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The Demand for Labour and Capital Inputs in Irish Manufacturing Industries, 1953-1973

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Précis: Factor-demand functions are estimated, for two types of labour (wage-earners and salaried-workers) and capital, for 40 manufacturing industries. Two sets of elasticity results are reported. The first set implicitly assumes Hicks-neutral technical change. The second set by including a time trend as an additional explanatory variable, relaxes this constraint. The magnitudes of the elasticity estimates are greater for the specification which includes the time trend. In the latter case, for those estimates which fulfil certain a priori requirements, the average own-elasticity of demand with respect to the cost of wage-earners was estimated to be -0.28. The elasticity of substitution between wage-earners and capital was generally less than one and greater than the corresponding elasticity between salaried-workers and capital.

I INTRODUCTION

The purpose of this paper is to estimate the elasticity of demand for labour and capital with respect to the costs of these inputs and to derive an estimate of the elasticity of substitution between labour and capital. While the relationship between wages and employment has been the subject of much research in Ireland (see, for example, Bradley and Cassidy (1979), Geary and McDonnell (1980), Higgins (1981)), only the papers by Geary and McDonnell and Higgins are comparable to the present exercise since these authors use a similar methodology. This paper, however, examines disaggregated data for manufacturing industries, whereas Geary and McDonnell

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looked at manufacturing industries in the aggregate and Higgins was concerned with selected sectors of the food industry. In addition, the latter works include materials as an additional input in the factor-demand functions whereas we are only concerned with labour and capital. The following are some specific features of our analysis:

(i) we examine a highly disaggregated set of manufacturing industries (40 sectors);
(ii) the parameters of the demand functions are derived from an explicit unit cost function facing each industry, with constant returns to scale assumed;
(iii) we specify a flexible mathematical form for the cost function – the translog – which enables us to estimate pairwise elasticities of substitution without imposing, a priori, unappealing restrictive assumptions;
(iv) two types of labour are distinguished in our analysis: wage earners and salaried workers. This enables us to examine the conditions underlying consistent aggregation of labour types, and may also provide clues to the phenomenon of non-declining pay differentials, despite undoubted increases in the supply of non-production workers.

The remainder of this paper is organised as follows. Section II discusses the methodology adopted and the data used. Specifically, we briefly discuss the theoretical background which enables us to estimate the parameters of the factor-demand-functions from the cost function facing each industry. We also introduce the translog function as one of a class of flexible functional forms which is less restrictive than the more commonly-used mathematical forms such as the Cobb-Douglas and CES. Section III presents the empirical findings. We present two sets of results in terms of elasticities. The second set of results is distinguished from the first by the inclusion of a time-trend term which enables us to test for the bias of technical change. Section IV discusses some implications of the results. We were particularly interested in the magnitude of the elasticity of demand for labour. Finally, Section V summarises the findings of the paper.

II METHODOLOGY AND DATA

In this paper we estimate the parameters of the cost function of 40 sectors of Irish manufacturing industry. As is well known, (see, for example, Varian (1978)), under mild restrictions a concave cost function $c(p, y)$ – which states the minimum cost of production for given input prices $p = (p_1, \ldots, p_n)$ and output level y – completely summarises production possibilities for a single output firm. Furthermore, the partial derivative of the cost function with respect to price gives the factor demands x:

$$\partial c/\partial p = x(p, y)$$

or, assuming constant returns to scale:

$$\partial c/\partial p = \tilde{x}(p)y$$

where $\tilde{x}$ are the factor requirements per unit of output.

We assume that c is of the translog form. The translog is one of the class of "flexible functional forms" which provide a second-order approximation to an arbitrary functional form. We can write the translog unit cost function as:

$$\ln(c/y) = a_0 + \sum_i a_i \ln p_i + \tfrac{1}{2}\sum_i \sum_j b_{ij} \ln p_i \ln p_j \qquad (1)$$

and

$$\frac{\partial \ln(c/y)}{\partial \ln p_i} = \frac{\partial (c/y)}{\partial p_i} \cdot \frac{p_i}{(c/y)} = \frac{\tilde{x}_i p_i}{c} = S_i = a_i + \sum_j b_{ij} \ln p_j . \qquad (2)$$

For this function to be well behaved we require:

(i) $\sum_{ij} b_{ij} = 0$; (ii) $b_{ij} = b_{ji}$ and (iii) $\sum_i S_i = \sum_i a_i = 1$.

Concavity is difficult to impose in the estimation but can be tested for by the usual determinantial tests on the hessian of (1).

The *raison d'être* of using flexible functional forms is their ability to encompass a wide range of substitution possibilities. As is well known, the CES function is less restrictive than the Cobb-Douglas, but, since it restricts all pairwise elasticities of substitution to be positive it is too restrictive when the number of inputs exceeds two. In the course of our empirical analysis, we experiment with a two-input specification of a value-added production function. We perform CES tests as follows:

$$\ln(K/L) = \alpha + \sigma \ln(w^*/r) + u \qquad (3)$$

where:

- K/L : capital labour ratio;
- w^* : per capita cost of both wage and salaried workers per working week;
- r : cost of capital services, which we proxy as the value of the remainder of net output divided by the stock of capital;
- u : error term;
- σ : elasticity of substitution.

We can easily test whether σ is statistically different from one (Cobb-Douglas). It should be noted that in the two-input case the elasticity of substitution derived from (2) should be approximately equal to σ in (3).

