Towards an Aggregate Production Function for Irish Agriculture

A. DESMOND O'ROURKE*
The Economic and Social Research Institute, Dublin

I INTRODUCTION

Much research effort has been expended in other countries in generating measures of the aggregate production function for the agricultural sector as a means of examining technological relationships between inputs and outputs, substitutability between inputs, economies of scale, optimum resource use, optimum growth paths, etc. Only one such effort has been published for Irish agriculture, that by Rasmussen with Sandilands (1962), which used data from the 1955-58 National Farm Surveys. Unfortunately, Rasmussen's study, published in 1962, pre-dated the emergence of the agricultural economics profession as a potent influence on Irish agricultural policy. (For example, the first issue of the Irish Journal of Agricultural Economics and Rural Sociology appeared only in 1967.) The small body of agricultural economic researchers were forced to devote most of their attention to specific farm management and commodity marketing problems. Accordingly, there has been no attempt to develop a more up-to-date measure of the aggregate production function for Irish agriculture.

The present study applies a method proposed by Tyner and Tweeten (1965 and 1966) to Irish time series data for the years 1956-75. The Tyner and Tweeten method was discussed in two papers in 1965 and 1966, identified here as TT-65 and TT-66. Ideally, one would define inputs and output,

*The author acknowledges the helpful comments of a referee. The usual disclaimer applies.

and estimate an appropriate production function in the conventional manner. However, if one wishes to define more than two inputs, multicollinearity in the data series used becomes a problem. Tyner and Tweeten's method overcomes that problem by making use of the fact that factor shares are equal to elasticities of production in equilibrium. Annual factor shares can be observed, and by use of a suitable adjustment equation, one can estimate the equilibrium factor shares and thus the elasticities of production for each input. In a Cobb-Douglas production function the elasticities correspond to the coefficients for each input. Accordingly, by assuming a Cobb-Douglas function with the elasticities as coefficients on each input, it is possible to estimate the constant term for any actual level of output and inputs. More specifically for a Cobb-Douglas function of the form:

$$Y = aX_1^{b_1} X_2^{b_2} \ldots X_n^{b_n} \qquad (1)$$

where Y is output and the X_i's are inputs, one first estimates each elasticity of production b_n, independently for the given values of X_i, then estimates the constant term, a, for given values of the Y and X_i's in a particular time period. Many forms of adjustment equation could be envisaged for estimating the individual b_i's. TT-65 suggested testing for evidence of changing factor shares over time and of possible autocorrelation. In the Irish case, preliminary analysis suggested that the factor share tends to move a constant proportion of the way towards the equilibrium b_i in any period. That is:

$$F_{it} - F_{it-1} = q_i (b_i - F_{it-1}) \qquad (2)$$

where F_{it} is the factor share of input i in time period t and q_i is the proportion of adjustment to equilibrium completed in one period.

II DEFINITIONS AND DATA SOURCES

One obstacle to estimation of a production function for Irish agriculture is that some key data series are either not compiled or are not published in a readily useable form. Reasons for the definition of variables used and methods of generating the data series are, therefore, discussed here at length so that readers can evaluate the reliability of individual parameters and future researchers can concentrate efforts at refinement on the weakest links. It needs to be stressed that the way in which variables are defined affects subsequent results and analyses.

The bulk of the data used in this study was taken from the estimates of the quantity and value of Irish agricultural output for the years 1965-75 published annually by the Central Statistics Office (CSO) in the June issue of the *Irish Statistical Bulletin.* The first problem to arise was how to define "Output (Y)." The CSO publishes two figures for gross output, one excluding, the other including, value of changes in livestock numbers. In most years, the difference is minimal. In fact, the simple correlation coefficient of the two series for 1965-75 was ·993. Neither series measures real output generated by the inputs used, but rather marketed output *after deductions* for produce used for further production on the farm on which it was produced or sold by one farmer to another *and addition* of production consumed on the farm where produced. Since Gross Output excluding value of changes in livestock numbers most closely approximates output as seen by a profit maximiser weighing the profitability of expenditure on inputs in a given year, it was used as our measure of Y and to generate factor shares.

In defining inputs, we attempted to approach as closely as possible to the nine categories defined by Tyner and Tweeten (TT-66, appendix) so as to permit a comparability check of Irish versus US results. The input categories used and main sources are summarised in Table 1. Expenditure on inputs 1, 2, 6, 7 and 9 could be culled directly from the CSO agricultural output report. Input 6 included repairs to machinery, spare parts, etc., and petrol, oil, etc., while input 7 included transport and marketing and other expenses of agriculture except rates and depreciation.

