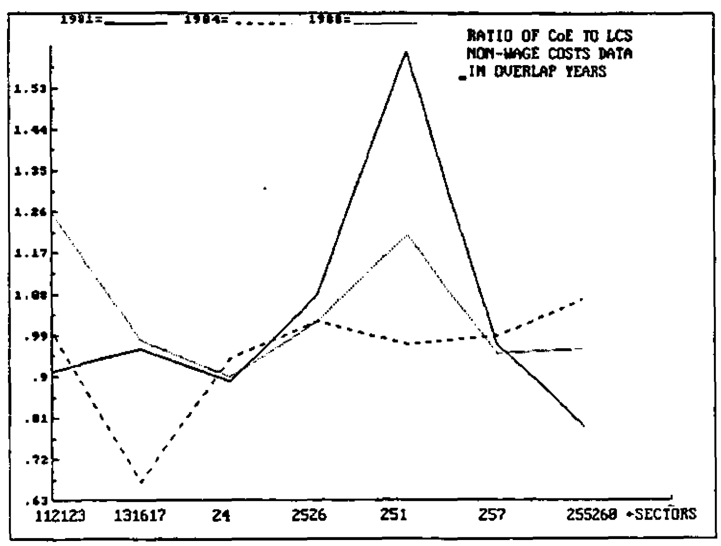

Figure B.4: Ratio of CoE to LCS non-wage costs I

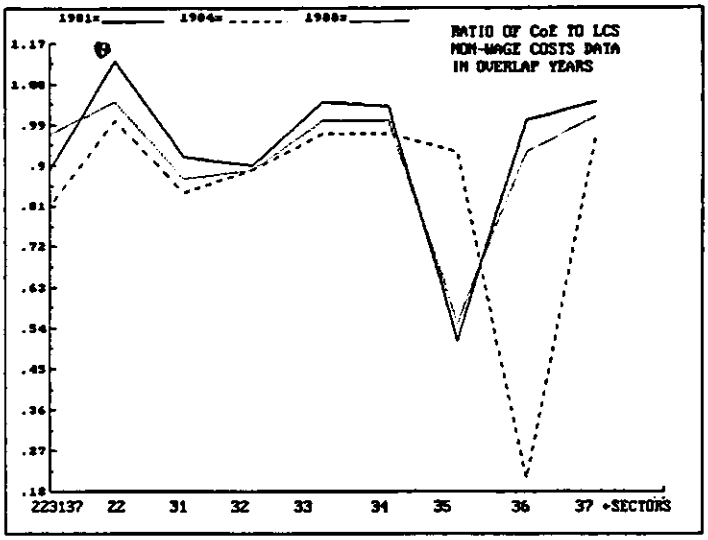

Figure B.5: Ratio of CoE to LCS non-wage costs II

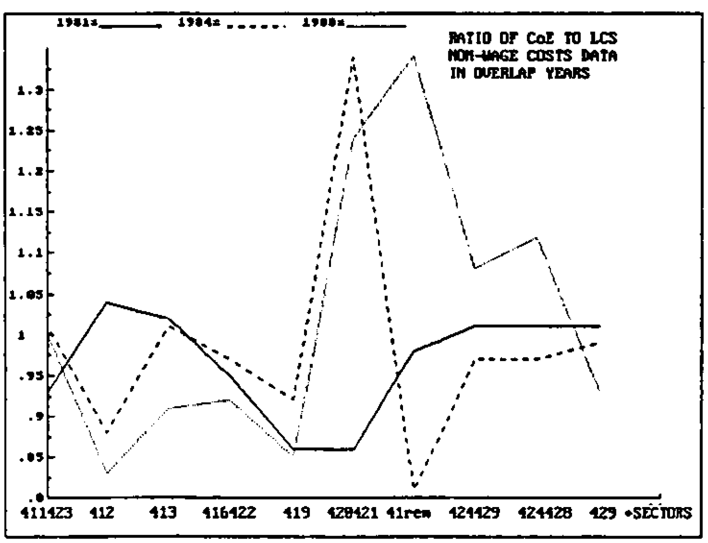

Figure B.6: Ratio of CoE to LCS non-wage costs III