The conditional factor-demand functions in (2) subject to the constraints specified are estimated using both a stacked OLS and an iterative Zellner procedure.

The adding-up condition is automatically satisfied by the data. We arbitrarily delete the equation for capital and derive its parameters from the homogeneity constraint. In the OLS case, symmetry is imposed by stacking the equations. The system to be estimated is as follows:

$$\begin{bmatrix} S_w \\ S_s \end{bmatrix} = a_1 \begin{bmatrix} 1 \\ 0 \end{bmatrix} + a_2 \begin{bmatrix} 0 \\ 1 \end{bmatrix} + b_1 \begin{bmatrix} \ln(w/s) \\ \ln(s/w) \end{bmatrix} + b_2 \begin{bmatrix} \ln(w/r) \\ 0 \end{bmatrix} + b_3 \begin{bmatrix} 0 \\ \ln(s/r) \end{bmatrix} + \begin{bmatrix} U_w \\ U_s \end{bmatrix} \tag{4}$$

where:

S_w : the share of wage earners in total costs;
S_s : the share of salaried workers in total costs;
w : per capita cost of wage earners per working week;
s : per capita cost of salaried workers per working week;
U_w, U_s : error terms on the assumption of errors in optimising behaviour.

We define:

$$b_{ww} = \frac{\delta S_w}{\delta \ln w} = b_1 + b_2$$

$$b_{ws} = \frac{\delta S_w}{\delta \ln s} = -b_1$$

$$b_{wk} = \frac{\delta S_w}{\delta \ln r} = -b_2$$

$$b_{ss} = \frac{\delta S_s}{\delta \ln s} = b_1 + b_3$$

$$b_{sw} = \frac{\delta S_s}{\delta \ln w} = -b_1$$

$$b_{sk} = \frac{\delta S_s}{\delta \ln r} = -b_3$$

$$b_{rr} = -(-b_2 - b_3)$$

$$b_{rs} = -b_3$$

$$b_{rw} = -b_2.$$

We also use a specification involving aggregate labour (wage earners and salaried workers combined):

$$S_{w*} = a + b^* \ln(w^*/r) \qquad (5)$$

where:

S_{w*} = wage and salaried-workers' share in total costs.

The two-input specification in (5) is estimated by OLS. If the variance-covariance matrix of the residuals in (4) is diagonal, OLS will be BLUE. The imposition of symmetry, however, renders the restriction of diagonality untenable and, thus, may render OLS inefficient; also the OLS estimate of the variance-covariance matrix may understate the true variance-covariance matrix. The appropriate estimator in these circumstances, assuming zero autocorrelation in the disturbances, is an iterative Zellner estimator. As is well known, this estimator is invariant to the choice of equation deleted, (see, for example, Berndt and Christensen (1973)).

The specification in Equation (4) implicitly assumes that technical change is Hicks-neutral. This is a restrictive assumption but it can be relaxed by adding a trend as an additional regressor to the share equations. The coefficient on the trend term will reflect the bias of technical change. For convenience of exposition, we refer to the estimates incorporating the Hicks-neutral technical change assumption as "constrained" and to those including the trend term as "unconstrained".

The production function is specified in terms of value-added. We consider three inputs: gross capital stock, wage earners and salaried workers – these latter categories broadly correspond to production and non-production workers. As an alternative specification we form an aggregate labour category by combining the two types of labour. Our specification could be criticised for excluding intermediate inputs especially energy-related inputs. However, excluding these inputs is unlikely to lead to serious specification errors since our sample period precedes the dramatic change in relative input prices following the oil price increases of 1973. Our units of observation are annual data on the manufacturing sectors of Irish industry as reported in the Census of Industrial Production (CIP). We have 21 observations for the period 1953-1973. The time period was dictated by two practical considerations: first 1973 is the latest year for which comprehensive capital stock data are available by industry, and secondly, in the same year the CIP classification was discontinued and replaced by the NACF[1] classification, with which there is unfortunately little correspondence. All of the data, except for the capital stocks, were extracted for each industry from various issues of the CIP reports of the Irish Statistical Bulletin. The capital-stock data were taken from Vaughan (1980).

In the case of expenditure on capital services the choice of remainder of net output might not appear appropriate; it would have been preferable to calculate cost of capital series for each industrial sector along the lines suggested by Geary and McDonnell (1979). However, the paucity of data available to do this exercise did not make it feasible. A deficiency in the use of the remainder of net output is that it includes a profit element which is cyclical and hence might lead to econometric difficulties. Our analysis initially considered 45 manufacturing industries; however, because of data problems we excluded distilling, shipbuilding, railways, sugar and cocoa, and estimated factor-demand functions for 40 industries.

III RESULTS

In this section we present the empirical findings: commentary is reserved to summarising the more interesting results, while we leave to the next section a discussion of the implications of the findings. While the only results which we report are the elasticity estimates derived from Equation (4), we also comment briefly on the parameter estimates of the translog functions[2].

Constrained Estimates

Our initial specification imposes the restriction of Hicks-neutral technical change. A number of parameters were sensitive to the estimation method. This was most notable with those parameters which were estimated imprecisely with OLS. About half of the parameters estimated with the Zellner estimator were rendered significant whereas these same parameters as estimated with OLS were non-significant.

