THE ECONOMIC AND SOCIAL RESEARCH INSTITUTE

Estimating the Demand for Skilled Labour, Unskilled Labour and Clerical Workers: A Dynamic Framework

Ide Kearney

December 1997

Working Paper No. 91

Estimating the Demand For Skilled Labour, Unskilled Labour and Clerical Workers: A Dynamic Framework

Ide Kearney

December 18, 1997

Abstract

We estimate long-run interrelated demand functions for skilled labour, unskilled labour, clerical labour and capital services within a dynamic framework using a panel of data on Irish manufacturing sectors during the 1980s. We group the sectors into three production 'types' - high-growth sectors, medium-growth sectors and declining sectors. The results indicate very important differences in the demand for skilled labour compared to the demand for unskilled labour and in the underlying production technologies for the three groups of sectors. The medium-growth group of sectors are characterised by a stable production technology where skilled labour, unskilled labour and capital are all limited substitutes in production and there is little evidence of skill-biased technical change or trade effects. Most of the relatively minor shifts in factor shares in this group are accounted for by movements in relative factor prices. This group numbered over half of all manufacturing employment throughout the period under study. The high-growth group of sectors has all the features of the production technology described in modern growth theory: skilled labour and capital are complements in production, technical progress is biased against unskilled labour and the skill-intensity of production is increasing over time. This favours the "skill-biased technical change" hypothesis. And the declining group of sectors are in secular decline with no stable long-run demand for labour. This would favour the "trade effect" hypothesis where low-skill technologies are relocating from Ireland to low-wage countries because of import penetration.

1. Introduction

The Irish labour market suffered a deep and prolonged recession in the 1980s. As can be seen from Figure 1.1, between 1980 and 1987 employment in industry fell continuously.

Since then however employment has grown strongly and most notably, in contrast to the industrial sector of most developed economies, there has been strong growth in employment in the industrial sector.

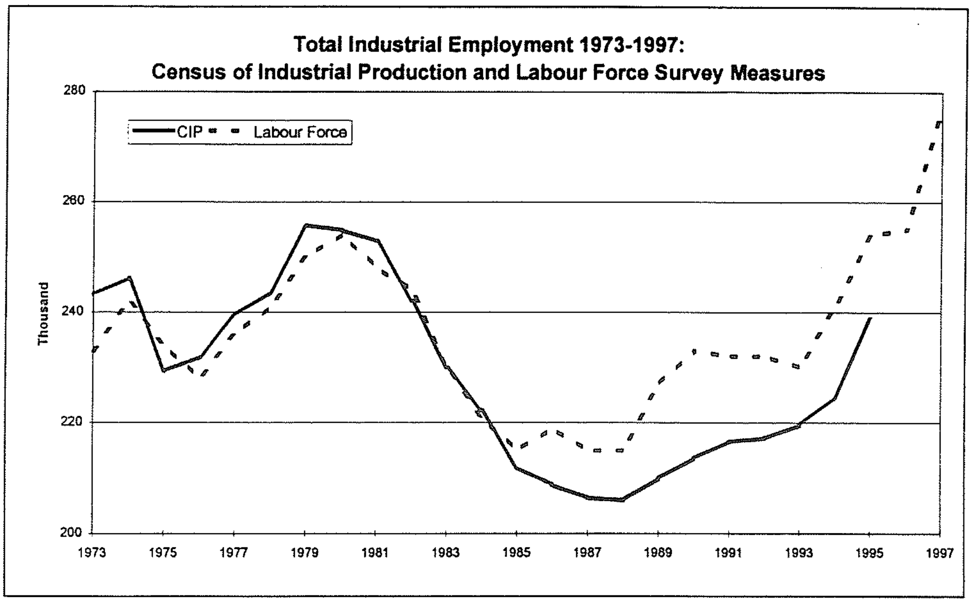

Figure 1.1: Total Employment in Industry 1973-1997: Census of Industrial Production and Labour Force Survey Measures

To understand the current strength of employment in the industrial sector it is necessary to examine the period of extensive restructuring in the 1980s. This is the main focus of this paper. We look across the full range of industrial sectors and across a range of different employment categories, at as detailed a level as the data permit, to try and profile the demand for labour in the manufacturing sector in this period.

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 (heterogeneity in production). Concurrent with, and intimately linked to, this change in production was the shift in the occupational structure and educational profile of the Irish workforce towards more highly 'skilled' workers (heterogeneity in labour input). In this paper we explicitly take account of both types of heterogeneity in estimating the demand for labour. Based on the descriptive analysis of the data in Kearney (1997) we distinguish three types of sector ranked by output performance (high-growth sectors, medium-growth sectors and declining sectors) and three categories of worker (skilled, unskilled and clerical workers). While there is a growing body of research on the dynamics of labour supply and the returns to education in Ireland, this is the first parametric study of the demand for labour in Ireland in the post-1973 period (since accession to the EU) which distinguished between skilled and unskilled labour.

The translog cost function is used to derive a set of long-run factor demand equations based on the assumption of cost-minimising behaviour. The parameters underlying these equations summarise the set of technological and economic relationships which describe the production process of a typical firm in the long-run. These parameters can be used to estimate the degree of substitution between different factors for a given level of output together with the own- and cross-price elasticities of demand.

This theoretical model specifies a simple static factor demand system. In the long-run cost-minimising behaviour requires that the restrictions of price homogeneity and symmetry must be satisfied. However there is no behavioural reason why these should hold in the short-run. To allow for possible short-run deviations from long-run optimal behaviour we adopt a dynamic specification in estimation. Within this framework all factors are variable and each can have different short–run adjustment behaviour.

Our results indicate very important differences in the demand for skilled labour compared to the demand for unskilled labour. A *general* increase in the wage level will, for an unchanged level of output, cause a much larger substitution out of unskilled labour than out of skilled labour. Indeed we found that in the high-growth group of sectors a general wage increase will cause net substitution into skilled labour at the expense of unskilled labour. A similar asymmetry of response applied to the demand for unskilled labour *relative* to skilled which is much more sensitive to movements in the unskilled wage than to movements in the skilled wage for an unchanged level of output.

Our results also indicate that there are significant differences in the underlying production technologies for the three groups of sectors. These can broadly be characterised into three types. The medium-growth group of sectors corresponds to the classical production technology where skilled labour, unskilled labour and capital are all limited substitutes in production. The high-growth group of sectors has all the features of the production technology described in modern growth theory: skilled labour and capital are complements in production, technical progress is biased against unskilled labour and the skill-intensity of production is increasing over time. And the declining group of sectors are in secular decline with no stable long-run demand for labour. This last group reflects the adverse consequences of import penetration or the so-called 'trade effect' described in Kearney (1997).

The explicit recognition of both heterogeneity in production and in labour input is central to understanding the current strong growth performance of the Irish manufacturing sector.

The sectoral composition of output in the manufacturing sector during the 1980s switched from low-productivity (declining sectors) to high-productivity (high-growth sectors) production. The dominance of a small group of high-growth sectors in the Irish manufacturing sector in the 1990s highlights the uniqueness of the Irish manufacturing sector within the EU which is reflected both in the strong growth in employment in the 1990s and in a superior employment performance in the 1980s relative to the EU average (see Bradley et al. (1997, pp. 40-41). The 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. The net effect of these changes was to increase the underlying growth potential of the manufacturing sector.

The results of this research highlighted a number of methodological issues in estimating the demand for labour using sectoral data. Firstly it is important to identify groups of sectors with relatively similar production processes. The theoretical model is based on individual firm behaviour. Therefore ideally the sectoral data should represent 'similar' sectors so that our parameters measure the true underlying technological and economic magnitudes of the production function (or dual cost function) rather than capturing differences between sectors. Secondly when using sectoral data to approximate for firm behaviour within sector changes can distort the estimated firm behaviour. Therefore we included net changes in the number of firms in each sector as an extra regressor in each equation. And thirdly estimation of long-run behaviour is not always possible if sectors are in secular decline so that the output decision dominates any changes in the factor mix.

The plan of the paper is as follows. Firstly in Section 2 we specify a system of interrelated long-run factor demand equations derived from the translog cost function. In addition to relative factor price terms, the factor demand equations include time dummies as a proxy for technical progress, the number of firms per sector to allow for net firm entry and exit causing shifts in the level of factor shares, and gross output to measure scale effects. With just two factors of production this system reduces to estimating a single equation. In Section 2.2.1 we specify a dynamic version of this two-factor single-equation model (denoted "partial system"). Following this in Section 2.2.2 we use the methodology developed by Anderson and Blundell (1982) to specify a dynamic interrelated factor demand system for four factors of production (denoted "full system").

Section 3.1 looks at the econometric issues involved in estimating single-equation dynamic models with a short panel of data. Because such models combine both fixed effects and lagged endogenous variables, instrumental variables estimators are necessary. For the single equation estimation we use a GMM estimator developed by Arrelano and Bond (1988). Section 3.2 discusses the empirical issues encountered in estimation and finally Section 3.3 briefly discusses the estimation of systems of dynamic equations using panel data.

We approach estimation in two stages. In Section 4 we estimate two alternative "partial systems" for each of the three groups of sectors. The first estimates the demand for skilled labour relative to unskilled labour while the second aggregates labour to a single homogenous input (aggregating skilled, unskilled and clerical workers) and estimates the demand for this homogenous labour relative to capital services. Despite the strong assumptions underlying these partial systems specification we use the estimation results to provide an overview of the dynamic relationships between different factors and for different groups of sectors. This helps inform the much more complicated modelling involved in estimating a set of interrelated dynamic equations for all four factors. In Section 5 we estimate a full system of dynamic equations for skilled labour, unskilled labour, clerical workers and capital services. Section 6 summarises our main findings.

2. The Demand for Labour: A Theoretical Framework

In modelling the demand for labour we assume cost minimisation behaviour of firms. We adopt this cost-minimisation paradigm because 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 us to estimate demand for labour functions.

Conditional long-run demand for labour functions can be derived from the first-order conditions for cost-minimisation behaviour by a given firm. The translog cost function is one of a class of flexible functional forms which are used to provide local approximations to the cost function of a cost-minimising firm. This form of cost function places no restrictions on the partial elasticities of substitution between factors. The static (long-run) version of the translog total cost function for sector s is given by

$$\ln TC_s = \alpha_{0s} + \sum_{i=1}^{N} \alpha_{is} \ln P_{is} + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \gamma_{ij} \ln P_{is} \ln P_{js} + \alpha_q \ln Q_s + \frac{1}{2} \gamma_{qq} \ln(Q_s)^2 + \sum_{i=1}^{N} \gamma_{iq} \ln P_{is} \ln Q_s \tag{2.1}$$

where TC_s is total cost for sector s, P_{is} is the price of factor i in sector s and Q_s is volume output in sector s. Total cost is the sum of the cost of the N different factor inputs

$$TC_s = \sum_{i}^{N} P_{is}.X_{is} \tag{2.2}$$

where X_{is} denotes the quantity of factor i in sector s. Since we do not have data on material inputs total cost sums to value-added. This value-added framework includes a maximum of four possible factors: three different labour inputs, namely skilled labour, unskilled labour and clerical workers, and capital services. The variable Q_s within this framework is then a measure of output *net* of all material inputs at constant prices. It is included to allow for non-homotheticity of the cost function implying non-constant returns to scale.

The constant term α_{0s} and the α_{is} parameters are sector-specific, all other parameters are assumed to be identical across all sectors. Thus we assume that all of the sectors included in (2.1) have common underlying technological parameters. Differentiating with respect to factor prices and applying Shephard's Lemma (i.e. assuming cost minimising behaviour) gives the cost share (S_{is}) equations for sector s:

$$\frac{\partial \ln TC_s}{\partial \ln P_{is}} = \frac{P_{is}}{TC_s}\frac{\partial TC_s}{\partial P_{is}} = \frac{P_{is}X_{is}}{TC_s} = S_{is} = \alpha_{is} + \sum_{j=1}^{N} \gamma_{ij} \ln P_{js} + \gamma_{iq} \ln Q_s \tag{2.3}$$

Because these are share equations they must sum to one, this adding-up condition implies the following restrictions with certainty:

$$\sum_{i}^{N} \alpha_{is} = 1, \ \sum_{i}^{N} \gamma_{ij} = 0, \ \sum_{i}^{N} \gamma_{iq} = 0 \tag{2.4}$$

If we ignore dynamics then the adding-up condition means that in practice only $n-1$ equations of the system 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:

$$\sum_{j=1}^{N} \gamma_{ij} = 0 \ \text{(Price homogeneity)} \tag{2.5}$$

$$\gamma_{ij} = \gamma_{ji}, \ \forall i, j; i \neq j \ \text{(Symmetry)}$$

The parameters of equation (2.3) can be used to derive point elasticity estimates. The Allen-Uzawa partial elasticities of substitution σ_{ij} are given by

$$\sigma_{ij} = (\gamma_{ij} + S_i.S_j)/S_iS_j, i \neq j, \text{ otherwise } \sigma_{ii} = (\gamma_{ii} + S_i^2 - S_{i)}/S_i^2 \tag{2.6}$$

Since the magnitude of the elasticity is dependent on the magnitude of the share values at any point in time, Hamermesh (1993, p35) argues that the Allen elasticity is useful mainly for classifying pairs of inputs according to the sign of σ_{ij}.

Own- and cross-price elasticities of demand are given by

$$\varepsilon_{ij} = S_j\sigma_{ij}, \quad \varepsilon_{ii} = S_i\sigma_{ii} \tag{2.7}$$

Estimates of elasticities using these formulae are clearly dependent on the level of the factor shares at any given point in time. Symmetry of the cost function ensures that the elasticity of substitution estimates are pairwise equal. However this is not true of the cross elasticities of demand.

Blackorby and Russell (1989) argue that the Morishima elasticity of substitution, μ_{ij},

$$\mu_{ij} = \varepsilon_{ij} - \varepsilon_{jj} \tag{2.8}$$

is a more economically relevant concept than the Allen partial elasticity of substitution[1]. 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. 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 $| \varepsilon_{ij} | < | \varepsilon_{jj} |$ where $\varepsilon_{ij} < 0$ then this implies that factor i decreases by less than factor j for a given increase in the price of factor j. Therefore the input *ratio* of factor i, j will increase if the price of input j increases, even though the demand for both input i and j decreases.

The price elasticity of demand estimates are, in the terminology of Berndt and Wood (1979), *gross price elasticities* since they are computed holding output constant. The corresponding *net price elasticities*, include a measure of the output response and thus cannot be computed with conditional factor demand functions. Under the assumption of linear homogeneity they can be computed as

$$\varepsilon^*_{ij} = \varepsilon_{ij} + S_j \eta, \quad \varepsilon^*_{ii} = \varepsilon_{ii} + S_i \eta \tag{2.9}$$

where η is the own-price elasticity of demand for output. We use estimates of the output elasticity of demand, taken from Bradley et al. (1993), to construct "guesstimates" of the net elasticities.

2.1. Specification of Long-Run Factor Demand Equations

The cost function can be extended to include additional variables. Here we include two extra terms in the factor share equations, to control for firm turnover and to proxy for technical progress.

$$S_{is} = \alpha_{is} + \sum_{j=1}^{N} \gamma_{ij} \ln P_{js} + \gamma_{it} T + \gamma_{iq} \ln Q_s + \gamma_{in} \ln NO_s \tag{2.10}$$

[1]More recently Davis and Shumway (1996) have argued that it is only under cost minimisation that the Morishima measure is *always* the correct measure of curvature and elasticity.

Factor-biased technical progress is typically proxied by the inclusion of a time trend (T) and we follow that convention here. Technical progress is Hicks neutral if $\gamma_{it} = 0\ \forall i$, if $\gamma_{it} \succ (\prec) 0$ technical progress is biased in favour (against) factor i.

We include the number of firms in a sector (NO_s) in the specification to control for the effects of firm entry to and exit from a sector on the demand for different factors. The factor demand specification derived in equation (2.10) is constructed based on the theory of *firm* behaviour. However our data relate to sectors rather than firms. Including NO_s as an additional variable serves as a proxy measure of net firm turnover so that the coefficients on the relative price, and other, terms will be estimated conditional on the number of firms per sector. The underlying assumption in this specification is that we can then interpret the estimated sector behaviour, controlling for sector size, "as if" it were the behaviour of a single firm.