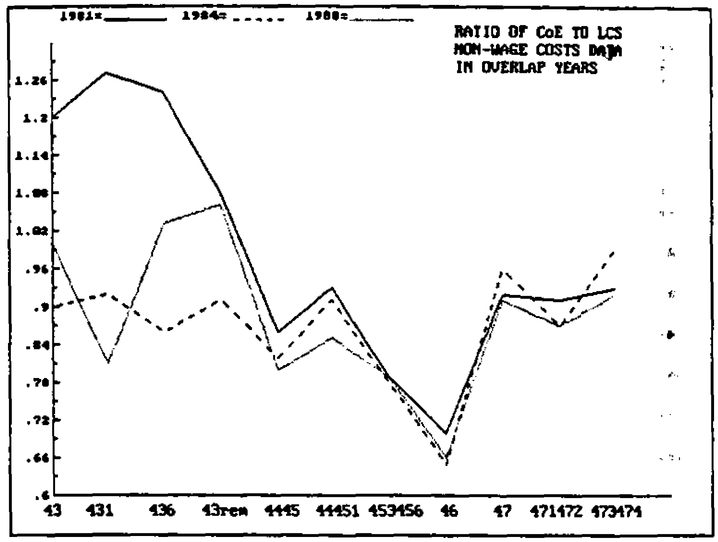

Figure B.7: Ratio of CoE to LCS non-wage costs IV

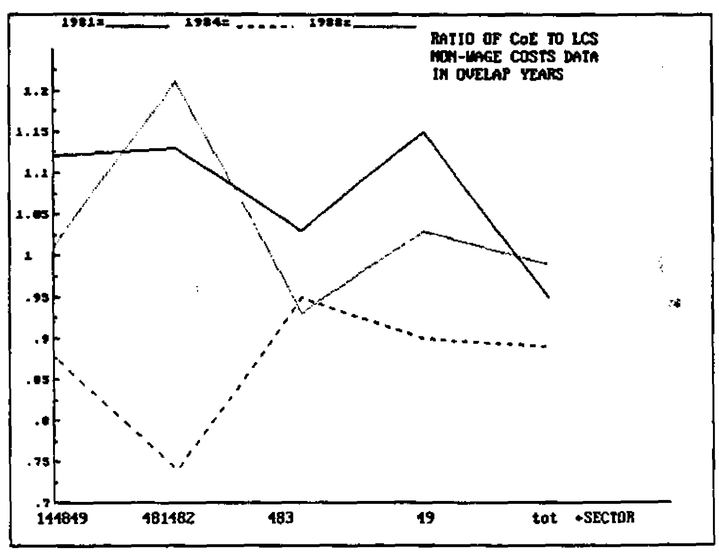

Figure B.8: Ratio of CoE to non-wage costs V

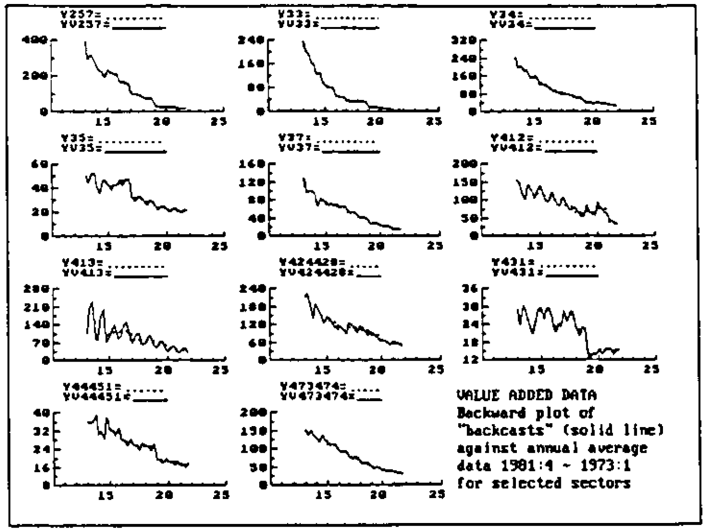

Figure B.9: Forecasts of Value-Added