The R^2s (computed as the ratio of one minus the residual sum of squares to the total sum of squares) were fairly low. In only 12 out of the 40 industries examined did the R^2s exceed 0.70; in many instances the R^2s statistics were below 0.10 and even some were negative. However, the results were sensitive to the specification of technical change.

1. NACF – Nomanclature Generale des Activities Economiques dans les Communites Europeannes. An account of the new classification is given in the June issue of the *Irish Statistical Bulletin*, 1979.
2. Details of the parameter estimates are available upon request.

Table 1: *Measures of factor substitution and own factor-demand elasticities in Irish manufacturing industries (Constrained estimates)*

Industry	*Elasticities of substitution* (σ_{ij})			*Ordinary demand elasticities* (η_{ii})		
	σ_{ws}	σ_{wr}	σ_{sr}	η_{ww}	η_{ss}	η_{rr}
I Food						
Bacon	−0.7409	0.7000	0.8220	−0.2424	−0.0941	−0.3817
	(0.244)	(0.094)	(0.137)	(0.040)	(0.106)n.s.	(0.052)
Slaughtering	−0.8328	0.5531	0.6282	−0.2795	−0.0912	−0.2323
	(1.003)n.s.	(0.100)	(0.114)	(0.086)	(0.363)	(0.039)
Butter, cheese, etc.*	1.2196	0.5264	0.6981	−0.4680	−0.7542	−0.2664
	(0.326)	(0.144)	(0.246)	(0.052)	(0.094)	(0.079)
Canning of fruit, etc.*	−0.2817	0.5748	0.5568	−0.2256	− .1647	−0.2984
	(0.249)n.s.	(0.053)	(0.087)	(0.037)	(0.112)n.s.	(0.025)
Grain milling and animal feedstuffs *	−0.0050	0.1280	0.3710	−0.6147	−0.7655	−0.4059
	(0.280) n.s.	(0.150)n.s.	(0.099)	(0.033)	(0.087)	(0.047)
Bread, etc.*	0.4850	0.9980	0.9870	−0.4763	−0.6449	−0.5754
	(0.316)n.s.	(0.010)	(0.011)	(0.034)	(0.148)	(0.005)
Margarine	2.2500	0.4080	0.1469	−0.6813	−0.4044	−0.0810
	(1.62)n.s.	(0.151)	(0.114)n.s.	(0.304)	(0.230)	(0.027)
Miscellaneous food preparation	0.8983	0.5435	0.5897	−0.4366	−0.5902	−0.2532
	(4.76)n.s.	(0.123)	(0.141)	(0.084)	(0.168)	(0.029)
II Drink and Tobacco						
Malting	−0.3598	1.2593	0.6818	−0.6244	−0.2324	−0.5267
	(0.244)n.s.	(0.159)	(0.066)	(0.079)	(0.104)	(0.057)
Brewing*	2.8460	0.6086	0.4424	0.7079	−0.9736	−0.2317
	(0.494)	(0.049)	(0.082)	(0.044)	(0.162)	(0.014)
Aerated and mineral waters*	0.3753	0.6670	0.3141	−0.4385	−0.2913	−0.2314
	(0.624)n.s.	(0.567)n.s.	(0.372)n.s.	(0.262)	(0.078)	(0.208)n.s.
Tobacco	−1.5160	1.1538	0.5304	−0.5122	−0.0542	−0.3049
	(0.662)	(0.144)	(0.107)	(0.099)	(0.165)n.s.	(0.038)
III Textiles						
Woollen and worsted	1.0530	0.9590	0.8969	−0.5461	−0.8838	−0.5032
	(0.250)	(0.136)	(0.187)	(0.059)	(0.154)	(0.068)
Linen and cotton spinning	−0.1563	0.8474	0.2459	−0.3655	−0.0387	−0.4113
	(0.353)	(0.039)	(0.120)	(0.028)	(0.215)n.s.	(0.016)
Jute, canvas, rayon, etc.	0.0200	1.088	0.4881	−0.5434	−0.2518	−0.4820
	(0.461)n.s.	(0.126)	(0.192)	(0.063)	(0.260)n.s.	(0.058)
Hosiery	−1.075	1.3539	−0.5022	−0.5318	0.6677	−0.4761
	(0.445)	(1.163)n.s.	(0.253)	(0.111)	(0.201)	(0.048)
Made-up textiles*	1.3824	0.4667	0.1840	−0.4287	−0.6840	−0.1994
	(0.203)	(0.178)	(0.160)n.s.	(0.087)	(0.053)	(0.077)
IV Clothing and Footwear						
Clothing (men's and boys')*	0.515	0.7965	0.3629	−0.3127	−0.4082	−0.4930
	(0.156)n.s.	(0.210)	(0.138)	(0.064)	(0.106)	(0.128)
Clothing (shirt making)	0.1221	0.4329	0.8531	−0.1834	−0.3974	−0.3016
	(0.226)n.s.	(0.219)	(0.236)	(0.075)	(0.094)	(0.128)
Clothing (women's and girls)*	−0.6406	1.5379	1.1341	−0.5534	−0.1659	−0.8575
	(0.263)	(0.141)	(0.140)	(0.056)	(0.131)n.s.	(0.080)
Clothing (misc. apparel)	−0.1556	0.8045	0.1681	−0.2470	0.0146	−0.4066
	(0.225)n.s.	(0.087)	(0.107)n.s.	(0.010)	(0.129)n.s.	(0.044)
Boots and shoes	−0.2408	1.2731	0.1287	−0.4608	0.1751	−0.6549
	(0.279)n.s.	(0.186)	(0.110)n.s.	(0.077)	(0.177)n.s.	(0.095)
V Wood and furniture						
Wood and cork	−0.2923	0.6355	0.2215	−0.2249	0.0473	−0.3263
	(0.284)n.s.	(0.436)	(0.287)n.s.	(1.55)n.s.	(0.084)n.s.	(0.240)n.s.
Furniture and fixtures*	0.2693	1.2129	0.5623	−0.4486	−0.3391	−0.7204
	(0.497)n.s.	(0.119)	(0.126)	(0.070)	(0.277)n.s.	(0.067)
VI Paper and Printing						
Paper, etc.*	1.369	1.049	−0.0102	−0.6652	−0.5434	−0.4191
	(0.310)	(0.077)	(0.055)n.s.	(0.047)	(0.142)	(0.007)
Printing*	0.2830	1.5577	0.4426	−0.6765	−0.2900	−0.7150
	(0.324)n.s.	(0.356)	(0.138)	(0.144)	(0.140)	(0.158)
VII Chemicals						
Fertiliser*	1.0317	1.4331	0.6139	−0.9506	−0.6627	−0.5093
	(0.633)	(0.197)	(0.153)	(0.116)	(0.263)	(0.65)n.s.
Oils and paints	0.7290	0.7620	0.8596	−0.5797	−0.6801	−0.3258
	(0.448)n.s.	(0.290)	(0.126)	(0.164)	(0.109)	(0.079)
Chemicals*	0.5913	0.3199	0.3196	−0.3055	−0.3186	−0.1018
	(0.556)n.s.	(0.189)n.s.	(0.149)	(0.100)	(0.088)	(0.55)n.s.
Soaps, etc.*	2.658	0.2400	−0.1769	−0.6592	−0.7438	−0.0387
	(0.879)	(0.172)n.s.	(0.213)n.s.	(0.212)	(0.274)	(0.037)n.s.
VIII Structural clay and cement						
Glass, etc.*	−0.2941	0.7223	0.7834	−0.2442	−0.1377	−0.4567
	(0.245)n.s.	(0.175)	(0.116)	(0.071)	(0.152)n.s.	(0.088)
Clay products/cement*	2.5049	1.0899	0.5165	−0.8534	−1.1252	−0.4023
	(0.319)	(0.114)	(0.119)	(0.061)	(0.105)	(0.093)
IX Metals and engineering						
Metal Trades*	1.0222	1.062	1.0332	−0.5821	−0.9157	−0.6157
	(0.322)	(0.095)	(0.129)	(0.046)	(0.161)	(0.058)
Machinery (non-electrical)	0.1700	0.1124	0.3769	−0.0237	−0.0820	−0.1017
	(0.427)n.s.	(0.145)n.s.	(0.122)	(0.081)n.s.	(0.204)n.s.	(0.064)n.s.
Machinery (electrical)	0.6294	0.2838	0.0669	−0.2242	−0.1962	−0.096
	(0.329)	(0.178)n.s.	(0.078)n.s.	(0.099)	(0.120)n.s.	(0.065)n.s.
Mechanically propelled vehicles	0.7676	0.3130	0.1930	−0.2043	−0.4612	−0.1780
	(0.223)	(0.082)	(0.072)	(0.038)	(0.112)	(0.044)
Assembly of vehicles other than mechanically propelled vehicles	−0.4144	0.5718	−0.5835	−0.0182	0.3726	−0.2996
	(0.179)	(0.127)	(0.290)	(0.039)n.s.	(0.117)	(0.054)
X Other Manufacturing						
Fellmongery	0.1078	1.1664	0.3406	−0.5647	−0.2100	−0.5436
	(0.280)	(0.218)	(0.130)	(0.102)	(0.124)n.s.	(0.103)
Leather	0.8702	0.5168	−0.1268	−0.3302	−0.3428	−0.2173
	(0.357)	(0.075)	(0.126)n.s.	(0.053)	(0.162)	(0.022)n.s.
Miscellaneous manufacturing industry*	−0.1528	1.3102	1.1911	−0.6842	−0.6013	−0.6881
	(0.469)	(0.551)	(0.264)	(0.213)	(0.141)	(0.203)

