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Input Substitution and Technical Change in Irish Agriculture — 1953-1977

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Précis: This paper seeks to find explanations for agriculture's changing resource structure over the past 25 years, using the framework of neoclassical production theory. The translog functional form was used to estimate the factor elasticities of substitution. The analysis distinguished two time periods, 1953-1970 and 1953-1977. The estimates did not satisfy all of the necessary conditions for a well-behaved technology, though the own price elasticities for 1953-1970 had the correct signs. The results indicate that labour and machinery were substitutable with an elasticity of substitution close to one over the period 1953-1970. Labour and materials were highly substitutable with an estimated elasticity in excess of one. Technical change was found to be machinery and materials using and labour saving.

I INTRODUCTION

The purpose of this paper is to test for (i) the degree of resource substitution that exists in agriculture, and (ii) the nature of technological change in the period 1953-1977. The most recently published study of input technologies in this sector is by O'Rourke (1978). However, that study assumed the underlying production function to be of the Cobb-Douglas form and because of its restrictive assumptions it rules out the possibility of testing the more interesting hypotheses of neoclassical production theory. The present study assumes that the technologies may be represented by a flexible functional form, the translog. Production technologies are characterised by (i) factor substitution, (ii) technological change, (iii) scale effects. This paper assumes the existence of constant returns to scale and concentrates on estimating factor elasticities of substitution and technological biases.

The contents are organised as follows. Section II gives a brief outline of the theoretical model. Section III discusses the empirical model and presents

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the relevant parameter estimates and the estimated comparative static measures. Section IV summarises the findings of the paper and draws some conclusions.

II METHODOLOGY

To arrive at estimates of the Allen-Uzawa partial elasticities of substitution and factor demand elasticities, the translog cost function is used and Shephard's duality theorem is invoked. A brief outline of the theoretical background is sufficient, as it is well known and accounts may be found in the references cited. Every production function $Q = f(X)$, $X = (X_1, \ldots, X_n)$ possesses a dual cost function $C = C(Q, P)$, $P = (P_1, \ldots, P_n)$ (where X and P denote production inputs and their corresponding prices), according to the Shephard-Samuelson duality theorem (Diewert, 1978). Assuming constant returns to scale we can write the cost function as $C = Q.(P)$, which allows us to consider the relationship between cost and prices separately from output.

In the empirical analysis of production, the translog function is often applied, e.g., Berndt and Christensen (1973). The translog unit cost function may be written as

$$\ln C = a_0 + \sum_i a_i \ln P_i + \tfrac{1}{2} \sum_i \sum_j b_{ij} \ln P_i \ln P_j \qquad (1)$$

Differentiating Equation (1) with respect to $\ln P_i$ yields the derived factor demand equations (Shephard's Lemma) in terms of the factor cost shares S_i.

$$S_i = a_i + \sum_j b_{ij} \ln P_j \qquad (2)$$

Following Diewert (1978, pp. 5-11) a well behaved cost function will satisfy certain regularity conditions. These conditions imply the following constraints on Equation (2).

$\sum_i S_i = 1$, adding up condition

$\sum_j b_{ij} = 0$, linear homogeneity in input prices

$b_{ij} = b_{ji}$, symmetry condition which ensures that the cost function is continuously twice differentiable and hence that the input demand functions are smooth.

Since the translog cost function is only an approximation to a true cost function we can expect neither monotonicity nor concavity of factor prices to be satisfied globally. Monotonicity is tested by ensuring that the predicted shares from Equation (2) are all positive while concavity may be verified by testing whether the matrix of elasticities of substitution is negative semi-definite at each observation.

The Allen-Uzawa partial elasticities of substitution (σ_{ij}), the responsiveness of relative input shares to relative price changes, and the ordinary input demand elasticities (η_{ij}), the responsiveness of input quantities to input prices, may be defined using Equation (2) as:

$$\sigma_{ij} = b_{ij}/S_iS_j + 1, \forall i, j; i \neq j$$

$$\sigma_{ii} = b_{ii}/S^2 - 1/S_i + 1, \forall i$$

$$\eta_{ij} = b_{ij}/S_i + S_j, \forall i, j; i \neq j$$

$$\eta_{ii} = b_{ii}/S_i + S_i - 1, \forall i$$

These formulae suggest a number of testable hypotheses. It can be seen from Equation (2) that if the Cobb-Douglas function characterises the technologies then $b_{ij} = 0, \forall i, j$. If the underlying production function is of the Leontief form then all the elasticities of substitution between input pairs will be zero.