Finally it is important to point out the measurement difficulties attached to Q_s. This variable is measured using data on *gross* output in constant prices. This serves as an approximation to a pure test for homotheticity within the translog specification. Interpretation of the estimated parameter γ_{iq} must therefore proceed with caution, a non-zero value may be an indication that homotheticity is rejected but it could also signal a rejection of the assumption of weak separability between material inputs and value-added which underpins the validity of the value-added specification (see Kearney (1997) for details).

2.2. Introducing Short-Run Dynamics

Equation (2.10) is the general specification of the set of steady state factor demand equations for estimation. Empirical estimation of such static 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 suggested 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 more "data-based dynamic model" both respects the long-run behavioural restrictions and allows for asymmetric short-run responses to changes in factor prices and other explanatory variables.

There are significant short-run costs to adjusting factor demands (for example, the costs of hiring and firing workers) and these costs may vary between different factors. Because of these costs of adjusting employment, firms often hoard labour during recessionary periods[2].

[2] For example, in a micro study of UK labour market flexibility, Haskel, Kersley and Martin (1997) found

The costs of adjusting the demand for skilled labour are generally higher than the costs of adjusting the demand for unskilled labour (Hamermesh, 1993, p278). And it is well known that the costs of adjusting the demand for capital in the short-run are high due to the irreversibility of investment and putty-clay elements of technology. All of these considerations highlight the need to introduce dynamic factor adjustment into the modelling process. 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 this paper we approach the specification of dynamic factor demand equations in two stages. In the first stage we specify dynamic interrelated factor demands with only two factors of production. We term this specification "partial systems estimation". Given the adding-up condition this reduces to specifying a single dynamic equation for estimation. Using this partial specification we estimate two alternative sets of factor demand equations. The first estimates 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. The second aggregates labour to a single homogenous input (aggregating skilled, unskilled and clerical workers) and estimates the demand for this homogenous labour relative to capital services.

Both of these specifications involve strong *a priori* assumptions. The first assumes that skilled labour and unskilled labour have an identical, unitary, elasticity of substitution with all other factors or factor bundles. The second assumes that skilled, clerical and unskilled labour are perfect substitutes. Another strong restriction associated with estimating within a two-factor framework is that cost-minimisation dictates that the two factors cannot be complements.

Despite the strong assumptions underlying this partial systems specification we use the estimation results to provide an overview of the dynamic relationships between different factors and for different groups of sectors. This can help to inform the much more complicated modelling involved in specifying a set of interrelated dynamic equations for all four factors.

In the second stage we specify a system of interrelated dynamic factor demand equations for any number of factors. For our purposes this fully specifies dynamic equations for our four factors of production, skilled labour, unskilled labour, clerical workers and capital services. We loosely term this specification "full systems estimation [3]". We specify a general dynamic system which allows for joint estimation of four interrelated factor demand equations following the modelling approach developed in Anderson and Blundell (1982).

---

that employment and capacity were adjusted more in the long-run and hours of work in the short run.

[3]specification retains the maintained hypothesis that the value-added factor bundle is weakly separable from the gross-output factor bundle. Hence we ignore material and energy inputs in our specification.

2.2.1. Short-Run Dynamics With Two Factors

Within a two-factor system the adding-up condition implies that only one equation need be estimated. The dynamic specification of the general equation for factor i, in error correction format, with price homogeneity imposed and including two lags[4] is as follows:

$$\begin{aligned}\Delta S_{ist} &= \beta_i \Delta S_{ist-1} + \delta_{ij0}\Delta \ln \frac{P_{jst}}{P_{ist}} + \delta_{ij1}\Delta \ln \frac{P_{jst-1}}{P_{ist-1}} \\ &+\delta_{iq0}\Delta \ln Q_{st} + \delta_{iq1}\Delta \ln Q_{st-1} + \delta_{in0}\Delta \ln NO_{st} + \delta_{in1}\Delta \ln NO_{st-1} \\ &-\lambda_i \left[S_{ist-2} - \alpha_{is} - \gamma_{ij} \ln \frac{P_{jst-2}}{P_{ist-2}} - \gamma_{iq} \ln Q_{st-2} - \gamma_{in} \ln NO_{st-2} \right]\end{aligned} \tag{2.11}$$

The final term in brackets is the static factor demand equation (2.10) for factor i. Theoretical restrictions on these long-run parameters imply the following simplifications:

$$\gamma_{ij}=\gamma_{ji},\ \gamma_{iq} = -\gamma_{jq},\ \gamma_{in} = -\gamma_{jn} \tag{2.12}$$

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 so that not all coefficients in the factor demand system are identified. However we are only interested in the long-run behavioural parameters which are identified by the adding-up condition.

With just two factors, and given the adding up condition, the short-run adjustment coefficient on the lagged dependent variable for the second j equation is simply $-\beta_i$. We will examine in the next sub-section the more complicated dynamics introduced when there are more than two factors.

All parameters are assumed constant 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

[4]Nickell (1986), in an analysis of the impact of aggregation on the estimation of dynamic models of labour demand, shows that aggregation across firms or across different types of labour induces a second-order lag of the dependent variable. Therefore second-order lags are included here.

model to explain. For example they may reflect differences in the historical accumulation of technologies in different sectors where the rate of change of such differences has asymptoted out in the present sample to an intercept shift. The presence of this sector-specific term has important implications for econometric estimation of equation (2.11) which are discussed in the next section.

Equation (2.11) is the "general" dynamic specification of the two-factor demand system which we use as our estimating equation. 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 (2.11) can be written as:

$$\begin{aligned} \Delta S_{ist} &= \pi_1 \Delta S_{ist-1} + \pi_2 \Delta S_{ist-2} \\ &+\pi_{ij0}\Delta \ln \frac{P_{jst}}{P_{ist}} + \pi_{ij1}\Delta \ln \frac{P_{jst-1}}{P_{ist-1}} + \pi_{ij2}\Delta \ln \frac{P_{jst-2}}{P_{ist-2}} \\ &+\pi_{iq0}\Delta \ln Q_{st} + \pi_{iq1}\Delta \ln Q_{st-1} + \pi_{iq2}\Delta \ln Q_{st-2} \\ &+\pi_{in0}\Delta \ln NO_{st} + \pi_{in1}\Delta \ln NO_{st-1} + \pi_{in2}\Delta \ln NO_{st-2} \end{aligned} \tag{2.13}$$

This is the form we use for estimation. The two formulations are observationally equivalent[5] so that the parameters of interest in equation (2.11) can be recovered from the estimating equation (2.13) 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 (2.13). Time dummies are included in all the estimating equations. These are included to capture unobserved aggregate effects due to technical change which is assumed uniform across all the sectors included in estimation.

2.2.2. Short-Run Dynamics With More Than Two Factors

The systems analogue of equation (2.11) can be written in matrix form as

$$\Delta S_{st} = B\Delta S_{st-1} + D_0 \Delta X_{st}^{'} + D_1 \Delta X_{st-1}^{'} - \Lambda(S_{st-2} - \Gamma X_{st-2}) \tag{2.14}$$

[5] See Greenhalgh, et al. (1990) for details.

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 $X^{\tilde{}}_{st}$ 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 (2.10), 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 (2.14) cannot be identified. Because the covariance matrix is singular it is necessary, as in the static case, to eliminate one of the collinear share equations within the brackets. This redundant variable problem extends to the vector of lagged dependent variables where one element is also eliminated. However we can still estimate the full set of short-run adjustment parameters on the explanatory variables D_0 and D_1. If we denote a matrix with the n^{th} row deleted with a subscript n and with the n^{th} column deleted with a superscript n then we can rewrite (2.14) as:

$$\Delta S_{st} = B^n \Delta S_{n,st-1} + D_0 \Delta X^{\tilde{}}_{st} + D_1 \Delta X^{\tilde{}}_{st-1} - \Lambda^n (S_{n,st-2} - \Gamma_n X_{st-2}) \qquad (2.15)$$

The parameters of the n^{th} long-run factor share equation which is eliminated from estimation can be identified via the adding-up condition (2.4). Similarly the short-run parameters in B^n and Λ^n are identified by making each column of B^n and Λ^n sum to zero, however we cannot fully identify the parameters in B and Λ in equations (2.14). 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.

In our data set we have four separate factors, skilled workers denoted h, unskilled workers denoted l, clerical workers denoted c and capital services denoted k. The full set of equations for estimation from (2.15) is

$$\begin{bmatrix} \Delta S_{hst} \\ \Delta S_{lst} \\ \Delta S_{cst} \\ \Delta S_{kst} \end{bmatrix} = \begin{bmatrix} \beta_{hh} & \beta_{hl} & \beta_{hc} \\ \beta_{lh} & \beta_{ll} & \beta_{lc} \\ \beta_{ch} & \beta_{cl} & \beta_{cc} \\ \beta_{kh} & \beta_{kl} & \beta_{kc} \end{bmatrix} \begin{bmatrix} \Delta S_{hst-1} \\ \Delta S_{lst-1} \\ \Delta S_{cst-1} \end{bmatrix} + \begin{bmatrix} \delta_{hh0} & \delta_{hl0} & \delta_{hc0} & \delta_{hk0} & \delta_{hq0} & \delta_{hn0} \\ \delta_{lh0} & \delta_{ll0} & \delta_{lc0} & \delta_{lk0} & \delta_{lq0} & \delta_{ln0} \\ \delta_{ch0} & \delta_{cl0} & \delta_{cc0} & \delta_{ck0} & \delta_{cq0} & \delta_{cn0} \\ \delta_{kh0} & \delta_{kl0} & \delta_{kc0} & \delta_{kk0} & \delta_{kq0} & \delta_{kn0} \end{bmatrix} \begin{bmatrix} \Delta \ln P_{hst} \\ \Delta \ln P_{lst} \\ \Delta \ln P_{cst} \\ \Delta \ln P_{kst} \\ \Delta \ln Q_{st} \\ \Delta \ln NO_{st} \end{bmatrix}$$

$$+\begin{bmatrix} \delta_{hh1} & \delta_{hl1} & \delta_{hc1} & \delta_{hk1} & \delta_{hq1} & \delta_{hn1} \\ \delta_{lh1} & \delta_{ll1} & \delta_{lc1} & \delta_{lk1} & \delta_{lq1} & \delta_{ln1} \\ \delta_{ch1} & \delta_{cl1} & \delta_{cc1} & \delta_{ck1} & \delta_{cq1} & \delta_{cn1} \\ \delta_{kh1} & \delta_{kl1} & \delta_{kc1} & \delta_{kk1} & \delta_{kq1} & \delta_{kn1} \end{bmatrix} \begin{bmatrix} \Delta \ln P_{hst-1} \\ \Delta \ln P_{lst-1} \\ \Delta \ln P_{cst-1} \\ \Delta \ln P_{kst-1} \\ \Delta \ln Q_{st-1} \\ \Delta \ln NO_{st-1} \end{bmatrix} - \begin{bmatrix} \lambda_{hh} & \lambda_{hl} & \lambda_{hc} \\ \lambda_{lh} & \lambda_{ll} & \lambda_{lc} \\ \lambda_{ch} & \lambda_{cl} & \lambda_{cc} \\ \lambda_{kh} & \lambda_{kl} & \lambda_{kc} \end{bmatrix}$$

$$\left(\begin{bmatrix} S_{hst-2} \\ S_{lst-2} \\ S_{cst-2} \end{bmatrix} - \begin{bmatrix} \alpha_{hs} & \gamma_{hh} & \gamma_{hl} & \gamma_{hc} & \gamma_{hk} & \gamma_{hq} & \gamma_{hn} \\ \alpha_{ls} & \gamma_{lh} & \gamma_{ll} & \gamma_{lc} & \gamma_{lk} & \gamma_{lq} & \gamma_{ln} \\ \alpha_{cs} & \gamma_{ch} & \gamma_{cl} & \gamma_{cc} & \gamma_{ck} & \gamma_{cq} & \gamma_{cn} \end{bmatrix} \begin{bmatrix} 1 \\ \ln P_{hst-2} \\ \ln P_{lst-2} \\ \ln P_{cst-2} \\ \ln P_{kst-2} \\ \ln Q_{st-2} \\ \ln NO_{st-2} \end{bmatrix} \right) \quad (2.16)$$

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 7. The typical equation for factor i (assuming these adding up restrictions are applied to the equation for factor $j \neq i$) is:

$$\begin{aligned} \Delta S_{ist} = \; & \beta_{ih}\Delta S_{hst-1} + \beta_{il}\Delta S_{lst-1} + \beta_{ic}\Delta S_{cst-1} + \delta_{ih0}\Delta \ln P_{hst} + \delta_{il0}\Delta \ln P_{lst} \\ & + \delta_{ic0}\Delta \ln P_{cst} + \delta_{ik0}\Delta \ln P_{kst} + \delta_{iq0}\Delta \ln Q_{st} + \delta_{in0}\Delta \ln NO_{st} \\ & + \delta_{ih1}\Delta \ln P_{hst-1} + \delta_{il1}\Delta \ln P_{lst-1} + \delta_{ic1}\Delta \ln P_{cst-1} + \delta_{ik1}\Delta \ln P_{kst-1} \\ & + \delta_{iq1}\Delta \ln Q_{st-1} + \delta_{in1}\Delta \ln NO_{st-1} - \lambda_{ih} ecm_{hst-2} - \lambda_{il} ecm_{lst-2} - \lambda_{ic} ecm_{cst-2} \end{aligned} \quad (2.17)$$

where ecm_{ist} is the long-run factor share equation for factor i in sector s in year t based on (2.10). 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:		
$\gamma_{kh} = \gamma_{hk}$	$\gamma_{kl} = \gamma_{lk}$	$\gamma_{kc} = \gamma_{ck}$

Within this set 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 a the equation for factor $j \neq i$) is given as:

$$\begin{aligned}
\Delta S_{ist} = \; & \pi_{iH1}\Delta S_{hst-1} + \pi_{iH2}\Delta S_{hst-2} + \pi_{iL1}\Delta S_{lst-1} + \pi_{iL2}\Delta S_{lst-2} \\
& \pi_{iC1}\Delta S_{cst-1} + \pi_{iC2}\Delta S_{cst-2} + \pi_{il0}\Delta \ln P_{lst} + \pi_{il1}\Delta \ln P_{lst-1} \\
& +\pi_{il2}\Delta \ln P_{lst-2} + \pi_{ih0}\Delta \ln P_{hst} + \pi_{ih1}\Delta \ln P_{hst-1} + \pi_{ih2}\Delta \ln P_{lst-2} \\
& +\pi_{ic0}\Delta \ln P_{cst} + \pi_{ic1}\Delta \ln P_{cst-1} + \pi_{ic2}\Delta \ln P_{cst-2} \\
& +\pi_{ik0}\Delta \ln P_{kst} + \pi_{ik1}\Delta \ln P_{kst-1} + \pi_{ik2}\Delta \ln P_{kst-2} \\
& +\pi_{iq0}\Delta \ln \frac{Q_{st}}{NO_{st}} + \pi_{iq1}\Delta \ln \frac{Q_{st-1}}{NO_{st-1}} + \pi_{iq2}\Delta \ln \frac{Q_{st-2}}{NO_{st-2}} \\
& +\pi_{in0}\Delta \ln NO_{st} + \pi_{in1}\Delta \ln NO_{st-1} + \pi_{in2}\Delta \ln NO_{st-2}
\end{aligned} \tag{2.18}$$

Because of possible collinearity between gross output per sector and the number of firms per sector as regressors, these are reparameterised in (2.18) 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 7 the implications of these restrictions for the relationship between the estimated π parameters from (2.18) 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 (2.15) are fully specified.

3. Dynamic Modelling With Panel Data

3.1. Econometric Issues in Estimation

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

$$y_{it} = \sum_{j=1}^{p} \alpha_j y_{i(t-j)} + \underline{\beta}'(L)\underline{x}_{it} + \lambda_t + u_{it} \tag{3.1}$$

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 $m \times 1$ vector of polynomials 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 error term u_{it} is modelled as the sum of an industry specific effect η_i and an idiosyncratic error term v_{it}, $u_{it} = \eta_i + v_{it}$.

Given the structure of our data panel[6] 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[7], 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 (3.1) 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}

$$y_{i1} = f(\underline{x}_{i,t-j}, \eta_i, \lambda_1, \nu_{i1})$$

[6]The data panel covers 12 years. First differencing and including two lags leaves $T = 9$ for each group. For the Medium and Declining groups of sectors we have 29 sectors, for the High Growth group of sectors we have 11 sectors.