Notes:

Notes:

(i) Asympototic standard errors in parentheses. These are calculated as follows: SE (σ_{ij}) = SE (b_{ij})/$S_i S_j$; SE (n_{ii}) = SE (b_{ii})/S_i.

(ii) An * denotes that concavity is not rejected as a maintained hypothesis for this industry.

(iii) Key: w = wages; s = salaries; r = cost of capital services.

(iv) n.s. denotes not significantly different from zero at the 95 per cent confidence level.

Table 2: *Measures of factor substitution and own factor-demand elasticities in Irish manufacturing industries (Unconstrained estimates)*

Industry	*Elasticities of substitution* (σ_{ij})			*Own demand elasticities* (η_{ii})		
	σ_{ws}	σ_{wr}	σ_{sr}	η_{ww}	η_{ss}	η_{rr}
I Food						
Bacon	0.2910	-0.0848	-0.2205	0.0047	-0.0118	0.0611
	(0.325)n.s.	(0.115)	(0.188)n.s.	(0.077)n.s.	(0.114)n.s.	(0.065)n.s.
Slaughtering	0.3864	0.1608	0.0170	-0.1236	-0.1397	-0.0552
	(0.842)n.s.	(0.151)	(0.137)n.s.	(0.104)n.s.	(0.283)n.s.	(0.054)n.s.
Butter, cheese, etc.*	1.8652	0.1444	0.0117	-0.5803	-0.5807	-0.0462
	(0.217)	(0.060)n.s.	(0.049)n.s.	(0.046)	(0.060)	(0.024)
Canning of fruit, etc.*	0.0740	0.5665	0.2228	-0.2819	-0.1323	-0.2389
	(0.250)n.s.	(0.130)n.s.	(0.161)n.s.	(0.056)	(0.095)n.s.	(0.063)
Grain milling and animal	1.1582	0.1222	0.0071	-0.2305	-0.3664	-0.0393
feedstuffs*	(0.610)	(0.135)	(0.091)n.s.	(0.112)	(0.191)n.s.	(0.046)n.s.
Bread, etc.*	0.4199	0.9889	0.9759	-0.4638	-0.6097	-0.5691
	(0.336)n.s.	(0.004)n.s.	(0.022)	(0.036)	(0.157)	(0.002)
Margarine*	0.0242	0.4433	0.2171	-0.3087	-0.1523	-0.0986
	(0.997)n.s.	(0.141)n.s.	(0.049)	(0.215)n.s.	(0.135)n.s.	(0.017)
Miscellaneous food preparation*	0.6625	0.1170	0.3716	-0.1668	-0.4007	-0.0925
	(0.411)	(0.098)n.s.	(0.200)n.s.	(0.064)	(0.135)	(0.053)n.s.
II Drink and Tobacco						
Malting*	0.2031	0.3055	0.2964	-0.1850	-0.2290	-0.1429
	(0.244)n.s.	(0.229)n.s.	(0.066)	(0.118)n.s.	(0.087)	(0.088)n.s.
Brewing	4.2431	-0.0839	-0.0855	-0.3588	-0.8925	0.0275
	(0.584)	(0.072)n.s.	(0.151)n.s.	(0.057)	(0.163)	(0.022)n.s.
Aerated and mineral	0.5683	0.4897	0.1985	-0.3595	-0.2789	-0.1658
waters*	(0.326)n.s.	(0.149)	(0.146)n.s.	(0.077)	(0.062)	(0.056)
Tobacco	0.5431	-0.0987	-0.0291	-0.0212	-0.0853	0.0236
	(0.695)n.s.	(0.088)n.s.	(0.137)n.s.	(0.106)n.s.	(0.146)n.s.	(0.034)n.s.
III Textiles						
Woollen and worsted	0.1418	0.2316	0.7352	-0.1216	-0.4075	-0.1687
	(0.250)n.s.	(0.174)n.s.	(0.187)	(0.070)n.s.	(0.088)	(0.092)n.s.
Linen and cotton spinning	-0.5371	0.5431	0.7286	-0.1939	-0.0807	-0.3166
	(0.329)n.s.	(0.092)	(0.144)	(0.048)	(0.162)n.s.	(0.044)
Jute, canvas, rayon etc.*	0.0079	0.5334	0.2436	-0.2673	-0.1248	-0.2368
	(0.412)n.s.	(0.162)	(0.212)n.s.	(0.071)	(0.202)n.s.	(0.080)
Hosiery	-1.6238	0.2937	0.4308	0.0625	0.4398	0.1703
	(0.729)	(0.089)	(0.236)	(0.103)n.s.	(0.443)n.s.	(0.038)
Made-up textiles*	1.0152	0.4706	-0.1905	-0.3675	-0.3124	-0.1565
	(0.304)	(0.201)	(0.204)n.s.	(0.089)n.s.	(0.160)n.s.	(0.088)
IV Clothing and footwear						
Clothing (men's and boys')	0.8836	0.1678	0.1247	-0.1294	-0.4206	-0.1093