It may be worth noting that several authors, (Burgess (1975), Appelbaum (1978), Geary and McDonnell (1980)), have found different results when comparing estimates of production possibilities for primal and dual representations of the technology, when using the same functional form.

This formulation of the input demand relationships contains a number of maintained hypotheses about producer behaviour. It is important to state these explicitly at this stage since the empirical results will be conditional on these hypotheses holding good. At the beginning of each production period the producer chooses a bundle of inputs to produce a given output at minimum cost. Constant returns to scale assume that the variable inputs as a group are weakly separable from output which implies that the marginal rate of substitution between any two inputs is independent of the level and composition of output. Further research should indicate the sensitivity of the results to these maintained hypotheses.

III ESTIMATION AND RESULTS

Five inputs are considered: machinery and equipment, labour, feedstuffs, fertilisers and seeds. The analysis would have been enhanced if land had been included as an input. Unfortunately, it proved impossible to construct a meaningful expenditure variable. Formally the exclusion of the land variable assumes that the inputs included as a group are weakly separable from the one excluded. A detailed account of the data is provided in Appendix 1. The time period was dictated by data availability. The adding-up condition was automatically satisfied by the data. Accordingly one equation — that for seeds — was deleted and the symmetry[1] and linear homogeneity conditions were imposed in the estimation.

1. Symmetry may be tested by computing the ratio of the difference between the weighted error sum of squares for the constrained and unconstrained estimates divided by the number of restrictions, to the weighted error sum of squares for the unconstrained estimates divided by the number of residual degrees of freedom. This statistic is asymptotically distributed as an F-statistic. For 1953-1977, $F^* = 10.9$. This is greater than the tabular F value for a one percent significance test with 6 and 72 degrees of freedom. For 1953-1970, $F^* = 0.17 < F_{0.05}$ (6,44). Thus symmetry is rejected for the entire sample but is not rejected for the period 1953-1970.

Table 1: *IZEL Parameter estimates of the translog cost function*

	1953–1977	*1953–1970*
a_M	.0342	.0453
	(.0110)	(.0045)
a_L	.7569	.7053
	(.0348)	(.0253)
a_{Fs}	.1113	.1490
	(.0210)	(.0177)
a_{Fe}	.0450	.0534
	(.0091)	(.0094)
b_{MM}	.1268	.0474
	(.0186)	(.0177)
b_{ML}	–.0348	.0048
	(.0151)	(.0121)
b_{MFs}	–.1123	–.0697
	(.0143)	(.0183)
b_{MFe}	.0047	.0025
	(.0104)	(.0074)
b_{LL}	.0140	–.0343
	(.0493)	(.0454)
b_{LFs}	.0360	.0553
	(.0293)	(.0324)
b_{LFe}	.0103	.0129
	(.0122)	(.0155)
b_{FsFs}	.1063	.0689
	(.0228)	(.0348)
b_{FsFe}	–.0398	–.0470
	(.0103)	(.0166)
b_{FeFe}	.0258	.0301
	(.0088)	(.0135)
	Implied estimates of the remaining parameters	
a_S	.0526	.0470
b_{MS}	.0156	.0150
b_{LS}	–.0255	–.0387
b_{Fss}	.0098	–.0075
b_{Fes}	–.0010	.0015
b_{Ss}	.0011	.0297

Asymptotic standard errors in parentheses.

(i) Key: M = Machinery, L = Labour, Fs = Feedstuffs, Fe = Fertilisers, S = Seeds.

(ii) The conventional R^2 figures (computed as one minus the ratio of the error sum of squares to the total sum of squares in each equation) and the Durbin-Watson statistics are as follows:

1953-1977, R^2 = .9088 (M), .6922 (L), .3648 (Fs), .7439 (Fe).
DW= .3755 (M), .4777 (L), .6435 (Fs), .8357 (Fe).
1953-1970, R^2 = .9618 (M), .6750 (L), .5740 (Fs), .4766 (Fe).
DW=1.4399 (M), 1.0053 (L), .9473 (Fs), 1.1619 (Fe).

(iii) The excluded equation, seeds, constitutes less than 2 per cent of estimated costs. The calculation of the standard errors for the excluded parameters would be tedious and was not attempted.