[7]Much of this section follows the review of linear dynamic panel data models in Sevestre and Trognon (1992).

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, where a fixed effects assumption means that the initial observations will also be fixed and exogenous.

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 now faces two problems for least squares estimation. The first is the semi-inconsistency of the estimators due to the influence of the initial observations on the semi-asymptotics with T finite. The second is due to the upward bias induced through the correlation between the fixed effects and the lagged endogenous variables. The fixed effects can be eliminated from equation (3.1) by first differencing (or some other suitable transformation), however this induces correlation between the lagged endogenous variables and the error term, hence the OLS first difference estimates will again be biased (this time downwards) (see Urga, 1992).

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 Arrelano and Bond, 1988). The error terms are assumed to have zero mean, finite 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 (3.1) 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. Similarly all further lags of the dependent variable are valid instruments based on the linear moment restrictions:

$$E(\Delta v_{it}, y_{it-j}) = 0 \; j = 2, ..., t-(q+1); t = (q+1), ..., T \tag{3.2}$$

The AB GMM estimator is derived using these conditions without necessitating further assumptions on the initial conditions y_{i1} or on the distributions of the fixed effects η_i or the error terms v_{it}. If an x_{it} variable is not strictly exogenous[8], 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 (2.13) of the previous section the relative price term is not strictly exogenous given its definitional relationship with the dependent variable[9], so we consider this AB GMM panel data estimator to be particularly suited for estimation of dynamic equations such as equation (2.13).

If we stack all the observations in equation (3.1) over time we can rewrite the equation as

$$y_i = W_i \underline{\delta} + i_i \eta_i + v_i \tag{3.3}$$

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 estimator is given by

$$\delta = [(\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' W_i^*)]^{-1} [(\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' y_i^*)] \tag{3.4}$$

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

$$\begin{pmatrix} 2 & -1 & \dots & & 0 \\ -1 & 2 & \dots & & 0 \\ . & . & & & . \\ . & . & & & -1 \\ 0 & 0 & \dots & -1 & 2 \end{pmatrix}$$

[8]Strict exogeneity between x_{it} and v_{it} requires $E(x_{it}, v_{it}) = 0$.

[9]The definitional relationship between S_l and $\frac{P_k}{P_l}$ is $S_l = \frac{P_l X_l}{P_l X_l + P_k X_k} = (1 + \frac{P_k}{P_l}\frac{X_k}{X_l})^{-1}$.

In our empirical analysis we use this one-step estimator where the reported standard errors are corrected for heteroscedasticity[10].

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

$$Z_i = \begin{pmatrix} y_{i1} & 0 & 0 & 0 & 0 & 0 & \Delta\underline{x}'_{i2} & 0 & 0 \\ 0 & y_{i1} & y_{i2} & 0 & 0 & 0 & 0 & \Delta\underline{x}'_{i3} & 0 \\ 0 & 0 & 0 & y_{i1} & y_{i2} & y_{i3} & 0 & 0 & \Delta\underline{x}'_{i4} \end{pmatrix} \tag{3.5}$$

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." (Arrelano 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 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.

3.2. Empirical Issues in Estimation

We approach the empirical estimation in the spirit of the general to specific approach to econometric modelling. That is, we begin with the most general specification possible given data restrictions and then test the validity of alternative reductions of this general system. 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 Kearney (1997).

[10]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.

The data cover 69 manufacturing sectors over the period 1979-1990. The variables include data on employment and wages for skilled workers, unskilled workers and clerical workers. Kearney (1997) 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. The appendix in Kearney (1997) contains a full description of the panel data set.

We exclude three sectors which were included in the analysis of Kearney (1997) and which 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. This change slightly alters the three groups of sectors defined in Kearney (1997): the high-growth group now includes eleven sectors (with Gas and Gasworks excluded), the medium-growth group excludes both Electricity and Water, and the Finished Metal Products sector (NACE 316319) moves from the declining group to the medium-growth group. This means that the latter two groups now both contain twenty-nine sectors. This reshuffling means that the declining group includes only sectors which have had zero growth or below on average over the period 1979-1990.

The utilities sectors were all relatively high-wage sectors, their exclusion has altered the pattern noted in Kearney (1997) where the ratio of skilled to unskilled wages in the declining sector was higher than in the Medium growth sector, that is no longer the case, the ranking is in keeping with the overall ranking of the three groups of sectors.

While the total number of firms in the overall manufacturing sector has fallen 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 3.1 shows the time path of the number of firms in each group. It is clearly important to take this into account in modelling demand for labour functions; this is why we include the number of firms NO in our general specifications (2.13) and (2.18).

We estimate the single equation (2.13) using the DPD package developed by Arrelano and Bond (1988).The most complicated empirical feature of this estimation was the choice of instrument set for the Z matrix in (3.5). The final choice of instrument set was based on preliminary testing of a wide range of instruments. There were three 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 (3.2). However in practice

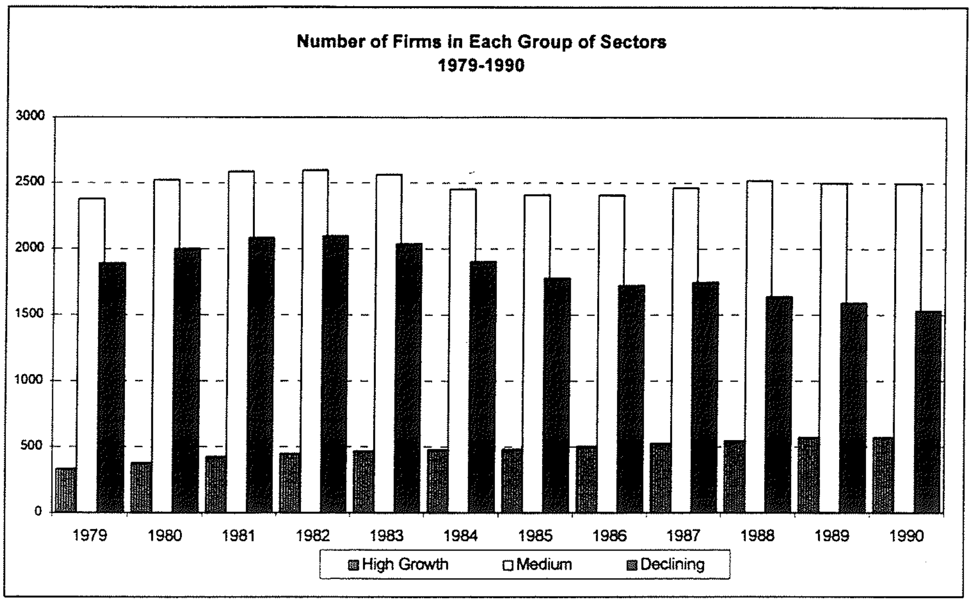

Figure 3.1: Number of Firms in High Growth, Medium Growth and Declining Groups of Sectors, 1979-1990

we found it was better to start with the third lag (based on the Sargan test)[11].

2. The definitional relationship between the endogenous variable and the factor price terms means that the factor price terms are also endogenous[12]. 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 po-

[11]Denny and Van Reenen (1993) adopted a similar formulation of their instrument set.

[12]

1. 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.

tential instruments were ΔQ and ΔNO (see (3.5)). Estimation both with and without these variables did not significantly alter the results.

In all cases where the equation included time dummies these were also included in the instrument set.

The estimated regressions are weighted by each sector's average share in total cost (as defined in 2.2) for all sectors. This weighting reduces the noise in the data as shown in Figures 9.1 and 9.2. These graphs refer to the data on skilled labour's share of the skilled and unskilled wage bill for the medium-growth group of sectors. They cross-plot gross output against the skilled labour share. Figure 9.1 uses the actual (unweighted) data for all 29 sectors for the 12 years of the sample while Figure 9.2 plots these data weighted by the average share in the total wage bill. Weighting significantly reduces the noise in the sample by re-ranking the sectoral data on the basis of each sector's relative importance in overall total cost. In the unweighted data two sectors with high gross output (Meat Products, NACE 412 and Dairy Products, NACE 413) are significant outliers from the central cluster of data points. These are both sectors with very low shares of labour in gross output (6.7% and 7.6% respectively compared with an average for all medium-growth sectors of 23.5%). The weighted data highlight much more clearly a discernable positive relationship between the skilled wage bill share and gross output.

Weighting the regressions serves to reduce noise in the data, particularly in small sectors, and also helps to reduce noise due to firm migration between sectors (Bound et al. (1994) p.384).

3.3. Systems Estimation with Panel Data

The issue of fixed effects and its implications for dynamic single equation estimation with short panels 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 used are different for different equations analogous to (3.5) 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) or instrumental variables estimators (Morrison, 1997). For the estimation of system (2.18) we used several different estimators[13]: multivariate least squares, two stage least squares with instrumental variables, three stage least 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. The fact that the system of equations in (2.18) are expressed in first differences eliminates the fixed effects but will introduce correlation between the lagged endogenous variable and the error term in each equation. Therefore we estimated (2.18) 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 performed GMM estimation, allowing for heteroscedasticity and an MA(1) error term, of (2.18) with this same instrument set.

4. Empirical Results: Partial Systems Estimation

In this section we present the results of estimating dynamic labour demand functions for three groups of sectors: eleven high-growth sectors, twenty nine medium-growth sectors and twenty nine declining sectors. Firstly we report the estimation results for the "partial systems" demand for labour functions defined by (2.11). Section 4.1 gives the results of estimating the demand for skilled labour relative to unskilled labour. Section 4.2 gives the results of estimating the demand for homogenous labour relative to capital.

These results, while predicated on rather strong assumptions of weak separability and/or perfect substitutability, are useful in providing a first estimate of the skilled-unskilled and labour-capital bivariate relationships underlying the production technologies in each group of sectors. Furthermore, from these results we can begin to disentangle the relative importance of scale effects (gross output), firm turnover effects (number of firms in each sector) and time-specific effects for each group of sectors.

Given these partial systems results, we proceed in Section 5 to estimate "full systems" demand for labour functions. These give the estimated interrelated demand functions as

[13] All systems estimation was done using the TSP package.

defined in (2.14) for skilled labour, unskilled labour, clerical workers and capital services.

4.1. The Demand for Skilled Workers

The general specification of the equation for modelling the demand for skilled labour (AT) relative to unskilled (IW) is given by[14]:

$$\begin{aligned}
\Delta SLAT_t = {} & \pi_1 \Delta SLAT_{t-1} + \pi_2 \Delta SLAT_{t-2} + \pi_{su0} \Delta \ln(\frac{CLIW}{CLAT})_t \\
& + \pi_{su1} \Delta \ln(\frac{CLIW}{CLAT})_{t-1} + \pi_{su2} \Delta \ln(\frac{CLIW}{CLAT})_{t-2} \\
& + \pi_{su0d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t} + \pi_{su1d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t-1} \\
& + \pi_{su2d} \Delta \ln(\frac{CLIW}{CLAT})_t \cdot D_{8790t-2} + \pi_{sn0} \Delta \ln(NO)_t \\
& + \pi_{sn1} \Delta \ln(NO)_{t-1} + \pi_{sn2} \Delta \ln(NO)_{t-2} + \pi_{sq0} \Delta \ln(Q)_t \\
& + \pi_{sq1} \Delta \ln(Q)_{t-1} + \pi_{sq2} \Delta \ln(Q)_{t-2} + \pi_{82} D_{82} + \pi_t D_t
\end{aligned} \tag{4.1}$$

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 Kearney (1997) suggested that most of the restructuring from unskilled to skilled workers 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 described in Section 3.1. Time dummies D_t are included in each of the general specifications. In estimation the coefficients on these are measured as 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. These exogenous shocks are interpreted as proxying for technological shocks.

[14]In the results reported in this section we exclude clerical workers from estimation. Where clerical workers were included in the definition of unskilled workers this did not significantly alter the estimation results. See Kearney (1997) for further details on why clerical workers are excluded from the definition of unskilled (or indeed skilled) labour.

4.1.1. The Demand for Skilled Workers : Medium Growth Sectors

This section reports the results of estimating equation (4.1) for the medium-growth-Growth group of sectors over the period 1979-1990 using the share of skilled workers in the total wage bill[15] as the dependent variable. This is a partial system which is useful for cross-group comparisons and for classification of the magnitude of elasticity estimates.

The variables used are the share of skilled workers 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}). Table 4.1 gives some summary statistics on these data[16].

Skilled Workers, 29 Medium-Growth Sectors						
	$SLAT_{st}$	$CLAT_{st}$	$CLIW_{st}$	$\frac{CLAT}{CLIW}_{st}$	NO_{st}	Q_{st}
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 4.1: Descriptive Statistics on Panel Data for Medium Growth Sectors

Table 4.2 reports diagnostic tests of equation (4.1) for medium growth sectors[17]. In this and subsequent summary diagnostics tables for partial systems estimation 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.

[15]The total wage bill here excludes the wage bill of clerical workers.

[16]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.

[17]The table reports computed statistics followed by the significance level in brackets. Estimation is done using the DPD program. All reported results are GMM one step estimates with test statitistics 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 (4.1)						
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 4.2: Demand for Skilled Workers 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 significant of all second order lags (including the dependent variable) is increased.

The third specification (3) omits the structural break variables. This further reduction is also 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[18]. 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.

It is interesting to look at the implied behavioural parameters of equation (2.11) as estimated in the general specification (1) with no restrictions. Tables 4.3 and 4.4 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 4.3: Estimated Coefficients of Equation (2.11): 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 skilled workers' 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 1.325% growth[19] in that sector's skilled wage share.

The results indicate modest short-run increasing returns to scale but that in the long run there is a negative, albeit weak, relationship with gross output. This negative scale effect is computed controlling for firm entry and exit effects. This is a very interesting result because we have seen from a simple cross-plot of the share of skilled wages against gross output (Figure 9.2), and from computed correlations, that the bivariate relationship is positive. The negative *conditional* correlation suggests that the inclusion of the firm entry/exit variable is very important in disentangling changes within sectors from pure within-firm effects.

However, as pointed out previously, this scale effect is also likely to reflect any misspecification due to the omission of other factors of production from the partial specification.

The elasticity estimates[20] indicate low substitutability between skilled and unskilled work-

[18] 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)].

[19] Calculated using the average skilled workers' share of 0.20 from Table 4.1.

[20] The elasticity estimates in the table are read as follows: s=skilled; u=unskilled; σ_{su} is the elasticity of

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 4.4: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in Medium Growth Sectors

ers in production and inelastic own and cross price elasticities of demand, particularly for unskilled workers. 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.

Taken in combination these results suggest a very interesting pattern. In the pre-1987 period there were limited substitution possibilities between skilled and unskilled workers, 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 4.5: Estimated Coefficients of Equation (2.11): Demand for Skilled Labour in Medium Growth Sectors

Tables 4.5 and 4.6 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 worker's wage share in this group of sectors.

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 (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 4.6: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in Medium Growth Sectors

There are no time-specific effects, these correspond to exogenous shocks which we choose to characterise here as technological shocks (although they could also be considered as demand shocks). The absence of time effects confirms the profile of this group of sectors (described in Kearney (1997)) as representing the median firm in Irish manufacturing during the 1980s. While there was a massive influx of largely foreign-owned, high-technology industry and a shakeout in traditional industries, this group of industries remained the stable core of manufacturing with little change in a broadly fixed-inputs production process.

Overall these partial systems results suggest that changes in the share of skilled worker's in the medium-growth group of sectors is most strongly related to firm turnover effects. On average a net additional firm will increase the skill intensity of this group. Substitution possibilities between skilled and unskilled workers are very low. Long-run scale effects are negligible and there is no evidence of significant technological shocks.

4.1.2. The Demand for Skilled Workers : High Growth Sectors

Skilled Workers, 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 4.7: Descriptive Statistics on Panel Data for High Growth Sectors

Table 4.8 gives the diagnostic results of estimating equation (4.1) for the high-growth group of sectors. Degree 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. The table also includes the implied average elasticity of substitution between skilled and unskilled workers for each of these variants. These estimates indicate that by controlling for scale effects or firm entry/exit effects, the elasticity estimate has more reasonable numbers. 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.