	(0.234)	(0.066)	(0.111)n.s.	(0.035)n.s.	(0.133)	(0.041)
Clothing (shirt making)*	0.2144	0.1973	0.6484	-0.0989	-0.3659	-0.1624
	(0.226)n.s.	(0.065)	(0.131)	(0.029)n.s.	(0.114)	(0.040)
Clothing (women's and girls')	0.1376	0.4605	0.1853	-0.2058	-0.1404	-0.2380
	(0.228)	(0.057)	(0.140)n.s.	(0.032)n.s.	(0.107)n.s.	(0.038)
Clothing (misc. apparel)	-0.0925	0.5784	0.0857	-0.1813	0.0136	-0.2856
	(0.248)n.s.	(0.137)	(0.153)n.s.	(0.062)	(0.126)n.s.	(0.070)
Boots and shoes	-0.1771	0.4845	0.0855	-0.1672	0.0603	-0.2621
	(0.119)n.s.	(0.055)	(0.110)n.s.	(0.023)	(0.115)n.s.	(0.034)
V Wood and furniture						
Wood and Cork	-0.0935	0.2601	-0.0182	-0.0952	0.0516	-0.1206
	(0.213)n.s.	(0.047)	(0.102)n.s.	(0.030)	(0.101)	(0.042)
Furniture and fixtures*	0.3029	0.4225	0.0768	-0.1804	-0.1901	-0.2372
	(0.449)n.s.	(0.140)	(0.226)	(0.074)	(0.242)	(0.064)
VI Paper and printing						
Paper, etc.	0.5776	0.1929	0.1317	-0.1590	-0.2954	-0.0921
	(0.376)n.s.	(0.087)	(0.091)n.s.	(0.057)	(0.142)	(0.039)
Printing*	0.2569	0.5603	0.2866	-0.2743	-0.2174	-0.2827
	(0.436)n.s.	(0.194)	(0.138)	(0.114)	(0.170)	(0.088)
VII Chemicals						
Fertiliser*	1.2902	-0.0371	0.2653	-0.1410	-0.5410	-0.0222
	(0.844)	(0.116)n.s.	(0.153)n.s.	(0.106)n.s.	(0.302)	(0.040)n.s.
Oils and paints	-0.3077	-0.0567	0.8295	0.0871	-0.4220	-0.1309
	(0.472)n.s.	(0.087)n.s.	(0.116)	(0.095)n.s.	(0.104)	(0.032)
Chemicals	-0.0793	0.4456	0.3910	-0.2920	-0.2530	-0.1337
	(0.516)n.s.	(0.069)	(0.050)	(0.078)	(0.096)	(0.017)
Soaps, etc.	-1.0865	0.0929	0.0437	0.1771	0.3178	-0.0379
	(0.988)	(0.106)n.s.	(0.192)n.s.	(0.196)n.s.	(0.333)n.s.	(0.029)n.s.
VIII Structural clay and cement						
Glass, etc.	-0.5285	0.3570	0.8671	-0.0854	-0.0445	-0.2700
	(0.306)n.s.	(0.045)	(0.116)	(0.028)	(0.184)n.s.	(0.025)
Clay products/cement*	2.8668	0.4916	0.1385	-0.5340	-1.0226	-0.1733
	(0.390)	(0.109)	(0.139)n.s.	(0.064)	(0.117)	(0.221)n.s.
IX Metals and engineering						
Metal trades*	1.6116	0.4612	0.3001	-0.4022	-0.8559	-0.2481
	(0.508)	(0.090)	(0.147)	(0.072)	(0.223)	(0.055)
Machinery* (non-electrical)	-0.2275	0.4689	0.4135	-0.1649	-0.0718	-0.2652
	(0.427)n.s.	(0.108)	(0.157)	(0.069)	(0.219)	(0.045)
Machinery* (electrical)	1.0241	0.4001	-0.0167	-0.3329	-0.3657	-0.1446
	(0.329)	(0.124)	(0.078)n.s.	(0.079)	(0.112)	(0.041)
Mechanically propelled	0.2099	0.2640	0.2146	-0.1255	-0.1893	-0.1557
vehicles*	(0.335)n.s.	(0.066)	(0.072)	(0.044)	(0.158)n.s.	(0.038)
Assembly of vehicles	-0.9956	-0.0122	0.5523	0.1629	0.6037	-0.0809
other than mechanically propelled vehicles	(0.350)	(0.185)n.s.	(0.456)n.s.	(0.075)	(0.198)	(0.074)n.s.
X Other manufacturing						
Fellmongery	0.6028	0.1201	-0.1320	-0.0884	-0.2039	-0.0261
	(0.364)n.s.	(0.100)	(0.182)n.s.	(0.052)n.s.	(0.210)n.s.	(0.044)n.s.
Leather*	0.9367	0.5178	-0.1087	-0.3397	-0.3804	-0.2202
	(0.308)	(0.075)	(0.108)n.s.	(0.053)	(0.140)	(0.034)
Miscellaneous manufacturing	0.3133	0.4042	0.8008	-0.3515	-0.5811	-0.3547
industry*	(0.386)n.s.	(0.283)	(0.163)	(0.116)	(0.150)	(0.099)