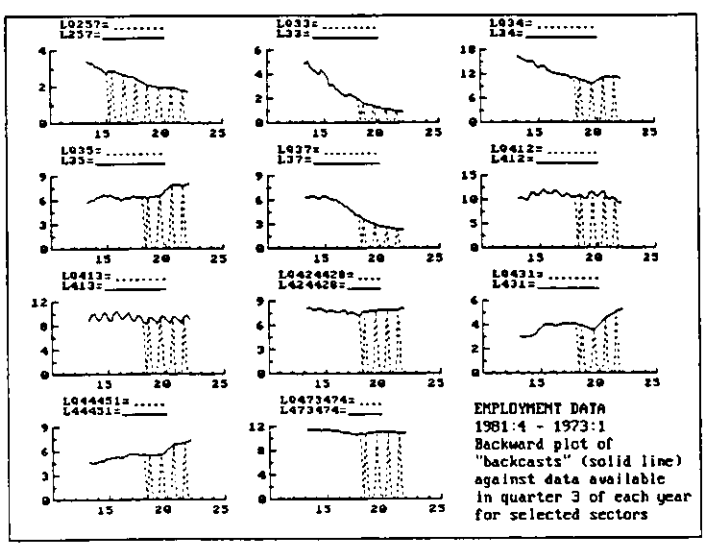

Figure B.10: Forecasts of Employment

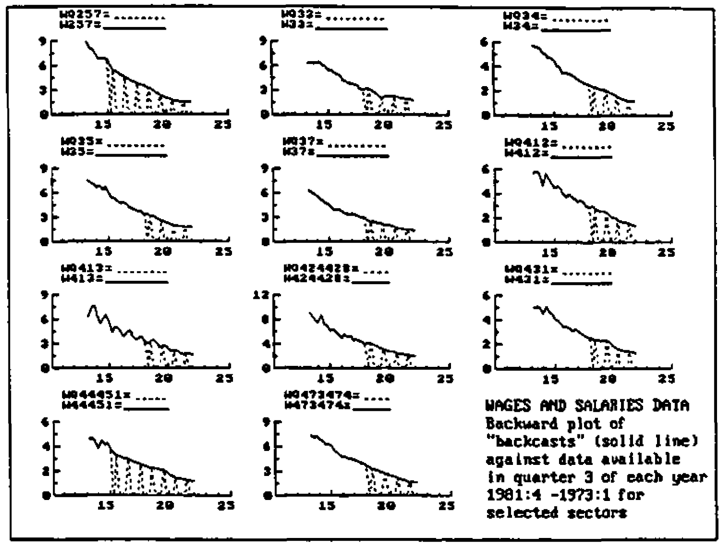

Figure B.11: Forecasts of Wages

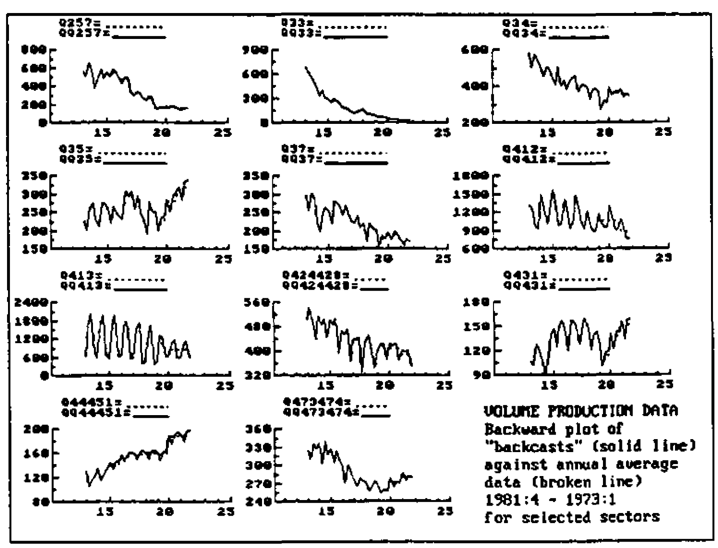

Figure B.12: Forecasts of Volume Output

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