The estimated elasticities and behavioural parameters from specification (1) and (2) are shown in Tables 4.9, 4.10 and 4.11. For both specifications the estimated coefficients are of similar magnitude. The coefficients on the time dummies[21] 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). Note that β_s is positive suggesting overadjustment in the short-run. Both short-run and long-run firm entry/exit and scale effects are positive.

This group of sectors shows the highest estimated elasticity of substitution. This illustrates the higher sensitivity of this group to relative wage rates. Given that the wage gap between skilled and unskilled workers in this group, while the highest, narrowed slightly during the period (see Kearney (1997)), this has in itself increased the relative employment of skilled workers. It could be argued that the narrowing of the wage gap, in the only group of sectors where the skill component of employment is relatively high and rising rapidly, reflects the impact of a steady increase in the supply of skilled workers during the period.

[21] These should be multiplied by 11, the number of sectors, to arrive at meaningful magnitudes since we are using weighted data.

Estimation Diagnostics for Equation (4.1): General Specification								
Joint Significance of:	(1)		(2)		(3)		(4)	
$\Delta \ln(\frac{CLIW}{CLAT})$	395.9(.00)	$\chi 2(3)$	175.5(.00)	$\chi 2(3)$	535.2(.00)	$\chi 2(3)$	284.9(.00)	$\chi 2(3)$
$\Delta \ln(\frac{CLIW}{CLAT}) \cdot D_{8790}$					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 4.8: Demand for Skilled Workers in High Growth Sectors: Testing General Specification

Overall these results indicate significant scale, firm turnover and technological effects in this sector. The most interesting feature is the high degree of substitutability between skilled and unskilled workers suggested by these results.

Estimated Coefficients:Specification (1)								
	Adjustment Coefficients				Long_Run Parameters			
$SLAT$	λ_s	0.318	β_s	0.086	*Skilled*		*Unskilled*	
$\ln(\frac{CLIW}{CLAT})$	δ_{su0}	-0.126	δ_{su1}	0.040	γ_{su}	0.102	γ_{us}	0.102
$\ln(Q)$	δ_{sq0}	0.039	δ_{sq1}	0.0004	γ_{sq}	0.090	γ_{uq}	-0.090
$Constant$	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}	D_{88}	D_{89}	D_{90}
-.0008	.0004	.0023	.0004	.0014	.0001	-.0001	.0020	-.0011

Table 4.9: Estimated Coefficients of Equation (2.11): Demand for Skilled Labour in High Growth Sectors

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 4.10: Estimated Coefficients of Equation (2.11): 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 4.11: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in High Growth Sectors

4.1.3. The Demand for Skilled Workers: Declining Sectors

Table 4.1 gives some descriptive statistics on the data for the declining group of sectors.

Skilled Workers, 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 4.12: Descriptive Statistics on Panel Data for Declining Sectors

Estimation Diagnostics for Equation (4.1)						
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 4.13: Demand for Skilled Workers in Declining Sectors: Testing General Specification

The diagnostic results of estimating equation (4.1) for this group of sectors reported in Table 4.13 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 4.13. 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. This may be due to a high degree of heteroscedasticity within this group since the Sargan test is not robust to heteroscedasticity (see Arrellano and Bond, 1988).

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 4.14: Estimated Coefficients of Equation (2.11): 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 4.15: Estimated Elasticities of Substitution and Demand For Skilled and Unskilled Labour in 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 (4.13).

The estimated behavioural parameters and implied elasticity estimates from specification (3) are given in Tables 4.14 and 4.15. The results indicate that the 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 0.725 percentage point was knocked off the skilled labour share)[22].

[22]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.

4.2. The Demand for Homogenous Labour

In this section we present the results of estimating the demand for labour relative to capital. Labour is defined as a homogenous single input, aggregated across the skilled, unskilled and clerical worker categories. The general specification of the equation for the demand for homogenous labour, where there are only two inputs, labour and capital, is given by:

$$\begin{aligned}
\Delta SL_t = \; & \pi_1 \Delta SL_{t-1} + \pi_2 \Delta SL_{t-2} \\
& + \pi_{lk0} \Delta \ln(\frac{PK}{CL})_t + \pi_{lk1} \Delta \ln(\frac{PK}{CL})_{t-1} + \pi_{lk2} \Delta \ln(\frac{PK}{CL})_{t-2} \\
& + \pi_{lk0d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t} + \pi_{lk1d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t-1} \\
& + \pi_{lk2d} \Delta \ln(\frac{PK}{CL})_t \cdot D_{8790t-2} \\
& + \pi_{ln0} \Delta \ln(NO)_t + \pi_{ln1} \Delta \ln(NO)_{t-1} + \pi_{ln2} \Delta \ln(NO)_{t-2} \\
& + \pi_{lq0} \Delta \ln(Q)_t + \pi_{lq1} \Delta \ln(Q)_{t-1} + \pi_{lq2} \Delta \ln(Q)_{t-2} \\
& + \pi_{82} D_{82} + \pi_t D_t
\end{aligned} \tag{4.2}$$

Most of the estimated equations show signs of misspecification. This in itself is a powerful argument for disaggregating the labour input. The shifts in the relative shares of different types of labour suggested from the analysis in Kearney (1997) would suggest that aggregation across different types of labour is not valid.

4.2.1. The Demand for Labour : Medium Growth Sectors

Table 4.16 reports the diagnostic tests of estimating equation (4.2) for the medium-growth group of sectors. The general specification (1) is rejected by the Sargan test, specification (2) re-estimates this omitting time dummies (given their insignificance).

The parameter estimates for specification (2) indicate a similar pattern with relation to the firm entry/exit and scale regressors as for the skilled results, with the scale effect much weaker than the composition 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). However imposing perfect substitutability between different types of labour, given that the results in section 4.1 indicated very low substitutability between skilled and unskilled labour, makes this result difficult to interpret.

Estimation Diagnostics for Equation (4.2)				
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 4.16: Demand for Homogenous Labour in Medium Growth Sectors: Testing General Specification

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 4.17: Estimated Coefficients of Equation (2.11): Demand for Homogenous 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 4.18: Estimated Elasticities of Substitution and Demand For Labour and Capital in Medium Growth Sectors

4.2.2. The Demand for Labour : High Growth Sectors

Degrees of freedom restrictions meant that equation (4.2) could not be estimated for the eleven high-growth sectors. Instead we estimated several competing reductions of this equation; Table 4.19 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, hence it was not a useful tool in discriminating between the models.

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.

The 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 (4.2): 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 4.19: Demand for Homogenous Workers 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 4.20: Estimated Coefficients of Equation (2.11): Demand for Homogenous Labour in High Growth Sectors

Tables 4.20 and 4.21 give the estimated coefficients and elasticities from specification (4). This specification estimates a Cobb-Douglas technology with the elasticity of substitution equal to one. (The estimated elasticity in specification (3) is also close to one.)

The 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[23].

Firm entry is biased towards labour, scale effects are biased towards capital (and stronger). These latter arguably are capturing the distortionary impact which transfer pricing in this group of sectors has on the official data for value-added and output.

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 4.21: Estimated Elasticities of Substitution and Demand For Labour and Capital in High Growth Sectors

[23] These time dummies should be multiplied by 11, the number of sectors, to arrive at meaningful magnitudes since we are using weighted data.

4.2.3. The Demand for Labour : Declining Sectors

Diagnostics for Equation (4.2)				
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 4.22: Demand for Homogenous Labour in Declining Sectors: Testing General Specification

Table 4.22 gives the diagnostic tests for estimating equation (4.2) for the declining group of sectors. As in Section 4.1 the Sargan test rejects the overidentifying restrictions for the general specification and for all reductions. We proceed on the assumption that this is partly due to non-robustness of this test to heteroscedasticity.

Further reductions of this general specification were rejected by the diagnostic tests. Specification (2) in Table 4.22 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.

The implied elasticity estimates from specification (1) are negative violating standard economic theory. Firm exit reduces labour's share of value-added. 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.

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 4.23: Estimated Coefficients of Equation (2.11): Demand for Homogenous 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 4.24: Estimated Elasticities of Substitution and Demand For Labour and Capital in Declining Sectors

4.3. Summary of Partial Systems Results

A number of stylised facts relevant to modelling the three groups of sectors emerge from these empirical results:

The Demand for Skilled Labour Relative to Unskilled Labour:

1. Technological Shocks (Time Dummies): For the medium-growth group of sectors time dummies are not significant. For the declining group technological shocks were largely biased towards skilled labour. For the High growth group there is evidence of significant and large technological shocks which vary in impact from year to year.

2. Long Run Firm Turnover Effects (Number of Firms Per Sector): These are significant for the high-growth and the medium-growth groups and indicate that (net) additional new firms will increase the skilled labour share. There is no evidence of firm turnover effects for the declining group of sectors.

3. Long Run Scale Effects (Gross Output): Estimated scale effects are weaker than firm turnover effects. For the medium-growth group they are biased towards unskilled labour, for the high-growth group they are biased towards skilled labour. There is no evidence of scale effects for the declining group of sectors.

4. Long Run Substitution Possibilities: The results suggest limited to zero substitutability between skilled and unskilled labour for the medium-growth and declining groups. By contrast the high-growth group has evidence of a high degree of substitutability between these factors (elasticity of substitution greater than one).

5. Lag Length=2: Reducing the lag length from two to one is rejected in all but the declining group.

6. Long Run Structural Break in Elasticities post-1987: The inclusion of an interactive dummy variable on the relative price term was rejected for all groups.

The Demand for Homogenous Labour Relative to Capital:

1. Technological Shocks (Time Dummies): For the medium-growth group of sectors time dummies are not significant. For the declining and High growth group there is evidence of significant and large technological shocks which vary in impact from year to year.

2. Long-Run Firm Turnover Effects (Number of Firms Per Sector): These are significant for all groups. They indicate that (net) additional new firms will increase labour's share of value added.

3. Long-Run Scale Effects (Gross Output): Estimated scale effects are biased in favour of capital in the high-growth group, this effect is stronger than the firm turnover effect. In the medium-growth group they are also biased towards capital but are much weaker. For the declining group however they are biased towards labour. Given the fact that output growth has been negative in this group this captures a long-run downward trend in labour's share of value added.

4. Long-Run Substitution Possibilities: The results suggest high substitutability between labour and capital for the medium-growth group. The high-growth group has evidence of a Cobb-Douglas technology. The declining group results violated standard economic theory.

5. Lag Length=2: Reducing the lag length from two to one is rejected in all groups.

6. Long-Run Structural Break in Elasticities post-1987: The inclusion of an interactive dummy variable on the relative price term was not rejected for the medium-growth and declining groups.

The results of estimating the demand for homogenous labour indicated misspecification while the results of estimating the demand for skilled labour indicated limited substitution with unskilled labour for both the medium and declining groups of sectors. On the face of it, this is a strong argument in favour of disaggregating the labour input in estimating the relationship between labour and capital.

5. Empirical Results: Full Systems Estimation

The results from the partial systems estimation strongly suggest the necessity of moving to a full set of interrelated factor demand equations if we are to fully understand the evolution in the demand for different types of labour, and the demand for this labour relative to capital in the Irish manufacturing sector in the 1980s. In this section we report the results of estimating the full set of interrelated factor demand equations as set out in Section 7. Estimation is done for each of our three groups of sectors for four factors: skilled labour, unskilled labour, clerical workers and capital.

We include second-order lags in all equations, in addition we test for both firm turnover and scale effects and a full set of time dummies. However we do not test for a structural break in 1987 as the partial systems estimation suggested that this was not significant.

As discussed in Section 3.3, we compared instrumental variables estimators with multivariate least squares and FIML[24] estimates of (2.18). In all cases the IV and GMM estimators were very unstable, with a failure to converge[25] and high estimated covariance terms. By contrast the least squares results did converge with sensible coefficient estimates which agreed with the partial systems estimates. Therefore, despite unresolved issues relating to the small-sample properties of these estimators (see Krishnakumar (1992) p.149), we used the multivariate least squares and FIML estimates in further full systems estimation.

	Skilled	*Unskilled*	*Clerical*	*Capital*
High Growth	0.051	0.126	0.024	0.799
Medium Growth	0.096	0.380	0.055	0.470
Declining	0.101	0.503	0.054	0.343

Table 5.1: Average Shares for Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services in Total Value Added

Table 5.1 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. By contrast over 50% of total value-added is accounted for by the unskilled wage bill in the declining group.

[24] Initial values for FIML estimates were taken from multivariate least squares estimates.

[25] 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.

	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 5.2: Within and Between Groups Shares of Total Skilled, Unskilled and Clerical Employment

Table 5.2 shows the within group and between group shares in 1979 and 1990 for skilled, unskilled and clerical employment. Looking first at the within group shares we can see that the high-growth group's employment mix shifted towards employing more skilled and clerical workers, with a cumulative growth rate in employment levels of 159% and 126% over the period 1979-1990. There was comparatively little change in the medium-growth and declining groups factor mix over the period, although in both there was a gradual decline in the unskilled employment 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 workers 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.

These differences are reflected in the results we report in this section. The estimation of long run factor demand functions was most successful for the medium-growth group of sectors with the underlying parameters indicating limited substitution possibilities between factors except for clerical-unskilled labour which are complements in production. The results for the high-growth group suggested a different underlying production technology, with evidence of capital-skill and clerical-skill complementarity in production and a greater degree of substitutability between skilled labour and unskilled labour. The results for the declining group were very unstable. They suggested a long-run Cobb-Douglas technology in this group.

5.1. Medium Growth Sectors

The estimation results reported here are based on FIML estimation[26]. The hypotheses listed in Table 5.3 are 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
5. H_5 : Cobb-Douglas Technology With No Scale or Firm Turnover Effects (All long-run coefficients jointly insignificant)
6. H_6 : Long Run Homotheticity (Scale Effects Insignificant)
7. H_7 : Firm Turnover Effects Insignificant
8. H_8 : 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 5.3 specification (1) is the most general specification, which includes time dummies and imposes no behavioural restrictions. The restrictions imposed by price homogeneity and symmetry are not rejected by this specification. Time dummies are insignificant, as found in the partial systems estimation. 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

[26]FIML estimates were preferred over multivariate least squares because there was much faster convergence.

		(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)	
$H_5 : \gamma_{ij} = 0, \forall i, j$	$\chi_2(12)$		15.9(.20)	23.93(.02)
$H_6 : \gamma_{iq} = 0, i = h, l, c$	$\chi_2(3)$		0.23(.97)	0.57(.90)
$H_7 : \gamma_{in} = 0, i = h, l, c$	$\chi_2(3)$		2.50(.47)	8.58(.03)
$H_8 : \pi_{ij2} = 0, \forall i, j$	$\chi_2(36)$		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 5.3: Specification Testing of Four Equation Factor Demand System for Medium Growth Sectors: Based on FIML Estimation of (2.18)

insignificant in this specification (H_6) we found that dropping these led to behaviourally implausible elasticity signs (positive own elasticity of demand for clerical workers and capital). Therefore we retained these long-run scale effects in our preferred specification.

Table 5.4 gives the elasticities of substitution and demand between skilled, unskilled, clerical and capital for the medium-growth group as estimated from the long run parameters[27]. These elasticities are evaluated using the period average factor shares.

The Allen own and cross elasticity of substitution is computed using the product of the relevant factor shares as the denominator (see equation (2.6)). Thus factors with very low shares will tend to have high computed elasticities of substitution. This partly explains why the *magnitude* of the own and cross elasticities of substitution for clerical labour (share= 0.055) and to some extent skilled labour (share= 0.096) 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-

[27]The estimated long run coefficients with standard errors in parentheses are:

γ_{lh}	γ_{ch}	γ_{cl}	γ_{hk}	γ_{lk}	γ_{ck}	γ_{hq}	γ_{lq}	γ_{cq}	γ_{hn}	γ_{ln}	γ_{cn}
−.012	.007	−.11	−.036	.054	.071	−.112	.234	.193	−.051	−.074	−.009
(.01)	(.04)	(.06)	(.04)	(.10)	(.10)	(.16)	(.36)	(.36)	(.05)	(.15)	(.12)

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
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	
Gross Price 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

Table 5.4: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: Medium Growth Sectors

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. By contrast the signs of the Morishima elasticities of substitution suggest that while clerical workers are strong complements with unskilled labour, unskilled workers are actually limited substitutes for clerical workers.

These elasticity of substitution estimates, and the estimated gross elasticities of demand (which measure the changes in the demand for each factor in response to a one percent change in a given factor price holding output constant), 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.