A trend variable was included as an additional argument in the share equations as a proxy for technical change. We add an error term to the system of equations in (2) on the assumption of errors in optimising behaviour.

The parameters were estimated using an iterative Zellner (IZEL) estimator (see for example Berndt and Christensen (1973), pp. 88-89). Given symmetry, OLS will not produce efficient estimates if the errors from each share equation are contemporaneously related and with a single-step Zellner estimator the estimates are not invariant with respect to the choice of equation deleted. This problem should be surmounted by iteration.

The conventional R^2 indicate that the model explains an acceptable degree of variation in the dependent variables. While it is always difficult to interpret the DW statistics in system estimation the possibility of serious autocorrelation is more likely for the extended time period.

Of the 10 estimated b_{ij} coefficients six are statistically significant (1953-1977) and for the sub-period (1953-1970) five parameters are significantly different from zero. The major feature of interest, however, is the difference between the estimates for the two sample periods.[2]

III.1 *Technical Change*

The coefficients of the trend in each share equation may be interpreted as a measure of technological bias (Binswanger 1974). For machinery and labour respectively the estimated coefficients were .0083 (SE = .0084) and –.0684 (SE = .0230) and for feedstuffs and fertilisers the estimates were .0503 (SE = .0142) and .0165 (SE = .0066). These results conform to *a priori* expectations and suggest that technical change has been labour saving and machinery and materials using over the period 1953-1977. For the 1953-1970 data set the estimates were: .0087 (SE = .0039), machinery; –.0365 (SE = .0193), labour; .0194 (SE = .0134), feedstuffs; .0118 (SE = .0072), fertilisers.

III.2 *Measures of Substitution*

Various tests as to the compatability of the results with neoclassical theory were undertaken. The tests highlighted the differences between the parameter estimates for the periods 1953-1970 and 1953-1977. While monotonicity held at each observation for both periods, concavity of input prices was rejected at the share means and at the various observations examined for the translog function estimated over the 1953-1977 interval. For the period 1953-1970 a necessary but not a sufficient condition for concavity, namely, negative own elasticities of substitution, held at the observations examined. However, not all of the eigenvalues of the σ_{ij} matrix were negative, thus rejecting concavity for this sub-period also.

The probable reasons for the rejection of concavity are many, for instance, the quality of the data and the level of aggregation applied. It should also be

2. A Chow test, $F^* = 15.10 > F_{0.01}$ (7,44), indicated considerable parameter instability over the two sample periods.

borne in mind that the translog function is only an approximation to the true cost function and thus the rejection of cost-minimising behaviour may reflect the inaccuracy of the approximation rather than the compatability of the restriction with producer behaviour. The maintained hypothesis that adjustment to price changes is instantaneous might be too restrictive especially during a regime of large price variation characteristic of the post-1973 period of EEC membership. If the maintained hypothesis of producer equilibrium is false, concavity could be rejected even if the technology was well behaved. The finding that rejection of concavity is not as strong for the period 1953-1970, which was distinguished by moderate price variation, gives more support to this argument. Furthermore the tentative result that autocorrelation is a more serious problem for the extended time period suggests that the assumption of instantaneous adjustment is too restrictive for this set of observations. Despite the rejection of concavity it is interesting to examine the implied σ_{ij} and η_{ij} estimates. The elasticity estimates given in Table 2 are evaluated at the share means.[3]

Table 2: *Allen-Uzawa elasticities of substitution*

	Machinery	*Labour*	*Feedstuffs*	*Fertilisers*
		1953–1970		
Machinery	–4.2432	1.0905	–3.0889	1.3526
	(2.2872)	(0.2275)	(1.0729)	(1.0524)
Labour		–0.7476	1.4720	1.2667
		(0.1242)	(0.2764)	(0.3207)
Feedstuffs			–2.3255	–2.0334
			(0.9257)	(1.0711)
Fertilisers				–6.7969
				(2.1131)
		1953–1977		
Machinery	2.9777	0.4234	–4.2667	1.5002
	(1.6837)	(0.2497)	(0.6686)	(1.1195)
Labour		–0.6988	1.3086	1.2013
		(0.1495)	(0.2510)	(0.2402)
Feedstuffs			–1.3471	–1.2120
			(0.5528)	(0.5710)
Fertilisers				–6.9992
				(1.1177)

Asymptotic standard errors in parentheses.