Notes:

(i) Asympotic standard errors in parentheses.
(ii) An * denotes that concavity is not rejected as a maintained hypothesis for this industry.
(iii) Key: w = wages; s = salaries; r = cost of capital services.
(iv) n.s. denotes not significantly different from zero at the 95 per cent confidence level.

Malinvaud (1970) has suggested that the conventional Durbin-Watson statistic can still be used in system estimation as a test of the null hypothesis of zero autocorrelation. Only in comparatively few instances could the null hypothesis be rejected. The "significant" elasticity estimates should thus be treated with caution.

Two sets of partial elasticity results are reported: the Allen-Uzawa elasticities of substitution, σ_{ij} (Uzawa (1962)), and the ordinary demand elasticities, η_{ij}. These are defined as:

$$\sigma_{ij} = \frac{b_{ij}}{S_i S_j} + 1, \forall_{i,j}, i \neq j; i,j = w,s,r,$$

$$\eta_{ii} = \frac{b_{ii}}{S_i} + S_i - 1, \forall_i, i = w,s,r, \tag{6}$$

$$\eta_{ij} = \frac{b_{ij}}{S_i} + S_j, \forall_{i,j}, i \neq j; i,j = w,s,r.$$

In common with most studies we present the Allen-Uzawa elasticities of substitution and the own-price elasticities for the own-price effects.

Before commenting on the substitution measures it is necessary to establish whether the conditions for concavity are satisfied; the principal minors of the σ_{ij} matrix should alternate in sign, the first being $\leqslant 0$. Strictly, this test should be carried out at every observation; this would involve computing the principal minors for 840 σ_{ij} matrices! It is proposed to carry out the test for the matrix of Allen-Uzawa elasticities calculated at the share means. Concavity is rejected in 21 out of 40 industries examined. In the following remarks pertaining to Table 1 we will address ourselves almost exclusively to those industries which appear to have well-behaved cost functions.