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 or clerical workers, while substitutability with capital is close to zero. A lower substitution in response to clerical workers than to unskilled workers may reflect the skill specificity of clerical work (typing, shorthand, telephone operators, etc.)

4. Clerical workers are strong complements to unskilled workers. 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. Clerical workers are strong substitutes for capital while capital is a weak substitute for clerical workers.

6. There is a relatively high degree of substitutability between unskilled workers and capital. By contrast unskilled workers are weak complements to clerical workers.

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 *gross elasticity of total employment with respect to wages* (measured as the response to a 1% overall increase in wages with no change in relative wages or output) for the medium-growth group of sectors is -0.1 for skilled workers, -0.62 for unskilled workers and -1.77 for clerical workers. Thus we can see that a general increase in wage levels has a large differential effect on the demand for skilled, unskilled and clerical labour.

Changes in relative wages will cause changes in relative employment ratios. Furthermore the impact of increases in relative wage levels on the relative demand for labour depends on which category of wage is responsible for the change. This asymmetry is directly measured by the Morishima elasticity of substitution. We can summarise these relationships as follows:

1. *Skilled Relative to Unskilled Labour*: The elasticity of skilled labour relative to unskilled labour is very similar whether the increase in the unskilled/skilled wage is due to a rise in unskilled wages (0.69) or a fall in skilled wages (0.54).

2. *Skilled Relative to Clerical Labour*: The reverse applies to the demand for skilled labour relative to clerical labour, which is higher if skilled wages fall (0.71) than if clerical wages rise (0.49). But again the magnitude of the responses is not hugely different.

3. *Unskilled Relative to Clerical Labour*: There is however a strong asymmetric response in the demand for unskilled labour relative to clerical labour depending on whether clerical wages rise (an elasticity of 0.12) or unskilled wages fall (-1.20). A fall in unskilled wages will cause a larger proportionate fall in the ratio of unskilled to clerical labour because of the very high negative elasticity of demand for clerical workers in response to changes in unskilled wages.

Overall there is not much differential impact on unskilled relative to skilled employment depending on which component of the relative wage changes, however there is a strong asymmetric effect for unskilled relative to clerical employment. Finally note that labour to capital ratios are more responsive to changes in the cost of capital than changes in wages for each category of labour.

5.2. 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)
$H_5 : \gamma_{ij} = 0, \forall i, j$	$\chi_2(12)$		143.69(.00)
$H_6 : \gamma_{iq} = 0, i = h, l, c$	$\chi_2(3)$		7.40(.06)
$H_7 : \gamma_{in} = 0, i = h, l, c$	$\chi_2(3)$		21.12(.00)
$H_8 : \pi_{ij2} = 0, \forall i, j$	$\chi_2(36)$		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 5.5: Specification Testing of Four Equation Factor Demand System for Medium Growth Sectors: Based on Multivariate Least Squares Estimation of 2.18

Estimation was done using multivariate least squares with standard errors robust to heteroscedasticity. The reported results in Table 5.5 indicate that homotheticity and symmetry were not rejected by the general specification (1) based on estimating equations (2.18). 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.

Table 5.6 gives the estimated elasticities of substitution and demand for the high-growth group[28]. The estimated own elasticity of substitution and demand for skilled labour is positive violating standard economic theory. However the estimated own price elasticity of demand for skilled labour is close to zero which we consider plausible. As discussed earlier, the formula for the Allen partial elasticity of substitution contains in the denominator the product of the factor shares so that the estimated elasticities for factors with very low shares may sometimes look strange. This is why the ranking of factors' pairwise relationships

[28] These were computed from the following estimated long-run parameters:

γ_{lh}	γ_{ch}	γ_{cl}	γ_{hk}	γ_{lk}	γ_{ck}	γ_{hq}	γ_{lq}	γ_{cq}	γ_{hn}	γ_{ln}	γ_{cn}
.008	−.006	.003	−.054	−.047	−.006	.011	.011	.009	−.023	−.015	−.003
(.007)	(.004)	(.005)	(.008)	(.021)	(.004)	(.007)	(.020)	(.004)	(.005)	(.052)	(.007)

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
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	
Gross Price 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

Table 5.6: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: High Growth Sectors

implied by the Allen partial elasticities is more reliable than the actual magnitudes. In addition to this small denominator problem there is the added difficulty for the high-growth group that transfer pricing distortions in the data mean that the labour share is understated.

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 substitutability between unskilled and capital and clerical-capital, to limited complementarity between skilled and capital, to high complementarity between skilled and clerical. By contrast the Morishima elasticities suggest that while clerical labour is a complement to skilled labour, skilled labour is a substitute for clerical labour.

The following technical and economic relationships are implied by these estimates:

1. The own elasticity of demand for skilled labour is positive but very close to zero (0.05). 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 the demand for capital is not responsive to the skilled wage (-0.02) the demand for skilled labour does have a limited response to the cost of capital (-0.25). This is an important finding since it supports the skill-capital complementarity hypothesis.

3. Skilled labour and clerical labour are also weak complements. The demand for clerical labour increases in response to a fall in the skilled wage (-0.19), the demand for skilled labour increases by less (-0.09) in response to a fall in the clerical wage.

4. Skilled labour and unskilled labour are limited substitutes. Also clerical labour and unskilled labour are limited substitutes. This latter contrasts directly with the results for the medium-growth group where clerical labour and unskilled labour were complements.

5. Unskilled labour and clerical labour are both limited substitutes for capital.

6. The demand for capital is estimated to have almost zero sensitivity to changes in wages.

The implied gross 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 positive elasticity for skilled labour is noteworthy. The demand for skilled labour is not sensitive to a rise in the price of skilled labour but will increase given a rise in the price of unskilled labour.

The limited sensitivity of skilled labour demand to changes in the skilled or clerical wage has also implications for the evolution of relative employment ratios in response to changes in wages:

1. *Skilled Relative to Unskilled Labour:* The increase in the ratio of skilled to unskilled labour is very different if unskilled wages rise (0.88) than if skilled wages fall (0.07).

2. *Skilled Relative to Clerical Labour:* The ratio of skilled to clerical labour increases if the clerical wage rises (0.53) but will fall if the skilled wage falls (-0.24).

3. *Unskilled Relative to Clerical Labour:* The elasticity of unskilled labour relative to clerical labour is very similar whether the unskilled wage changes (0.86) or the clerical wage changes (0.67).

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 with slightly weaker evidence of clerical-skill complementarity.

5.3. 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 (2.18) of the four factor demand equations failed to converge in estimation[29] as can be seen in Table 5.7. 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 5.7.

		(1)	(2)	(3)
$H_4 : D_t = 0 \forall t$	$\chi_2(36)$	20.2(.98)		
$H_5 : \gamma_{ij} = 0, \forall i, j$	$\chi_2(12)$	0.42(1.00)	0.24(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)	
$H_8 : \pi_{ij2} = 0, \forall i, j$	$\chi_2(36)$	126.22(.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 5.7: Specification Testing of Four Equation Factor Demand System for Declining Sectors: Based on Multivariate Least Squares Estimation of (2.18)

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. Table 5.12 in the next section uses these elasticity estimates to compute the implied change in skilled, unskilled and clerical employment due to a change in other factor prices relative to that factor's own price. These "guesstimates" seriously overestimate 1990 employment levels in this group of sectors, by 52% for skilled employment, over 80% for unskilled employment and 43% for clerical employment.

The dynamic equations for the declining group are shown in Section 8. 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

[29] All estimation was carried out using multivariate least squares with heteroscedastic-consistent standard errors.

Gross Price 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 5.8: Estimated Elasticities of Substitution and Demand Between Skilled Labour, Unskilled Labour, Clerical Workers and Capital Services: Declining Sectors

for unskilled labour and strong increasing returns for capital. There is also evidence of short-run increasing returns to scale for capital.

Overall we consider the results for the declining group to be very unsatisfactory and do not analyse them further. The interesting implication of this exercise is that it is very difficult to model stable long-run behaviour for a group of industries in secular decline.

5.4. The Estimated Dynamics

The main purpose of estimating these factor demand functions is to uncover evidence of stable long-run relations between the different factors. The inclusion of a full set of dynamics up to lag two is used solely because long-run behaviour cannot plausibly be held to always manifest itself within a single time period prescribed by the data. Thus the main focus of our discussion up to now has been on the long-run relations estimated within a framework that allows for short-run asymmetric deviations from long-run behaviour. Here we look briefly at some of the broad characteristics of the estimated dynamic equations for the medium-growth and high-growth groups. The full set of estimated dynamic equations for the three sectoral groups are set out in Section 8. Parsimonious reductions of these equations was not attempted so the individual coefficient estimates have low precision.

Medium Growth Dynamic Equations:

The adjustment coefficients on the long-run error correction terms are all correctly signed.

1. S_h equation: The coefficient on the skilled labour error correction term is greater than one (1.59) indicating significant short-run overshooting of equilibrium. Also the short-run coefficient on the lagged endogenous variable is greater than one (-1.34). The prices of skilled labour and capital are significant. There is evidence of a negative lagged firm turnover effect.

2. S_l equation: The only short-run coefficients of significance are on the scale and firm

turnover variables. These indicate short-run decreasing returns to scale and to new firm entry for unskilled labour.

3. S_c equation: There is marginal evidence of decreasing returns to scale and new firm entry for clerical labour.

4. S_k equation: The adjustment coefficients for this equation are derived via the adding up condition. The short-run parameters indicate significant short-run increasing returns to scale.

High Growth Dynamic Equations:

1. S_h equation: There is evidence of a negative short-run firm turnover effect. Time dummies oscillate between positive and negative effects.

2. S_l equation: The adjustment coefficients on the long-run error correction terms are positive. The coefficients on the time dummies are very large in this equation and the majority are negative. This would suggest technical bias against unskilled labour.

3. S_c equation: The coefficient on the clerical labour error correction term is greater than one (1.49) indicating significant short-run overshooting of equilibrium. Also the short-run coefficient on the lagged endogenous variable is greater than one (-1.29).Time dummies are generally negative.

4. S_k equation: The adjustment coefficients on the long-run error correction terms are all negative, this implies a positive adjustment coefficient on the long-run capital relation. Time dummies oscillate between positive and negative effects.

5.5. Discussion of Estimated Results

5.5.1. What are the Differences Between Groups?

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 workers. These industries will have skill-capital complementarity in production and a higher than average share of skilled workers. 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 workers is lower than in the new technology industries.

This profile of new technology industries and mature technology industries matches well with our High growth and medium-growth groups of sectors. The former 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 growth group have more installed production processes, they have a lower skilled labour share than the average and there is no support for the skill-complementarity hypothesis.

Do our results support the hypothesis of a lower elasticity of substitution in the new technology industries? The answer is yes but depends crucially on looking at the (asymmetric) Morishima elasticities of substitution. The Allen partial elasticity of substitution between skilled and unskilled labour is higher in the high-growth group (2.27) than in the medium-growth group (0.67). On the face of it this would reject the hypothesis. However the Morishima elasticity of substitution between unskilled and skilled labour in response to a change in the skilled wage is much lower in the high-growth group than in the medium-growth group. By contrast the elasticity of substitution between skilled and unskilled labour in response to a change in the unskilled wage is much higher in the high-growth group than in the medium-growth group. These asymmetries reflect the fact that the demand for skilled labour in the high-growth group is much more inelastic than in the medium-growth group while the demand for unskilled labour is more elastic in the high-growth group.

A second, related, set of differences emerged for the role of clerical labour in the two groups of sectors. In the high-growth group clerical labour is a complement to skilled labour (-0.19 given a change in the skilled wage) while in the medium-growth group clerical labour is a complement to unskilled labour (-1.64 given a change in the unskilled wage). This would suggest that the nature of clerical employment in the two groups is different. Specifically it would suggest a higher level of embodied skills for clerical labour in the high-growth group. As shown in Table 5.2 the increase in clerical employment in the manufacturing sector was particularly marked in the high-growth group[30].

In the medium-growth group the picture is more complicated, the net decrease in total clerical employment is composed of an increase in male employment (+289) and a fall in female clerical employment (-514). The complementarity between clerical labour and unskilled labour in the medium-growth group, coupled with a high degree of clerical-capital substitutability, would suggest that the large fall in female clerical employment reflects the replacement of traditional clerical workers with information technology (widespread com-

[30]There was a roughly equal increase in both male [1,570 or 174%] and female [1,561 or 98%] clerical employment.

puterisation, increased use of PCs, digital telephone exchanges, etc.). Furthermore there was a large increase in clerical wages relative to unskilled wages for the medium-growth group. These patterns would suggest that some of the fall in female clerical employment was concentrated in low-paid or part-time employment as discussed in Kearney (1997)[31]. One could argue further that, at the same time, the increase in male clerical employment reflects an increase in information technology skill requirements for clerical workers or, more fundamentally, a change in the nature of clerical work traditionally dominated by female workers.

5.5.2. What are the Differences Between Labour Types?

Alongside these differences across groups there are clear, consistent differences across the different types of labour. Clerical employment is the most elastic in the face of a change in the general wage level while skilled employment is the most inelastic. The gross elasticity of total employment with respect to wages is estimated at -0.1, -0.62 and -1.77 for skilled, unskilled and clerical labour in the medium-growth group and +0.25, -0.42 and -0.54 in the high-growth group. Thus a general wage shock to the manufacturing sector will increase the skilled labour share relative to unskilled and clerical.

Turning to the impact of relative wage shocks the prognosis for unskilled labour relative to skilled labour is also bleak. A 1% increase in the unskilled wage will increase the skilled-unskilled labour ratio by 0.69% in the medium-growth group and 0.88% in the high-growth group, quite a high level of substitution. However a reverse shock, a 1% increase in the skilled wage, will only reduce the ratio of skilled to unskilled employment by -0.54% in the medium-growth group and -0.07% in the high-growth group.

5.5.3. How plausible are these results for Ireland?

How plausible are these results in modelling the demand for labour in the Irish manufacturing sector? In particular, how do they compare with previous studies of the demand for labour in Ireland? To answer this question we compare our results with an earlier study of the Irish manufacturing sector covering the period 1970-1987. In this study Bradley et al. (1993) model output and input determination 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). The model is set up as a two-stage process. In the first stage the firm makes the "high-level" investment decision on where to

[31] Replacing part-time workers with full-time workers will artificially inflate measured wages since our data do not distinguish these categories.

locate production based on world demand and competitiveness (domestic factor costs relative to foreign factor costs). In the second stage the demand for four factors of production, conditional on output from the first stage, is estimated within a cost-minimisation framework[32]. Their factor demand specification includes labour, capital, materials and energy inputs.

It is difficult to directly compare their results both because they do not disaggregate the labour input and because they do not assume weak separability with material and energy inputs in production. What is comparable, and similar with our results, is the *magnitude* of their long-run gross elasticities which indicate limited substitution between factors (together with limited labour-capital complementarity in the traditional sector[33]). Bradley et al. argue that these limited substitution possiblities are plausible for Irish manufacturing. The argument is as follows. The effect of an increase in one of more factor prices, in addition to limited changes in the factor mix, will be an overall deterioration in competitiveness. In a small open economy, such as Ireland, where investment is easily transferred across geographical borders this will cause new investment to relocate elsewhere. Thus an increase in one or more factor prices will cause limited changes in the factor mix but a relatively large fall in output.

The *net* elasticity of demand for different factors, which is parameterised by the own price elasticity of demand for output (see equation (2.9)), includes this output effect. Bradley et al. (1993) estimated a very high price elasticity of demand for output in the traditional sector (-3.3 in 1987) and much lower in the modern sector (-0.5 in 1987). In Table 5.9 we use these estimates to provide rough guesstimates of the net elasticities of demand for skilled, unskilled, clerical labour and capital.

The net elasticity "guesstimates" for the medium-growth group indicate that, when we allow for an output response to an increase in one or more wage rates, the impact on the demand for labour is much more pronounced and everywhere negative. By contrast the net elasticity guesstimates for the high-growth sector suggest that even allowing for output to respond fully to a change in factor prices the demand for both skilled and clerical labour will rise given an increase in the unskilled wage.

[32]Bradley et al. (1993) use a Generalised Leontief specification with capital quasi-fixed in the short-run.