The most striking feature of this table is the difference between the estimates over the two periods. Over the entire sample, production does not conform to a well-behaved technology as one own elasticity of substitution is positive. Comparing individual estimates shows a considerable difference between the machinery labour elasticity for both periods though the estimate for the entire period has a large standard error. The remaining elasticities are

3. The comparative static measures involving the parameters of the excluded equation, seeds, are available upon request.

similar in sign and fairly similar in magnitude. Most of the elasticities possess plausible signs but the degree of substitution between labour and feedstuffs, for example, appears somewhat extreme. It should be remarked, however, that this result is not contradicted by the majority of similar studies known to the author. It could be argued that this elasticity estimate is biased upwards because of scale effects not explicitly allowed for in the model. However, substitution relationships can be quite subtle. For instance, many non-agricultural industry studies reveal strong substitution possibilities between labour and energy-related inputs. This result has often been rationalised by arguing that increasing relative energy prices induce firms to employ extra labour to control wastage. A similar explanation for labour and material inputs in agriculture may have some validity. The manner in which many material inputs are sold has changed considerably over the period analysed. Fertilisers were once sold in bulk form and the required nutrient combination was mixed on the farm demanding a high level of labour input. The shift to a compound product eliminated the labour requirement necessary for mixing the fertilisers.

The findings of this paper may be compared with those of other studies. Binswanger (1974, p. 383) found labour and machinery substitutable (σ_{LM} = 0.851) and labour and fertilisers complementary (σ_{LFE} = –0.672) and found the elasticity between machinery and fertilisers insignificantly different from zero. Woodland (1975, p. 178) found labour and equipment to be substitutable (σ_{LEQ} = 0.15). Lopez (1980, p. 43) using a generalised Leontief specification found labour and capital to be highly substitutable (σ_{LK} = 1.779) and found both capital and materials and labour and materials substitutable. Kako (1978, p. 632) in a study of Japanese rice production found a high elasticity of substitution between labour and machinery (σ_{LM} = 0.93) and between labour and other inputs (σ_{LO} = 2.056). Only Binswanger, however, reported standard errors for his elasticity estimates. The degree of substitution between labour and machinery found in this study is in close agreement with Binswanger and Kako. However, the present study suggests substitutability between labour and fertilisers while Binswanger found complementarity. Kako and Lopez find substitutability between labour and materials where this aggregate includes fertilisers.

The own and cross factor price demand elasticities are given in Table 3 where the estimates are evaluated at the share means.

All of the estimated η_{ij} are inelastic. This result has been found in general by the studies previously cited. It is useful in making predictions about changing factor shares.[4] In the case of labour, for instance, the model would predict that for every one per cent increase in its own price its share would decline by .06 per cent. More complete σ_{ij} and η_{ij} estimates are presented in Appendix 2.

4. Woodland (1975, p. 179) shows that the elasticity of S_i with respect to changes in its own price is given by $\partial \ln S_i / \partial \ln P_i = \eta_{ii} + (1 - S_i)$

Table 3: *Input demand elasticities*

Quantity of \ Price of	Machinery	Labour	Feedstuffs	Fertilisers
	1953–1970			
Machinery	−.3733	.6594	−.5989	.1081
	(.2012)	(.1375)	(.2080)	(.0841)
Labour	.0959	−.4520	.2854	.1012
	(.0200)	(.0751)	(.0536)	(.0256)
Feedstuffs	−.2717	.8900	−.4508	−.1625
	(.0944)	(.1671)	(.1795)	(.0856)
Fertilisers	.1190	.7659	−.3943	−.5433
	(.0926)	(.1939)	(.2077)	(.1689)
	1953–1977			
Machinery	.3127	.2433	−.8661	.1330
	(.1768)	(.1435)	(.1357)	(.0992)
Labour	.0445	−.4012	.2656	.1065
	(.0265)	(.0859)	(.0510)	(.0213)
Feedstuffs	−.4480	.7518	−.2735	−.1074
	(.0702)	(.1442)	(.1122)	(.0506)
Fertilisers	.1575	.6902	−.2460	−.6202
	(.1175)	(.1380)	(.1159)	(.0991)

Asymptotic standard errors in parentheses.