The elasticity of substitution between production workers and capital is quite high but generally less than one. It is interesting to note that the elasticity of substitution between non-production workers and capital is generally less than the corresponding elasticity between production workers and capital ($\sigma_{wr} > \sigma_{sr}$). The own-demand elasticity for production workers (η_{ww}) is inelastic though quite high. By contrast, the own-demand elasticity for non-production workers is much lower.

Other findings which we do not report but may be of interest refer to the elasticity estimates calculated for aggregate labour (wage and salaried workers). These estimates indicated that the own elasticity for aggregate labour was considerably below that for production workers. The translog estimate of the elasticity of substitution between capital and labour was virtually identical to that derived from the CES specification in Equation (3).

Unconstrained Estimates

As suggested in Section II, it is desirable that the restrictive assumption of Hicks-neutral technical change be relaxed; this is accomplished by the estimation of additional trend parameters. Incorrectly specifying the nature of technical change will have serious consequences for the price effects; changing factor ratios will be attributed exclusively to changing relative prices, hence biasing the effects of prices. In many reported studies of factor substitution, using the Hicks-neutral specification, some of the elasticity estimates seem implausibly high; see, for example, Berndt and Christensen (1973). We would expect, therefore, that if technical change is important, then the b_{ij} terms and the elasticities implied by them should differ considerably from the constrained estimates.

The parameter estimates for the augmented specification were considerably different. By conventional goodness-of-fit criteria the estimated share equations were much improved. In most cases technical change was significantly labour-saving; the exceptions to this were for the trend coefficients on salaried workers.

Table 2 furnishes the elasticity estimates. While concavity is not rejected in 21 of the industries examined, the industries in question are different to those in Table 1. Agreement is confined largely to the food industries while the test is conflicting for the engineering sectors.

Turning to the elasticity estimates we see clearly the effects of relaxing the maintained hypothesis of Hicks-neutral technical change. Inferences based on Table 1 are altered considerably. Substitution possibilities are less evident. More interesting, perhaps, is the fact that the own elasticity of demand for production workers is reduced; a value of around - 0.3 is typical. However, our observations above on Table 1 regarding the relative magnitudes of σ_{wr} and σ_{sr}, are robust with respect to the inclusion of the trend variable.

IV IMPLICATIONS AND DISCUSSION OF THE FINDINGS

The large number of results presented in this paper necessitates a degree of selectivity when discussing the findings. One important empirical implication is that technical change must be accounted for in some way if we are to avoid costly specification errors. Our remarks, therefore, will be confined to the results presented in Table 2. We shall concentrate on the following areas:

(i) the magnitude of the employment-wage elasticity;
(ii) consistent aggregation of labour types;
(iii) an explanation of non-declining returns to salaried workers.

(i) *The Elasticity of Demand for Labour*

Concavity is not rejected as a maintained hypothesis for 21 industries (Table 2), thus, for these industries, prices do have the expected effect in determining labour demand. The empirical results – which should be interpreted as short-run results – suggest that the effect of wage changes on employment is small. Our model is short run in the sense that the adjustment of the factor shares to changes in prices is assumed to be completed within the unit of observation, i.e., one year. In other words, we do not allow for dynamic effects. We believe that the rejection of concavity is itself an interesting finding; we do not intend to survey all of the possible reasons for its rejection here, as an extensive discussion can be found elsewhere (Appelbaum (1978)). Geary and McDonnell (1980, p. 251) found that concavity was rejected for some observations in their study of aggregate manufacturing industry and Higgins (1981, p. 257) reports that concavity was not satisfied for any observation for the sectors of the food industries which he examined.

If the implicit assumption of producer equilibrium is false, this could explain why we rejected concavity for about half of the industries, even if their technology was, in reality, well-behaved. After all, it takes time to change production processes and adjustment may be particularly slow in sheltered industries. Indeed, the industries for which we reject concavity: clothing, textiles and footwear, were large in relation to the market for their output over the period examined, 1953-1973, and their quasi-monopolistic situation may have been reflected in slow adjustment to changing relative input prices. On the other hand, the industries for which we cannot reject concavity (notably the food industries) sell the greater proportion of their output on the export market. There was presumably greater pressure on these open sectors to adjust so as to remain on their efficiency frontier. It would, of course, be unwise to extrapolate this observation to the post-1973 period.

It is of interest to compare the findings of this paper with those of Geary and McDonnell (1980) and Higgins (1981), while noting that the scope of these papers and the present exercise is quite different. While Geary and McDonnell (pp. 252-253) report four sets of estimates for primal and dual specifications of the technologies, the estimates which correspond to those of our paper indicate an own-price elasticity of about -0.70 and an elasticity of substitution between capital and labour of about 1.0. Higgins (pp. 261-262) finds an own-price elasticity of about -0.70 and -0.60 for bacon factories and dairy processing respectively and an elasticity not significantly different from 1.0 in the other meat processing industries. For all three sectors Higgins finds labour and capital to be highly substitutable.