[33]Bradley et al. suggest that capital and labour, when conditioned on value-added, are substitutes in this sector. However they argue 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 that this effect dominates giving rise to labour-capital complementarity. This hypothesis cannot be tested within our value-added specification but would concur with our finding that, conditional on value-added, labour and capital are substitutes in the Medium group.

Net Price Elasticity of Demand, ε^*_{ij}								
	Medium Growth				**High Growth**			
	Skilled	*Unskilled*	*Clerical*	*Capital*	*Skilled*	*Unskilled*	*Clerical*	*Capital*
Skilled	-0.79	-1.00	-0.05	-1.46	0.02	0.22	-0.10	-0.68
Unskilled	-0.25	-1.69	-0.42	-0.94	0.09	-0.66	0.04	-0.01
Clerical	-0.08	-2.89	-0.54	0.21	-0.22	0.20	-0.64	0.11
Capital	-0.30	-0.76	0.02	-2.27	-0.04	-0.00	0.00	-0.50

Table 5.9: Guesstimates of Net Elasticity Estimates

5.5.4. How do the results compare with International Stylised Facts?

How do these results compare with international evidence on the demand for labour? Hamermesh (1993, Chapter 3) surveys a wide range of empirical literature on the parameters characterising labour demand and summarises the main findings from this research in 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 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."'* Our only estimates of the elasticity of demand for homogenous labour comes from the partial systems estimation. Using these results we test the hypothesis $H_1 : -\varepsilon_{ll} < 1$.

2. *'We are fairly sure that the own-wage demand elasticity decreases as the skill embodied in a group of workers increases.'* We test this using the results of the full systems estimation as $H_2 : -\varepsilon_{ss} < -\varepsilon_{uu}$

3. *'We are fairly sure than capital and skill are p-complements[34].'* Using the full systems estimates this hypothesis can be formulated as $H_3 : \varepsilon_{sk} < 0 \cap \varepsilon_{ks} < 0$

4. *'We are fairly sure that workers and hours are both p-substitutes for capital.'* We assume workers to refer to clerical and unskilled labour. Using the full systems estimates this hypothesis can be formulated as $H_4 : \varepsilon_{uk} > 0 \cap \varepsilon_{ku} > 0 \cap \varepsilon_{ck} > 0 \cap \varepsilon_{kc} > 0$

[34]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.

	High Growth	Medium Growth
H_1	Yes, falls between [0,1]	Yes falls between [0.25,0.75]
H_2	Yes	No: $-\varepsilon_{ss} > -\varepsilon_{uu}$
H_3	Yes	No: $\varepsilon_{sk} > 0$ and $\varepsilon_{ks} > 0$
H_4	Yes	Yes

Table 5.10: Are International Stylised Facts on Labour Demand Supported By Our Estimates?

Table 5.10 summarises the support for these stylised facts in our estimated factor demand functions[35]. For the first hypothesis our estimated elasticity of demand for homogenous labour is higher than the 0.30 best guess (0.799 for high-growth and 0.618 for medium-growth) but does fall within the interval indicated. The second hypothesis is supported by the High Growth results but rejected the medium-growth results. Recall, however, that an alternative version of this hypothesis is supported by both groups as described earlier, namely the general-wage demand elasticity for skilled labour is lower than for unskilled labour in both groups of sectors. The third hypothesis is accepted for the high-growth group but rejected for the medium-growth group while the fourth is accepted for both. Overall our results for the high-growth group concur with the set of stylised facts distilled from the international evidence by Hamermesh, while the evidence for the skill-complementarity hypothesis for the medium-growth group is more mixed.

5.5.5. How well do the elasticity estimates proxy the actual change in employment?

Finally we look at the employment levels implied by our estimated cross-price elasticities of demand. Table 5.11 shows the cumulative change in relative factor prices in the three sectors between 1979 and 1990. We use the estimated cross elasticities of demand and the change in other factor prices *relative to that factor's own price* to estimate the implied level of employment in 1990. Table 5.12 gives the resulting "guesstimates" for skilled, unskilled and clerical employment. By comparing these with the actual employment numbers in 1990 we can estimate how much of the total change in employment is accounted for by changes in other factor prices.

For the medium-growth group the estimates are reasonably close to actual levels. Skilled employment is overestimated by almost 13%, unskilled by over 17% while clerical employment is underestimated by almost 3%. For the declining group employment is hugely overestimated

[35] We omit the Declining sector results from this analysis.

		High	**Medium**	**Declining**
Skilled/Unskilled	P_h/P_l	-6.33	2.29	4.13
Skilled/Clerical	P_h/P_l	2.67	-9.72	-10.9
Unskilled/Clerical	P_h/P_l	9.61	-11.74	-14.43
Skilled/Capital	P_h/P_k	-3.45	2.81	-4.81
Unskilled/Capital	P_h/P_k	3.08	0.51	-8.58
Clerical/Capital	P_h/P_k	-5.96	13.88	6.83
Number of Firms	NO	80.02	4.33	-16.37
Gross Output	Q	342.20	35.84	-29.32

Table 5.11: Cumulative Percentage Change in Relative Factor Prices, Number of Firms and Gross Output 1979-1990 (Weighted Data)

	Actual	Guesstimate	% of Actual
High Growth			
Skilled	8,321	3,251	39.1%
Unskilled	31,681	20,541	64.8%
Clerical	5,625	2,632	46.8%
Medium Growth			
Skilled	11,808	13,319	112.8%
Unskilled	76,556	89,919	117.4%
Clerical	11,434	11,130	97.3%
Declining			
Skilled	4,572	6,931	151.6%
Unskilled	39,724	71,658	180.4%
Clerical	3,866	5,544	143.4%

Table 5.12: Guesstimates of 1990 Employment Levels Using Gross Cross Elasticity of Demand Estimates

		Medium Growth		High Growth	
		Q	NO	Q	NO
Skilled Share	S_h	-1.17	-0.53	+0.21	-0.44
Unskilled Share	S_l	+0.62	-0.19	+0.09	-0.12
Clerical Share	S_c	+3.53	-0.16	+0.38	-0.13
Capital Share	S_k	-0.67	+0.28	-0.04	+0.05

Table 5.13: Estimated Elasticity of Factor Shares With Respect to Scale and Firm Turnover Effects: Estimates Based on Long-Run Parameters and Average Shares

while for the high-growth group employment is seriously underestimated.

The underestimation for the high-growth sectors is not surprising. To understand the evolution of employment in this group we must take into account the very large net increase in the number of firms (+80%) and the huge expansion in output (342% cumulative growth in real output) over the period. Table 5.13 gives the estimated percentage response of factor shares with respect to scale and firm turnover effects. Scale effects are biased strongly in favour of labour, especially skilled and clerical labour. Firm turnover effects are biased in favour of capital, on average net new firms have higher capital intensity.

It is also not surprising that the declining group's employment is overestimated using the estimated elasticities since little or no reliance can be placed in the estimation results obtained for this group of sectors. As argued in Kearney (1997) the continuous secular decline of this group of relatively low-skilled sectors over the period reflects the impact which strong cost competitiveness from low-wage countries has had as the Irish economy became increasingly open through the 1970s and 1980s. In these circumstances modelling long-run cost-minimising behaviour conditional on output for this group of sectors cannot work with output itself in freefall.

6. Conclusions

In this paper we estimate the long-run demand for labour in the Irish manufacturing sector in the 1980s for a variety of specifications. Firstly we estimate the demand for skilled labour relative to unskilled labour assuming that the skilled-unskilled factor mix is separable from all other factors of production. Secondly we estimate the demand for homogenous labour relative to capital. In addition to assuming the labour-capital mix is separable in production this also assumes that the demand for skilled and unskilled labour is identical. Finally we estimate the demand for three categories of labour, skilled, unskilled and clerical, jointly with the demand for capital. This specification assumes that the value-added generated from these inputs is separable in production from other factor inputs.

In addition to tackling the issue of heterogeneity of the labour input in production, we also explicitly address the issue of heterogeneity of output in production. That is we group our dataset of manufacturing sectors according to output growth performance where our taxonomy covers three types of sectors, namely high-growth, medium-growth and declining sectors.

The full systems results suggest some very important differences between the different groups of sectors and different types of labour, thereby confirming both output heterogeneity and labour input heterogeneity. The main findings can be summarised as follows:

1. A shock to the general wage level has a much larger impact on the demand for unskilled labour than the demand for skilled labour. In fact we found that a general increase in wages would lead to an increase in skilled employment in the high-growth group.

2. A shock to the skilled-unskilled wage level caused by a rise in the skilled wage has a smaller impact on the ratio of skilled to unskilled employment than a shock caused by a fall in the unskilled wage. This asymmetry is particularly pronounced for the high-growth group where the skilled-unskilled wage gap narrowed over the period.

3. Our results for the high-growth group of sectors support the skill-capital complementarity hypothesis, together with some evidence of technical bias against unskilled labour. By contrast the results for the medium-growth group find no evidence of skill-capital complementarity and no evidence of technical bias.

4. Firm turnover has a significant influence on the factor mix for both groups. Net new firms were found to be more capital-intensive than the average for both groups.

5. Scale effects were found in general to be biased in favour of labour inputs. It is difficult to interpret this effect since it may also be capturing evidence of misspecification consequent on the assumption that value-added is separable from gross output.

6. The role of clerical labour is different in the two groups. In the high-growth group clerical labour has more embodied skills than in the medium-growth group. We interpret this as capturing the idiosyncratic impact which the spread of information technology has had on the skill requirements of clerical jobs.

7. For the declining group of sectors we could not find evidence of long-run cost-minimising behaviour. This is a group where both the number of firms and gross output are in secular decline.

Overall the results confirm the trends suggested by the descriptive analysis in Kearney (1997). The medium-growth group has a relatively stable technology underlying its production process with little evidence of skill-biased technical change or trade effects. Most of the relatively minor shifts in factor shares in this group are accounted for by movements in relative factor prices. This group numbered over half of all manufacturing employment throughout the period under study. The declining group lends support to the "trade effect" hypothesis where these low-skill technologies are relocating from Ireland to low-wage countries. By contrast during the 1980s the high-growth group underwent rapid expansion, its behaviour corresponds closely with the "skill-biased technical change" hypothesis.

7. Specification of Dynamic Equations and Relationship with Estimated Coefficients

The following four equations are the behavioural equations from (2.15) with short-run adding up restrictions imposed:

$$\begin{aligned}\Delta S_{hst} = {} & \beta_{hh}\Delta S_{hst-1} + \beta_{hl}\Delta S_{lst-1} + \beta_{hc}\Delta S_{cst-1} + \delta_{hh0}\Delta \ln P_{hst} + \delta_{hl0}\Delta \ln P_{lst} \\ & +\delta_{hc0}\Delta \ln P_{cst} + \delta_{hk0}\Delta \ln P_{kst} + \delta_{hq0}\Delta \ln Q_{st} + \delta_{hn0}\Delta \ln NO_{st} \\ & +\delta_{hh1}\Delta \ln P_{hst-1} + \delta_{hl1}\Delta \ln P_{lst-1} + \delta_{hc1}\Delta \ln P_{cst-1} + \delta_{hk1}\Delta \ln P_{kst-1} \\ & +\delta_{hq1}\Delta \ln Q_{st-1} + \delta_{hn1}\Delta \ln NO_{st-1} \\ & -\lambda_{hh} ecm_{hst-2} - \lambda_{hl} ecm_{lst-2} - \lambda_{hc} ecm_{cst-2}\end{aligned} \tag{7.1}$$

$$\begin{aligned}\Delta S_{lst} = {} & \beta_{lh}\Delta S_{hst-1} + \beta_{ll}\Delta S_{lst-1} + \beta_{lc}\Delta S_{cst-1} + \delta_{lh0}\Delta \ln P_{hst} + \delta_{ll0}\Delta \ln P_{lst} \\ & +\delta_{lc0}\Delta \ln P_{cst} + \delta_{lk0}\Delta \ln P_{kst} + \delta_{lq0}\Delta \ln Q_{st} + \delta_{ln0}\Delta \ln NO_{st} \\ & +\delta_{lh1}\Delta \ln P_{hst-1} + \delta_{ll1}\Delta \ln P_{lst-1} + \delta_{lc1}\Delta \ln P_{cst-1} + \delta_{lk1}\Delta \ln P_{kst-1} \\ & +\delta_{lq1}\Delta \ln Q_{st-1} + \delta_{ln1}\Delta \ln NO_{st-1} \\ & -\lambda_{lh} ecm_{hst-2} - \lambda_{ll} ecm_{lst-2} - \lambda_{lc} ecm_{cst-2}\end{aligned} \tag{7.2}$$

$$\begin{aligned}\Delta S_{cst} = {} & \beta_{ch}\Delta S_{hst-1} + \beta_{cl}\Delta S_{lst-1} + \beta_{cc}\Delta S_{cst-1} + \delta_{ch0}\Delta \ln P_{hst} + \delta_{cl0}\Delta \ln P_{lst} \\ & +\delta_{cc0}\Delta \ln P_{cst} + \delta_{ck0}\Delta \ln P_{kst} + \delta_{cq0}\Delta \ln Q_{st} + \delta_{cn0}\Delta \ln NO_{st} \\ & +\delta_{ch1}\Delta \ln P_{hst-1} + \delta_{cl1}\Delta \ln P_{lst-1} + \delta_{cc1}\Delta \ln P_{cst-1} + \delta_{ck1}\Delta \ln P_{kst-1} \\ & +\delta_{cq1}\Delta \ln Q_{st-1} + \delta_{cn1}\Delta \ln NO_{st-1} \\ & -\lambda_{ch} ecm_{hst-2} - \lambda_{cl} ecm_{lst-2} - \lambda_{cc} ecm_{cst-2}\end{aligned} \tag{7.3}$$

$$\begin{aligned}\Delta S_{kst} = {} & -(\beta_{hh} + \beta_{lh} + \beta_{ch})\Delta S_{hst-1} - (\beta_{hl} + \beta_{ll} + \beta_{cl})\Delta S_{lst-1} \\ & -(\beta_{hc} + \beta_{lc} + \beta_{cc})\Delta S_{cst-1} + \delta_{kh0}\Delta \ln P_{hst} + \delta_{kl0}\Delta \ln P_{lst} \\ & +\delta_{kc0}\Delta \ln P_{cst} + \delta_{kk0}\Delta \ln P_{kst} + \delta_{kq0}\Delta \ln Q_{st} + \delta_{kn0}\Delta \ln NO_{st} \\ & +\delta_{kh1}\Delta \ln P_{hst-1} + \delta_{kl1}\Delta \ln P_{lst-1} + \delta_{kc1}\Delta \ln P_{cst-1} + \delta_{kk1}\Delta \ln P_{kst-1} \\ & +\delta_{kq1}\Delta \ln Q_{st-1} + \delta_{kn1}\Delta \ln NO_{st-1} \\ & +(\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) ecm_{hst-2} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) ecm_{lst-2} \\ & +(\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) ecm_{cst-2}\end{aligned} \tag{7.4}$$

These four equations include 93 parameters for estimation. First differencing, which eliminates the constant terms, reduces this to 90 parameters. Given the six short-run adding-up restrictions this leaves 84 free parameters to be estimated.