IV CONCLUSIONS

A number of important conclusions emerge. The specification of technologies within agriculture was found to differ significantly over the two time periods examined 1953-1970, 1953-1977. Specifically symmetry was rejected in the latter period but not rejected for the former period. Imposing symmetry as a maintained hypothesis yielded elasticity estimates that differed, both in magnitude and with respect to the assumptions of neoclassical production theory, for both time periods. Concavity was rejected for the observations examined. It is argued that the strong rejection of concavity in the estimates for the 1953-1977 period is in part a reflection of the static specification of the model.

Aside from these important theoretical difficulties, the empirical analysis produced reasonable factor elasticity of substitution, and input demand elasticity, estimates. It has been shown that labour and machinery and labour and materials were highly substitutable over the period 1953-1970. Furthermore the universality of Binswanger's result (1974, p. 383) viz. labour and fertiliser complementarity is rejected, subject to the *caveat* that our results do not fulfil the conditions for a well behaved technology, and cases some doubts on his application of this result to underdeveloped agricultural economies. The results indicated that all the own input demand elasticities were inelastic. Technical change was found to be capital and materials using and labour saving, though caution is warranted here as

Lopez (1980, p. 43) suggests one may be inadvertently attributing to technical change influences which are more properly related to scale effects.

The agricultural sector provides an ideal setting for testing the hypotheses of neoclassical production theory. The author hopes to extend the analysis in this paper to encompass a multiple-input multiple-output specification of the technology. That specification would enable the rigorous testing of many of the maintained hypotheses of this paper and would indicate the sensitivity of the results to the various assumptions adopted.

REFERENCES

APPLEBAUM, 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 Labour in US Manufacturing 1929-68", *Journal of Econometrics,* 1, pp. 81-113.

BINSWANGER, H. P., 1974. "A Cost Function approach to the Measurement of Factor Demand Elasticities and of Elasticities of Substitution", *American Journal of Agricultural Economics,* 56, pp. 377-386.

BURGESS, D. F., 1975. "Duality Theory and Pitfalls in the Specification of Technologies", *Journal of Econometrics,* 3, pp. 105-121.

DIEWERT, W. E., 1978. "Duality Approaches to Microeconomic Theory", Technical Report No. 281, *The Economic Series,* California: Stanford University.

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

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

KAKO, T., 1978. "Decomposition Analysis of Derived Demand for Factor Inputs: the Case of Rice Production in Japan", *American Journal of Agricultural Economics,* 60, pp. 628-635.

LOPEZ, R. E., 1980. "The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture", *American Journal of Agricultural Economics,* 62, pp. 38-45.

O'ROURKE, A. D., 1978. "Towards an Aggregate Production Function for Irish Agriculture", *The Economic and Social Review,* 9, pp. 191-205.

SLATTERY, D. G., 1975. "Fixed Capital Stock Estimation: An Empirical Exercise using Irish Data", *Journal of the Statistical and Social Inquiry Society of Ireland,* XXIII, Part II, pp. 90-133.

WOODLAND, A. D., 1975. "Substitution of Structures, Equipment and Labour in Canadian Production", *International Economic Review,* 16, pp. 171-187.

APPENDIX 1: VARIABLE DEFINITIONS

Expenditures

Labour:

Expenditure on labour in agriculture is measured as the "wages and salaries" component of agricultural expenses and includes employers' social welfare contributions. This refers only to hired male workers. Family labour cost was imputed by multiplying the unit wage cost of hired labour by the family male labour force.

Feedstuffs, Fertilisers, Seeds:

These items are directly reported as the materials component of agricultural expenses.

Machinery and Equipment:

The measure used in the analysis approximates expenditure on machinery and equipment services. In order to obtain estimates of the capital stock of machinery[5] the procedure used was to consider the capital stock at year t (K_t) as the summation of past capital acquisitions (k_{t-1}, i = 1, ..., T) where the importance of the latter declines geometrically as one goes back the series. Thus,

$$K_t = k_t + (1-d)k_{t-1} + (1-d)^2 k_{t-2} + \ldots$$

or,

$$K_t = k_t + (1-d)K_{t-1} \qquad \text{(A.1)}$$

where, d represents true economic depreciation.