Bradley and Cassidy (1979, p. 17), using annual data and a different methodology to the present paper, report a short-run own-price elasticity for the industrial sector of -0.33 and a long-run elasticity of -0.57. While the papers cited all differ in methodology and scope, it would not be an unreasonable summary to say that the demand for labour has been found to be price inelastic.

(ii) *Consistent Aggregation of Labour*

Berndt and Christensen (1974) have shown that for two inputs to be combined into a meaningful aggregate, the elasticity of substitution between each of the two inputs and any other input (in this case, capital) must be equal, i.e., $\sigma_{wr} = \sigma_{sr}$. As is evident in Table 2, this condition is not satisfied for each industry and hence we must conclude that the two labour types cannot be consistently aggregated. A similar conclusion is reached by Berndt and Christensen (1974) for US data.

(iii) *Non-Declining Relative Returns to Salaried Workers*

A standard *ceteris paribus* result is that the value marginal product of a variable factor should decline as the supply of the factor is increased. In the case of non-production workers we would expect on the basis of *ceteris paribus* assumptions that, since their supply has increased because of greater educational opportunities, their rate of return relative to non-production workers should decline; explanations for the non-occurrence of the latter phenomenon are given by Griliches (1969) and Welch (1970) who argue that the *ceteris paribus* assumption is invalid.[3] Alongside an increased supply of labour has been a growing capital stock; it is argued that capital is more complementary with non-production workers than with production workers, i.e., $\sigma_{wr} > \sigma_{sr}$. As suggested in Section III, this in fact holds in a majority of industries. More dramatic corrobation of the Griliches-Welch hypothesis is provided by Berndt and Christensen (1974) who find not alone that $\sigma_{wr} > \sigma_{sr}$, but that σ_{sr} is negative everywhere.

V SUMMARY

This paper estimates factor-demand functions for 40 manufacturing industries for the period 1953-1973. The estimation procedure involves specifying a particular functional form for the cost function – the translog – and estimating the derived factor-demand functions. This procedure provides additional information on the underlying technology.

3. An examination of the ratio of non-production workers' salaries to production workers' wages indicates that the ratio remained fairly constant up to 1970, thereafter it moved in favour of production workers.

The detailed results of the analysis are as follows:

(i) the factor-demand equations were estimated both exclusive and inclusive of a trend factor to discern the influence of technical change. The results suggest that technical change was non-neutral. The elasticity estimates were substantially reduced for the specification including time;

(ii) concavity of the cost function was not rejected in 21 out of the 40 sectors examined. Various reasons for the rejection of concavity were tentatively advanced; it was suggested that the acceptance of concavity was likely to be positively correlated with the degree of openness of the industrial sector;

(iii) in the sectors for which concavity was not rejected, the own-elasticity of demand for labour was small; an estimate of around -0.3 was typical;

(iv) because the analysis distinguished two types of labour, wage earners and salaried workers, we were able to test whether the Berndt-Christensen (1974) conditions for consistent aggregation hold. This hypothesis was rejected;

(v) our analysis also enables us to test the Griliches-Welch hypothesis regarding non-declining relative returns to non-production workers. We found that the elasticity of substitution between production workers and capital was greater than the corresponding elasticity for non-production workers and capital. This result confirms the Griliches-Welch rationale for the Irish case and is supportive of the findings of Berndt and Christensen for the US manufacturing sector.

REFERENCES

APPELBAUM, E. 1978. "Testing Neoclassical Production Theory", *Journal of Econometrics*, 7, pp. 87-102.

BERNDT, E.R. and L.R. CHRISTENSEN, 1973. "The Translog Function and the Substitution of Equipment, Structures and Labor in US Manufacturing 1929-1968", *Journal of Econometrics*, 1, pp. 81-114.

BERNDT, E.R. and L.R. CHRISTENSEN, 1974. "Testing for the Existence of a Consistent Aggregate Index of Labour Inputs", *American Economic Review*, 64, pp. 391-404.

BRADLEY, J. and C. CASSIDY, 1979. "Output, Real Wages and Taxation in a Two-Sector Model of the Irish Labour Market", *Technical Paper No. 4/RT/79,* Dublin: Central Bank of Ireland.

GEARY, P.T. and E.J. McDONNELL, 1979. "The Cost of Capital to Irish Industry: Revised Estimates", *The Economic and Social Review*, Vol. 10, pp. 287-299.

GEARY, P.T. and E.J. McDONNELL, 1980. "Implications of the Specification of Technologies: Further Evidence", *Journal of Econometrics*, 14, pp. 247-255.

GRILICHES, Z., 1969. "Capital-Skill Complementarity", *Review of Economics and Statistics*, 51, pp. 465-468.

HIGGINS, J. 1981. "Factor Demand and Factor Substitution in Selected Sectors of the Irish Food Industry", *The Economic and Social Review*, Vol. 12, pp. 253-266.

MALINVAUD, E., 1970. *Statistical Methods of Econometrics,* Chicago: Rand McNally and Co.

UZAWA, H., 1962. "Production Functions with Constant Elasticities of Substitution", *Review of Economic Studies*, 29, pp. 291-299.

VARIAN, H.R., 1978. *Microeconomic Analysis*, New York: W.W. Norton and Co.

VAUGHAN, R.N., 1980. *Measures of the Capital Stock in the Irish Manufacturing Sector, 1945-1973*, Dublin: The Economic and Social Research Institute, Paper No. 103.

WELCH, F., 1970. "Education in Production", *Journal of Political Economy*, 78, 35-59.