7.1. Recovering the Short-Run Adjustment Coefficients from the Estimated Equations

The π coefficients which are estimated using the set of first difference equations (2.18) identify the short-run adjustment coefficients as follows:

Factor h: Short-Run Adjustment Coefficients:

$$\begin{array}{ll}
\pi_{hH1} = 1 + \beta_{hh} & \pi_{hH2} = -\beta_{hh} - \lambda_{hh} \\
\pi_{hL1} = \beta_{hl} & \pi_{hL2} = -\beta_{hl} - \lambda_{hl} \\
\pi_{hC1} = \beta_{hc} & \pi_{hC2} = -\beta_{hc} - \lambda_{hc} \\
\pi_{hh0} = \delta_{hh0} & \pi_{hh1} = \delta_{hh1} - \delta_{hh0} \\
\pi_{hl0} = \delta_{hl0} & \pi_{hl1} = \delta_{hl1} - \delta_{hl0} \\
\pi_{hc0} = \delta_{hc0} & \pi_{hc1} = \delta_{hc1} - \delta_{hc0} \\
\pi_{hk0} = \delta_{hk0} & \pi_{hk1} = \delta_{hk1} - \delta_{hk0} \\
\pi_{hq0} = \delta_{hq0} & \pi_{hq1} = \delta_{hq1} - \delta_{hq0} \\
\pi_{hn0} = \delta_{hn0} - \delta_{hq0} & \pi_{hn1} = (\delta_{hn1} - \delta_{hn0}) - (\delta_{hq1} - \delta_{hq0})
\end{array}$$

Factor l: Short-Run Adjustment Coefficients:

$$\begin{array}{ll}
\pi_{lH1} = \beta_{lh} & \pi_{lH2} = -\beta_{lh} - \lambda_{lh} \\
\pi_{lL1} = 1 + \beta_{ll} & \pi_{lL2} = -\beta_{ll} - \lambda_{ll} \\
\pi_{lC1} = \beta_{lc} & \pi_{lC2} = -\beta_{lc} - \lambda_{lc} \\
\pi_{lh0} = \delta_{lh0} & \pi_{lh1} = \delta_{lh1} - \delta_{lh0} \\
\pi_{ll0} = \delta_{ll0} & \pi_{ll1} = \delta_{ll1} - \delta_{ll0} \\
\pi_{lc0} = \delta_{lc0} & \pi_{lc1} = \delta_{lc1} - \delta_{lc0} \\
\pi_{lk0} = \delta_{lk0} & \pi_{lk1} = \delta_{lk1} - \delta_{lk0} \\
\pi_{lq0} = \delta_{lq0} & \pi_{lq1} = \delta_{lq1} - \delta_{lq0} \\
\pi_{ln0} = \delta_{ln0} - \delta_{lq0} & \pi_{ln1} = (\delta_{ln1} - \delta_{ln0}) - (\delta_{lq1} - \delta_{lq0})
\end{array}$$

Factor c: Short-Run Adjustment Coefficients:

$$\begin{array}{ll}
\pi_{cH1} = \beta_{ch} & \pi_{cH2} = -\beta_{ch} - \lambda_{ch} \\
\pi_{cL1} = \beta_{cl} & \pi_{cL2} = -\beta_{cl} - \lambda_{cl} \\
\pi_{cC1} = 1 + \beta_{cc} & \pi_{cC2} = -\beta_{cc} - \lambda_{cc} \\
\pi_{ch0} = \delta_{ch0} & \pi_{ch1} = \delta_{ch1} - \delta_{ch0} \\
\pi_{cl0} = \delta_{cl0} & \pi_{cl1} = \delta_{cl1} - \delta_{cl0} \\
\pi_{cc0} = \delta_{cc0} & \pi_{cc1} = \delta_{cc1} - \delta_{cc0} \\
\pi_{ck0} = \delta_{ck0} & \pi_{ck1} = \delta_{ck1} - \delta_{ck0} \\
\pi_{cq0} = \delta_{cq0} & \pi_{cq1} = \delta_{cq1} - \delta_{cq0} \\
\pi_{cn0} = \delta_{cn0} - \delta_{cq0} & \pi_{cn1} = (\delta_{cn1} - \delta_{cn0}) - (\delta_{cq1} - \delta_{cq0})
\end{array}$$

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 (2.15) 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. In total we estimate 66 short-run coefficients. The remaining 18 free parameters estimated determine the long-run parameters of interest.

7.2. Recovering the Long-Run Parameters from the Estimated Coefficients

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:

$$\pi_{ch2} = \lambda_{ch} \cdot \gamma_{hh} + \lambda_{cl} \cdot \gamma_{lh} + \lambda_{cc} \cdot \gamma_{ch} - \delta_{ch1}$$
$$\pi_{cl2} = \lambda_{ch} \cdot \gamma_{hl} + \lambda_{cl} \cdot \gamma_{ll} + \lambda_{cc} \cdot \gamma_{cl} - \delta_{cl1}$$
$$\pi_{cc2} = \lambda_{ch} \cdot \gamma_{hc} + \lambda_{cl} \cdot \gamma_{lc} + \lambda_{cc} \cdot \gamma_{cc} - \delta_{cc1}$$
$$\pi_{ck2} = \lambda_{ch} \cdot \gamma_{hk} + \lambda_{cl}.\gamma_{lk} + \lambda_{cc} \cdot \gamma_{ck} - \delta_{ck1}$$
$$\pi_{cq2} = \lambda_{ch} \cdot \gamma_{hq} + \lambda_{cl}.\gamma_{lq} + \lambda_{cc} \cdot \gamma_{cq} - \delta_{cq1}$$
$$\pi_{cn2} = \lambda_{ch} \cdot (\gamma_{hn} - \gamma_{hq}) + \lambda_{cl} \cdot (\gamma_{ln} - \gamma_{lq}) + \lambda_{cc} \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{cn1} - \delta_{cq1})$$

Factor k: Long-Run Parameters:

$$\pi_{kh2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hh} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{lh} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}).\gamma_{ch} - \delta_{kh1}$$
$$\pi_{kl2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hl} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}) \cdot \gamma_{ll} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}).\gamma_{cl} - \delta_{kl1}$$
$$\pi_{kc2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hc} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}).\gamma_{lc} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{cc} - \delta_{kc1}$$
$$\pi_{kk2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hk} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}).\gamma_{lk} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{ck} - \delta_{kk1}$$
$$\pi_{kq2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot \gamma_{hq} + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}).\gamma_{lq} + (\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot \gamma_{cq} - \delta_{kq1}$$
$$\pi_{kn2} = (\lambda_{hh} + \lambda_{lh} + \lambda_{ch}) \cdot (\gamma_{hn} - \gamma_{hq}) + (\lambda_{hl} + \lambda_{ll} + \lambda_{cl}).(\gamma_{ln} - \gamma_{lq})$$
$$+(\lambda_{hc} + \lambda_{lc} + \lambda_{cc}) \cdot (\gamma_{cn} - \gamma_{cq}) - (\delta_{kn1} - \delta_{kq1})$$

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:		
$\gamma_{kh} = \gamma_{hk}$	$\gamma_{kl} = \gamma_{lk}$	$\gamma_{kc} = \gamma_{ck}$

8. The Estimated Dynamic Factor Equations

8.1. Medium Growth Sectors

Equation for Skilled Labour:

$$\Delta S_{hst} = -\underset{(.22)}{1.34}\,\Delta S_{hst-1} - \underset{(.16)}{0.12}\,\Delta S_{lst-1} - \underset{(.29)}{0.42}\,\Delta S_{cst-1} + \underset{(.03)}{0.10}\,\Delta\ln P_{hst} - \underset{(.05)}{0.03}\,\Delta\ln P_{lst}$$
$$-\underset{(.02)}{0.02}\,\Delta\ln P_{cst} - \underset{(.01)}{0.02}\,\Delta\ln P_{kst} - \underset{(.05)}{0.05}\,\Delta\ln Q_{st} - \underset{(.03)}{0.03}\,\Delta\ln NO_{st}$$
$$+\underset{(.03)}{0.09}\,\Delta\ln P_{hst-1} - \underset{(.04)}{0.03}\,\Delta\ln P_{lst-1} + \underset{(.03)}{.002}\,\Delta\ln P_{cst-1} - \underset{(.01)}{0.02}\,\Delta\ln P_{kst-1}$$
$$-\underset{(.07)}{0.10}\,\Delta\ln Q_{st-1} - \underset{(.03)}{0.10}\,\Delta\ln NO_{st-1}$$
$$-\underset{(.37)}{1.59}\,ecm_{hst-2} - \underset{(.15)}{0.16}\,ecm_{lst-2} - \underset{(.39)}{0.40}\,ecm_{cst-2}$$

Equation for Unskilled Labour:

$$\Delta S_{lst} = -\underset{(..50)}{0.34}\,\Delta S_{hst-1} - \underset{(.33)}{0.56}\,\Delta S_{lst-1} + \underset{(.58)}{0.15}\,\Delta S_{cst-1} + \underset{(.07)}{0.06}\,\Delta\ln P_{hst} + \underset{(.08)}{0.12}\,\Delta\ln P_{lst}$$
$$+\underset{(.05)}{0.000003}\,\Delta\ln P_{cst} - \underset{(.03)}{0.004}\,\Delta\ln P_{kst} - \underset{(.13)}{0.26}\,\Delta\ln Q_{st} - \underset{(.09)}{0.26}\,\Delta\ln NO_{st}$$
$$-\underset{(.09)}{0.05}\,\Delta\ln P_{hst-1} + \underset{(.09)}{0.02}\,\Delta\ln P_{lst-1} - \underset{(.05)}{0.06}\,\Delta\ln P_{cst-1} - \underset{(.02)}{0.01}\,\Delta\ln P_{kst-1}$$
$$-\underset{(.13)}{0.02}\,\Delta\ln Q_{st-1} - \underset{(.07)}{0.14}\,\Delta\ln NO_{st-1}$$
$$+\underset{(.65)}{0.007}\,ecm_{hst-2} - \underset{(.36)}{0.79}\,ecm_{lst-2} + \underset{(.68)}{0.36}\,ecm_{cst-2}$$

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:

$$
\begin{aligned}
\Delta S_{kst} = {} & 1.41\Delta S_{hst-1} - 0.31\Delta S_{lst-1} + 0.87\Delta S_{cst-1} - \underset{(.11)}{0.20}\,\Delta\ln P_{hst} - \underset{(.14)}{0.12}\,\Delta\ln P_{lst} \\
& - \underset{(.05)}{0.02}\,\Delta\ln P_{cst} + \underset{(.03)}{0.04}\,\Delta\ln P_{kst} + \underset{(.14)}{0.30}\,\Delta\ln Q_{st} - \underset{(.10)}{0.16}\,\Delta\ln NO_{st} \\
& - \underset{(.11)}{0.09}\,\Delta\ln P_{hst-1} - \underset{(.11)}{0.09}\,\Delta\ln P_{lst-1} - \underset{(.07)}{0.04}\,\Delta\ln P_{cst-1} + \underset{(.04)}{0.05}\,\Delta\ln P_{kst-1} \\
& + \underset{(.14)}{0.37}\,\Delta\ln Q_{st-1} - \underset{(.16)}{0.008}\,\Delta\ln NO_{st-1} \\
& + 1.06ecm_{hst-2} + 0.67ecm_{lst-2} + 0.45ecm_{cst-2}
\end{aligned}
$$

8.2. Declining Sectors

Equation for Skilled Labour:

$$\Delta S_{hst} = -\underset{(.11)}{1.06}\,\Delta S_{hst-1} + \underset{(.03)}{0.12}\,\Delta S_{lst-1} + \underset{(.12)}{0.29}\,\Delta S_{cst-1} + \underset{(.01)}{0.06}\,\Delta \ln P_{hst} + \underset{(.02)}{0.001}\,\Delta \ln P_{lst}$$
$$-\underset{(.01)}{0.01}\,\Delta \ln P_{cst} - \underset{(.006)}{0.006}\,\Delta \ln P_{kst} - \underset{(.02)}{0.007}\,\Delta \ln Q_{st} - \underset{(.01)}{0.03}\,\Delta \ln NO_{st}$$
$$+\underset{(.01)}{0.02}\,\Delta \ln P_{hst-1} - \underset{(.02)}{0.03}\,\Delta \ln P_{lst-1} - \underset{(.01)}{0.03}\,\Delta \ln P_{cst-1} - \underset{(.007)}{0.0004}\,\Delta \ln P_{kst-1}$$
$$+\underset{(.02)}{0.02}\,\Delta \ln Q_{st-1} + \underset{(.01)}{0.004}\,\Delta \ln NO_{st-1}$$
$$-\underset{(.18)}{1.04}\,S_{hst-2} + \underset{(.04)}{0.21}\,S_{lst-2} - \underset{(.15)}{0.31}\,S_{cst-2}$$

Equation for Unskilled Labour:

$$\Delta S_{lst} = \underset{(.40)}{0.34}\,\Delta S_{hst-1} - \underset{(.13)}{0.80}\,\Delta S_{lst-1} + \underset{(.64)}{1.83}\,\Delta S_{cst-1} + \underset{(.06)}{0.07}\,\Delta \ln P_{hst} + \underset{(.07)}{0.37}\,\Delta \ln P_{lst}$$
$$-\underset{(.05)}{0.02}\,\Delta \ln P_{cst} - \underset{(.03)}{0.004}\,\Delta \ln P_{kst} - \underset{(.08)}{0.11}\,\Delta \ln Q_{st} - \underset{(.07)}{0.19}\,\Delta \ln NO_{st}$$
$$-\underset{(.05)}{0.02}\,\Delta \ln P_{hst-1} + \underset{(.07)}{0.06}\,\Delta \ln P_{lst-1} - \underset{(.05)}{0.07}\,\Delta \ln P_{cst-1} - \underset{(.03)}{0.02}\,\Delta \ln P_{kst-1}$$
$$-\underset{(.08)}{0.05}\,\Delta \ln Q_{st-1} + \underset{(.06)}{0.04}\,\Delta \ln NO_{st-1}$$
$$+\underset{(.52)}{0.50}\,S_{hst-2} - \underset{(.16)}{0.57}\,S_{lst-2} + \underset{(.55)}{0.64}\,S_{cst-2}$$

Equation for Clerical Labour:

$$\Delta S_{cst} = -\underset{(.07)}{0.005}\,\Delta S_{hst-1} - \underset{(.03)}{0.07}\,\Delta S_{lst-1} - \underset{(.11)}{0.64}\,\Delta S_{cst-1} + \underset{(.01)}{0.008}\,\Delta \ln P_{hst} + \underset{(.01)}{0.04}\,\Delta \ln P_{lst}$$
$$+\underset{(.008)}{0.05}\,\Delta \ln P_{cst} - \underset{(.004)}{0.0007}\,\Delta \ln P_{kst} - \underset{(.01)}{0.04}\,\Delta \ln Q_{st} - \underset{(.008)}{0.03}\,\Delta \ln NO_{st}$$
$$+\underset{(.008)}{0.0005}\,\Delta \ln P_{hst-1} + \underset{(.01)}{0.02}\,\Delta \ln P_{lst-1} + \underset{(.007)}{0.014}\,\Delta \ln P_{cst-1} - \underset{(.004)}{0.004}\,\Delta \ln P_{kst-1}$$
$$-\underset{(.01)}{0.03}\,\Delta \ln Q_{st-1} - \underset{(.008)}{0.01}\,\Delta \ln NO_{st-1}$$
$$+\underset{(.11)}{0.02}\,S_{hst-2} - \underset{(.04)}{0.08}\,S_{lst-2} - \underset{(.16)}{0.58}\,S_{cst-2}$$

Equation for Capital:

$$
\begin{aligned}
\Delta S_{kst} = & -0.72\Delta S_{hst-1} - 0.75\Delta S_{lst-1} + 1.48\Delta S_{cst-1} - \underset{(.07)}{0.09}\,\Delta\ln P_{hst} - \underset{(.09)}{0.33}\,\Delta\ln P_{lst} \\
& - \underset{(.05)}{0.11}\,\Delta\ln P_{cst} + \underset{(.03)}{0.004}\,\Delta\ln P_{kst} + \underset{(.06)}{0.09}\,\Delta\ln Q_{st} + \underset{(.08)}{0.15}\,\Delta\ln NO_{st} \\
& - \underset{(.06)}{0.05}\,\Delta\ln P_{hst-1} - \underset{(.10)}{0.29}\,\Delta\ln P_{lst-1} - \underset{(.05)}{0.08}\,\Delta\ln P_{cst-1} + \underset{(.03)}{0.02}\,\Delta\ln P_{kst-1} \\
& + \underset{(.08)}{0.16}\,\Delta\ln Q_{st-1} + \underset{(.06)}{0.15}\,\Delta\ln NO_{st-1} \\
& + 0.53 S_{hst-2} + 0.45 S_{lst-2} + 0.25 S_{cst-2}
\end{aligned}
$$