In the analysis d was assumed to be .04. Using 1953 as a base year and ignoring any fixed investment prior to this date the capital stock was calculated up to 1977. Data on fixed investment are unavailable prior to 1953. However, a figure for total *Gross Domestic Fixed Capital Formation* is available for 1938 and assuming that agricultural machinery investment represents 6 per cent of this figure (the average share over the period 1953-1960) an estimate of machinery investment for the intervening years was made by linear interpolation. The capital stock for 1952 was then calculated and brought forward to 1977 using the formula in (A.1) with $k_t = 0$. The final estimate of the capital stock of machinery and equipment was found by adding the estimate of pre-1953 stock still in use to the post-1953 stock. Expenditure on machinery services was found by multiplying this figure by the estimated cost of capital. The overall estimate of machinery expenditure was found by adding the CSO estimate for repairs.

5. Subsequent to writing this paper the author's attention was drawn to an article by Slattery (1975) containing estimates of the stock of agricultural machinery. Both sets of estimates are in close agreement.

Shares: $S_i = C_i / \sum_{i=1}^{5} C_i$

where,

S_i = cost share of input i

C_i = expenditure on input i.

Prices:

All indexed to base 1953 = 1.000.

Labour:

Unit wage cost of hired agricultural labour.

Feedstuffs, Fertilisers, Seeds:

Prices of material inputs are reported in the *Irish Statistical Bulletin.*

Machinery and Equipment:

The calculation of this variable follows the approach of Geary and McDonnell (1979). The measure corresponds with the capital stock estimate used to generate the factor shares. The user cost of machinery capital may be defined as,

$$PM_t = PI_t(r_t + d)$$

where,

PM_t = Price of machinery and equipment services.

PI_t = Wholesale price of transportable capital for use in agriculture.

r_t = Prime lending rate of the commercial banks.

d = Annual economic depreciation rate.

APPENDIX 2

(i) Elasticity of substitution estimates for selected years (parameter estimates for period 1953–1970)

	σ_{ML}	σ_{MFs}	σ_{MFe}	σ_{LFs}	σ_{LFe}	σ_{FsFe}
1954	1.1229	–5.3877	1.5459	1.4815	1.2697	–2.5315
1956	1.1056	–5.0853	1.4883	1.5114	1.2690	–2.9014
1958	1.0983	–4.1644	1.4058	1.5078	1.2615	–2.4603
1960	1.0893	–4.4395	1.4546	1.5367	1.2940	–3.5090
1962	1.0912	–2.6758	1.3359	1.4551	1.2726	–1.7657
1964	1.0892	–2.5273	1.3063	1.4545	1.2587	–1.5771
1966	1.0843	–2.3996	1.3538	1.4386	1.2991	–2.0365
1968	1.0830	–2.0491	1.2422	1.4549	1.2368	–1.1903
1970	1.0722	–1.6787	1.2201	1.4677	1.2519	–1.3524

(ii) Own elasticity of demand estimates for selected years (parameter estimates for period 1953–1970)

	η_{MM}	η_{LL}	η_{FsFs}	η_{FeFe}
1954	–.1624	–.4110	–.4361	–.5208
1956	–.2485	–.3962	–.4175	–.5147
1958	–.3139	–.4257	–.4293	–.5375
1960	–.3394	–.3935	–.4035	–.4811
1962	–.3871	–.4773	–.4615	–.5483
1964	–.4003	–.4827	–.4626	–.5651
1966	–.4118	–.4652	–.4636	–.5131
1968	–.4418	–.5062	–.4665	–.5947
1970	–.4876	–.5118	–.4646	–.5831

(iii) Elasticity of substitution estimates for selected years (parameter estimates for period 1953–1977)

	σ_{ML}	σ_{MFs}	σ_{MFe}	σ_{LFs}	σ_{LFe}	σ_{FsFe}
1954	.1127	–9.2814	2.0251	1.3131	1.2145	–1.9899
1956	.2307	–8.7945	1.9905	1.3326	1.2139	–2.3031
1958	.2902	–7.3124	1.7619	1.3302	1.2080	–1.9296
1960	.3550	–7.7552	1.8537	1.3490	1.2338	–2.8175
1962	.3411	–4.9165	1.6308	1.2959	1.2168	–1.3415
1964	.3561	–4.6773	1.5752	1.2955	1.2057	–1.1818
1966	.3909	–4.4718	1.6643	1.2852	1.2379	–1.5708
1968	.4005	–3.9076	1.4547	1.2958	1.1883	– .8544
1970	.4784	–3.3114	1.4133	1.3042	1.2003	– .9916
1972	.4513	–4.0721	1.4456	1.3108	1.1876	–1.0858
1974	.5458	–2.1899	1.2649	1.3304	1.1885	– .5921
1976	.5495	–1.7417	1.2114	1.3486	1.1846	– .3516

(iv) Own elasticity of demand estimates for selected years (parameter estimates for period 1953–1977)

	η_{MM}	η_{LL}	η_{FsFs}	η_{FeFe}
1954	1.1388	–.3359	–.2270	–.5788
1956	.8943	–.3227	–.1907	–.5737
1958	.7051	–.3490	–.2134	–.5924
1960	.6304	–.3206	–.1646	–.5459
1962	.4879	–.3943	–.2826	–.6013
1964	.4475	–.3990	–.2855	–.6149
1966	.4123	–.3838	–.2879	–.5724
1968	.3185	–.4194	–.2957	–.6387
1970	.1679	–.4242	–.2906	–.6295
1972	.2621	–.3999	–.2704	–.6332
1974	–.0365	–.4845	–.3012	–.6573
1976	–.1003	–.5272	–.3118	–.6691

Key: M = Machinery; L = Labour; Fs = Feedstuffs; Fe = Fertilisers.

DATA APPENDIX

	Expenditure shares					Input prices				
Year	*M*	*L*	*Fs*	*Fe*	*S*	*M*	*L*	*Fs*	*Fe*	*S*
1953	.06054	.65386	.18465	.06342	.03753	1.000	1.000	1.000	1.000	1.000
1954	.06103	.64235	.17890	.07441	.04331	1.002	1.057	0.914	0.975	1.013
1955	.06407	.64684	.17157	.07335	.04417	1.032	1.089	0.929	0.995	1.158
1956	.06949	.65603	.16493	.07306	.03649	1.172	1.173	0.949	1.017	0.997
1957	.07506	.64301	.16680	.07583	.03930	1.280	1.205	0.949	1.025	1.052
1958	.07793	.62884	.17329	.07840	.04154	1.309	1.208	0.959	0.998	1.018
1959	.07601	.64543	.16905	.06898	.04053	1.227	1.267	0.947	0.802	1.154
1960	.08189	.65854	.15657	.06659	.03641	1.327	1.330	0.926	0.714	1.064
1961	.08252	.64230	.17392	.06244	.03882	1.411	1.417	0.901	0.662	1.138
1962	.09076	.58165	.20905	.08131	.03723	1.402	1.263	0.922	0.667	1.067
1963	.09139	.56563	.21805	.08843	.04063	1.332	1.258	0.936	0.674	1.104
1964	.09366	.57675	.21111	.08641	.03202	1.436	1.444	0.942	0.690	1.144
1965	.09505	.56614	.23147	.07813	.02921	1.644	1.698	0.978	0.718	1.155
1966	.09636	.59259	.21290	.07272	.02543	1.754	1.997	1.017	0.731	1.290
1967	.10182	.57252	.21102	.08985	.02479	1.849	2.037	1.038	0.748	1.331
1968	.10445	.55547	.21899	.09801	.02308	2.037	2.271	1.086	0.818	1.367
1969	.11288	.55460	.21351	.09788	.02113	2.285	2.643	1.096	0.830	1.424
1970	.12114	.55043	.21493	.09298	.02052	2.610	3.097	1.163	0.837	1.467
1971	.11212	.56035	.21189	.09682	.01882	2.705	3.833	1.241	0.904	1.627
1972	.11007	.57586	.20107	.09490	.01810	2.779	4.522	1.285	1.000	1.640
1973	.12472	.52011	.23733	.10297	.01487	3.897	5.274	1.757	1.092	1.809
1974	.15729	.48684	.22373	.11174	.02040	5.868	6.113	2.307	1.735	3.091
1975	.16485	.49352	.20479	.11934	.01750	6.866	7.312	2.439	2.580	3.390
1976	.17498	.45120	.23399	.12585	.01398	8.419	8.438	2.929	2.669	3.349
1977	.18049	.42125		.11682	.01855	9.671	9.915	3.821	2.944	5.078

Key: M = Machinery; L = Labour; Fs = Feedingstuffs; Fe = Fertilisers; S = Seeds.
Sources: Various Issues of the *Irish Statistical Bulletin* and the Central Bank of Ireland.