8.3. High Growth Sectors

Equation for Skilled Labour:

$$\Delta S_{hst} = -\underset{(.10)}{0.72}\,\Delta S_{hst-1} + \underset{(.05)}{0.21}\,\Delta S_{lst-1} + \underset{(.23)}{0.08}\,\Delta S_{cst-1} + \underset{(.01)}{0.04}\,\Delta \ln P_{hst} + \underset{(.01)}{0.03}\,\Delta \ln P_{lst}$$
$$-\underset{(.003)}{0.005}\,\Delta \ln P_{cst} - \underset{(.006)}{0.02}\,\Delta \ln P_{kst} - \underset{(.01)}{0.006}\,\Delta \ln Q_{st} - \underset{(.01)}{0.04}\,\Delta \ln NO_{st}$$
$$+\underset{(.01)}{0.03}\,\Delta \ln P_{hst-1} - \underset{(.018)}{0.024}\,\Delta \ln P_{lst-1} - \underset{(.006)}{0.01}\,\Delta \ln P_{cst-1} - \underset{(.008)}{0.02}\,\Delta \ln P_{kst-1}$$
$$+\underset{(.01)}{0.0005}\,\Delta \ln Q_{st-1} - \underset{(.01)}{0.01}\,\Delta \ln NO_{st-1} - \underset{(.09)}{0.75}\,ecm_{hst-2} + \underset{(.05)}{0.14}\,ecm_{lst-2} + \underset{(.25)}{0.20}\,ecm_{cst-2}$$
$$+\underset{(.0003)}{.0003}\,D_{h82} - \underset{(.0003)}{.0002}\,D_{h83} - \underset{(.0002)}{.0002}\,D_{h84} - \underset{(.0004)}{.0006}\,D_{h85}$$
$$-\underset{(.0002)}{.0001}\,D_{h86} + \underset{(.0003)}{.0004}\,D_{h87} + \underset{(.0001)}{.00003}\,D_{h88} + \underset{(.0002)}{.00002}\,D_{h89} - \underset{(.0004)}{.0004}\,D_{h90}$$

Coefficients on time are very small because they relate to weighted data -should multiply by 11=no
of sectors to get a true picture of magnitude. 85 strong

Equation for Unskilled Labour:

$$\Delta S_{lst} = \underset{(.21)}{1.05}\,\Delta S_{hst-1} + \underset{(.12)}{0.32}\,\Delta S_{lst-1} + \underset{(.51)}{1.78}\,\Delta S_{cst-1} + \underset{(.06)}{0.03}\,\Delta \ln P_{hst} + \underset{(.07)}{0.19}\,\Delta \ln P_{lst}$$
$$+\underset{(.01)}{0.002}\,\Delta \ln P_{cst} + \underset{(.03)}{0.06}\,\Delta \ln P_{kst} - \underset{(.07)}{0.05}\,\Delta \ln Q_{st} - \underset{(.05)}{0.11}\,\Delta \ln NO_{st}$$
$$+\underset{(.06)}{0.02}\,\Delta \ln P_{hst-1} - \underset{(.07)}{0.08}\,\Delta \ln P_{lst-1} - \underset{(.02)}{0.05}\,\Delta \ln P_{cst-1} + \underset{(.03)}{0.03}\,\Delta \ln P_{kst-1}$$
$$+\underset{(.04)}{0.07}\,\Delta \ln Q_{st-1} + \underset{(.04)}{0.09}\,\Delta \ln NO_{st-1} + \underset{(.26)}{1.39}\,ecm_{hst-2} + \underset{(.14)}{0.33}\,ecm_{lst-2} + \underset{(.54)}{1.46}\,ecm_{cst-2}$$
$$+\underset{(.001)}{.0005}\,D_{h82} - \underset{(.001)}{.0013}\,D_{h83} - \underset{(.001)}{.0015}\,D_{h84} - \underset{(.001)}{.0037}\,D_{h85}$$
$$+\underset{(.001)}{.0011}\,D_{h86} + \underset{(.001)}{.0004}\,D_{h87} - \underset{(.001)}{.00002}\,D_{h88} - \underset{(.001)}{0.0002}\,D_{h89} - \underset{(.001)}{.0024}\,D_{h90}$$

Note that the adjustment parameters are all overshooting, but can quote from Hendry -

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:

$$\Delta S_{kst} = -0.58\Delta S_{hst-1} - 0.79\Delta S_{lst-1} - 0.57\Delta S_{cst-1} - \underset{(.05)}{0.05}\,\Delta \ln P_{hst} - \underset{(.05)}{0.15}\,\Delta \ln P_{lst}$$
$$- \underset{(.01)}{0.02}\,\Delta \ln P_{cst} + \underset{(.02)}{0.04}\,\Delta \ln P_{kst} + \underset{(.05)}{0.03}\,\Delta \ln Q_{st} + \underset{(.04)}{0.12}\,\Delta \ln NO_{st}$$
$$- \underset{(.05)}{0.09}\,\Delta \ln P_{hst-1} + \underset{(.07)}{0.05}\,\Delta \ln P_{lst-1} + \underset{(.01)}{0.02}\,\Delta \ln P_{cst-1} + \underset{(.03)}{0.06}\,\Delta \ln P_{kst-1}$$
$$- \underset{(.03)}{0.04}\,\Delta \ln Q_{st-1} + \underset{(.04)}{0.006}\,\Delta \ln NO_{st-1} - 0.98ecm_{hst-2} - 0.72ecm_{lst-2} - 0.17ecm_{cst-2}$$
$$- \underset{(.001)}{.001}\,D_{h82} + \underset{(.001)}{.001}\,D_{h83} + \underset{(.0008)}{.0001}\,D_{h84} + \underset{(.0013)}{.0024}\,D_{h85}$$
$$+ \underset{(.001)}{.00006}\,D_{h86} - \underset{(.0009)}{.0013}\,D_{h87} - \underset{(.0006)}{.00006}\,D_{h88} - \underset{(.001)}{.0003}\,D_{h89} + \underset{(.0012)}{.0017}\,D_{h90}$$

The adjustment coefficients for the k equation are strange, almost a one for one adjustment between h and k, this may reflect distortions in the data.

9. Tables and Graphs

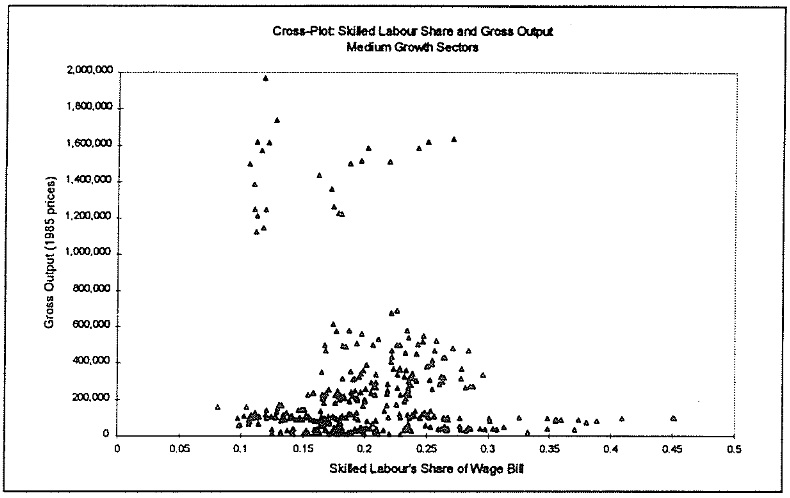

Figure 9.1: Cross-Plot of Skilled Labour Share of Wage Bill and Gross Output for Medium Growth Sectors: Unweighted Data

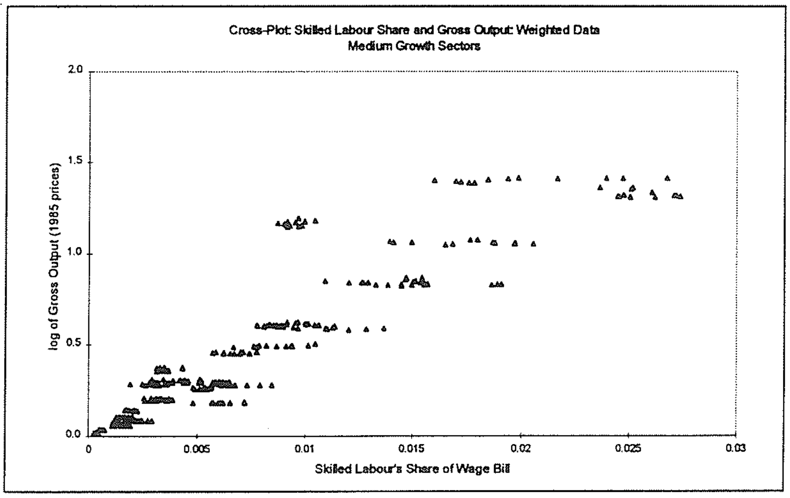

Figure 9.2: Cross-Plot of Skilled Labour Share of Wage Bill and Gross Output for Medium Growth Sectors: Weighted Data

References

[1] Anderson, R.G. and J.G. Thursby (1986) "Confidence Intervals for Elasticity Estimators in Translog Models", *Review of Economics and Statistics*, Vol. LXVIII, No. 4, 647-656.

[2] Arrelano, M. and S. Bond (1988) "Dynamic Panel Data Estimation Using DPD - A Guide for Users", Institute for Fiscal Studies, Working Paper 88/15, London.

[3] Arrelano, M. and S. Bond (1991) "Some Tests of Specification for Panel Data: Monte Carlo Evidence and An Application to Employment Equations", *Review of Economic Studies*, Vol. 58, pp. 277-297.

[4] Anderson, G. and R. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equations Systems", *Econometrica*, Vol 50(6) November.

[5] Anderson, G. and R. Blundell (1983) "Testing Restrictions in a Flexible Dynamic Demand System: An Application to Consumers' Expenditure in Canada", *Review of Economic Studies*, Vol L (3) July.

[6] Anderson, G. and R. Blundell (1984) "Consumer Non-Durables in the U.K.: A Dynamic Demand System", *Economic Journal Supplement*, Vol. 94.

[7] Balestra, P. (1992) "Introduction to Linear Models for Panel Data" Chapter 2 in Matyas, L. and P. Sevestre (1992) *The Econometrics of Panel Data: Handbook of Theory and Applications*, Kluwer Academic Publishers.

[8] Berman, Bound and Griliches, (1994) "Changes in the Demand for Skilled Labor Within US Manufacturing: Evidence from the Annual Survey of Manufactures" *Quarterly Journal of Economics*, May.

[9] Berndt, E. R. and D. O. Wood (1979) "Engineering and Econometric Interpretations of Energy-Capital Complementarity", *American Economic Review*, Vol 69 (3).

[10] Blackorby, C. and R. Russell, (1989), "Will the Real Elasticity of Substitution Please Stand Up?" , *American Economic Review* , pp.882-888.

[11] Boyle, G.E. and P.D. Sloane, (1982) "The Demand for Labour and Capital Inputs in Irish Manufacturing Industries, 1953-1973", *The Economic and Social Review*, 13,3,153-170.

[12] Bradley, J., J. Fitz Gerald and I. Kearney, (1993) "Modelling Supply in an Open Economy using a Restricted Cost Function", *Economic Modelling*, January, 11-21.

[13] Bradley, J., Fitz gerald, P. Honohan and I. Kearney (1997) "Interpreting the Recent Irish Growth Experience", in Duffy, D., J. Fitz Gerald, I. Kearney and F. Shortall (1997) *Medium-Term Review: 1997-2003*, Economic and Social Research Institute, Dublin.

[14] Bresson, G., Kramarz, F. and Sevestre, P., (1992) "Heterogenous Labor and the Dynamics of Aggregate Labor Demand: Some Estimations Using Panel Data", *Empirical Economics*, 17:153-168

[15] Broer, D.P. and G. van Leeuwen, (1994) "Investment Behavour of Dutch Industrial Firms: A Panel Data Study", *European Economic Review*, October, 38, 8, 1555-1580

[16] Davis, G. C. and R. Shumway (1996) "To Tell the Truth About Interpreting the Morishima Elasticity of Substitution", *Canadian Journal of Agricultural Economics*, 44, 173-182.

[17] Denny, K. and J. Van Reenen (1993) "Empirical Models of Firm-Level Profitability Based on UK Panel Data", UCD Working Paper 93/16.

[18] Echevarria, C. (1997) "Changes in Sectoral Composition Associated with Economic Growth", *International Economic Review*, Vol 38, No.2, May.

[19] Friesen, J. (1992) "Testing Dynamic Specification of Factor Demand Equations for US Manufacturing", *Review of Economics and Statistics* Vol LXXIV (2), May.

[20] Garcia Cervero (1997) "Growth, Technology and Inequality: An Industrial Approach", EUI Working Paper ECO 97/26.

[21] Greenhalgh, C., G. Mavrotas and R. Wilson (1990) "Panel Data Methods vs Seemingly Unrelated Regression Estimates - A Comparison Using Export Volumes (And Prices)", mimeo, University of Oxford.

[22] Hamermesh, D., (1993) *Labor Demand*, Princeton University Press.

[23] Haskel, J., (1996a) "The Decline in Unskilled Employment in UK Manufacturing", CEPR Discussion Paper No. 1356, February.

[24] Haskel, J., B. Kersley and C. Martin (1997) "Labour Market Flexibility and Employment Adjustment: Micro Evidence from UK Establishments", *Oxford Economic Papers* 49, 362-379.

[25] Holly, S. and P. Smith (1989) "Interrelated Factor Demands for Manufacturing: A Dynamic Translog Cost Function Approach", *European Economic Review*, 33, 1, January.

[26] Holtz-Eakin, D., W. Newey and H. Rosen (1988) "Estimating Vector Autoregressions With Panel Data",*Econometrica*, Vol. 56, No. 6, pp 1371-1395.

[27] Hsaio, C. (1985) "Benefits and Limitations of Panel Data", *Econometric Review*, 4, pp121-174.

[28] Jaramillo, F., F. Schiantarelli and A. Sembenelli (1993) "Are Adjustment Costs for Labor Asymmetric? An Econometric Test on Panel Data for Italy", *Review of Economics and Statistics* Vol. LXXV (4), November.

[29] Jimenez, M. and D. Marchetti (1995) "Thick-Market Externalities in US Manufacturing: A Dynamic Study with Panel Data", European University Institute, Florence, Working Paper No 95/14.

[30] Kearney, I. (1997) "Shifts in the Demand for Skilled Labour in the Irish Manufacturing Sector: 1979-1990", Economic and Social Research Working Paper 83, April.

[31] Krishnakumar, J. (1992) "Simulataneous Equations" Chapter 7 in Matyas, L. and P. Sevestre (1992) *The Econometrics of Panel Data: Handbook of Theory and Applications*, Kluwer Academic Publishers.

[32] Lindquist, K-G, (1995) "The Existence of Factor Substitution in the Primary Aluminium Industry: A Multivariate Error-Correction Approach Using Norwegian Panel Data", *Empirical Economics*, 20, 361-383.

[33] Matyas, L. and P. Sevestre (1992) *The Econometrics of Panel Data: Handbook of Theory and Applications*, Kluwer Academic Publishers.

[34] Morrision, C. (1997) "Assessing the Productivity of Information Technology Equipment in U.S. Manufacturing Industries". *Review of Economics and Statistics*, LXXIX, 3, August.

[35] Nickell, S.J.(1986) "Dynamic Models of Labour Demand" in *Handbook of Labour Economics*, Ashenfelter and Layard, (eds.), Vol. 1, Ch. 9

[36] Nickell, S. and B. Bell, (1996) "Changes in the Distribution of Wages and Unemployment in OECD Countries", *American Economic Review: Papers and Proceedings*, Vo. 86, No. ", pp. 302-308.

[37] Nickell, S. and B. Bell, (1995) "The Collapse in Demand for the Unskilled and Unemployment Across the OECD", *Oxford Review of Economic Policy*, Vol. 11, No. 1, Spring, pp. 40-62.

[38] Romer, P., (1994) "The Origins of Endogenous Growth", *Journal of Economic Perspectives*, p3-22.

[39] Sevestre, P. and A. Trognon, (1992) "Linear Dynamic Models", Chapter 6 in Matyas, L. and P. Sevestre (1992) *The Econometrics of Panel Data: Handbook of Theory and Applications*, Kluwer Academic Publishers.

[40] Shadman-Mehta, F. and H. Sneesens, (1995) "Skill Demand and Factor Substitution", CEPR Discussion Papers No 1279, November.

[41] Stewart, J., (1989) "Transfer Pricing: Some Empirical Evidence from Ireland", *Journal of Economic Studies*, 16, 3, pp. 40-56.

[42] Urga, G. (1992) "The Econometrics of Panel Data: A Selective Introduction" *Ricerche Economiche*, XLVI, 3-4, pp 379-396.

[43] Wansbeek, T. and P. Bekker, (1996) "On IV, GMM and ML in a dynamic panel data model", Economic Letters, 51, pp 145-152.