It was difficult to estimate the value of labour services used in Irish agriculture since most are performed by family members who are not remunerated on any regular time or piece rate. Accordingly, we valued the opportunity cost of all farm labour at that actually paid per hired worker. For example, in 1975, 33,500 hired male workers were paid £38·9 million in wages, salaries and employers' contribution to Social Security, so that the opportunity cost of labour for the entire 242,800 male workers was estimated at £281·9 million. This estimate begs a number of questions about the contribution of female workers, the underemployment of male labour, the treatment of labour occupied part-time off-farm, etc. However, the information to answer these questions is not available. We can only hope that no additional sources of error have been introduced by our method of valuing expenditure on the labour input.

The CSO does not compile a series on investment in real estate, primarily land. A number of ways of estimating the value of such investment suggested themselves. One would be to obtain a record of the sales price of land over time. However, price of reported sales is a marginal price and is likely to be above the average value of all land. In addition, inter-year comparison of such prices would only be valid if the mix of lands sold in each year was reasonably homogeneous. A second method would be to attempt some

Table 1: *Input categories for Irish agriculture and main sources of data used*

	Input Category	*Source of Data*
1.	Fertiliser and lime	A
2.	Feed and seed	A
3.	Labour	B and C
4.	Machinery: interest on investment and depreciation	B, D and E
5.	Real Estate: interest on investment	F, B and E
6.	Repairs, petrol, oil, etc.	B
7.	Miscellaneous operating expenses	B
8.	Cattle: interest on investment	G and E
9.	Real Estate taxes (Rates)	B

Sources: A. CSO estimated output of agricultural products.

B. CSO estimates of income arising in agriculture.

C. All labour valued at the same average earnings as hired labour.

D. Machinery depreciation reported in B was multiplied by 6·5 to generate an estimate of the average capital value of machinery employed in a year. Interest on this investment was charged at ordinary overdraft rates reported in E.

E. Interest rates reported in Moynihan, M., "Currency. and Central Banking in Irealnd, 1922-60," and in the *Central Bank Quarterly Bulletin.*

F. The opportunity cost of land was estimated by applying ordinary bank deposit rates to the value of employment and other trading income arising in agriculture.

G. June 1 cattle inventory was valued at average export prices for that year. Interest was charged on that value at ordinary bank deposit rates.

measure of the productivity of Irish land in the manner used for rateable valuations. However, the cost of such measures would be enormous and the changes from year to year probably very small. Accordingly, income accruing to landholders as approximated by the CSO entry "Income from self-employment and other trading income" was used as a measure of the value of all Irish land in any year. The logic of this is that if purchasers could be found for all the farmland in Ireland in any year, those purchasers would be willing to pay the equivalent of the income which farmers could have earned from holding the land. The opportunity cost of the land, then, is the interest the farmer foregoes by not selling and lodging the proceeds of sale at ordinary bank deposit rates. Use of this method of valuing land would put the average value of an acre of Irish farmland at £8·2 in 1956 and £39·4 in 1975. While a more direct measure of the opportunity cost of land would have been desirable, it is hoped that this measure captures fairly accurately the relative changes in the opportunity cost of land from year to year.

Valuation of investment in livestock provided a different kind of problem. Cattle could be divided into one-year age categories on June 1 and valued at the average export prices for calves, stores, fat cattle and milch cows. However, no similar convenient categories existed for pigs, sheep or fowl. Accordingly, only cattle, the major species involved, were included in the livestock valuation. The opportunity cost of cattle was set at the ordinary deposit rate of interest foregone on the moneys invested in cattle inventory. This appears reasonable in light of the traditional mode of operation of Irish farmers where cattle purchases were made by drawing down personal savings. However, as more and more cattle purchases are financed by borrowing from banks and other lending institutions charging interest rates well above deposit rates, this method of valuation will underestimate the opportunity cost of investment in livestock, so that the method may have had a slight downward bias in recent years.

The complete data series used in generating factor shares and in the subsequent analyses are set out in appendix Table 1. While all the series showed growth over time, those involving interest on investment in real estate, machinery or livestock grew fastest as both overdraft and deposit rates of interest increased by 6-8 percentage points between 1956 and 1975. For example, ordinary deposit rates rose from 1·5 to 7·75 per cent, ordinary overdraft rates from 6·25 to 13·75 per cent. Expenditure on labour rose at about the same rate as the agricultural product price index. The share of labour expenditure changed little over the two decades as the decline in manpower was offset by rapidly increasing agricultural wage, salary and social insurance costs. Real estate taxes (rates) fell by about one-third in real terms. Expenditure on all nine inputs accounted for about 80 per cent of gross output in the first decade, 93·5 per cent in the second decade.

III ESTIMATED FACTOR SHARES

Estimates of the rate of adjustment (q_i) of factor shares to equilibrium and of average elasticities of production in the twenty-year period 1956-75 are presented in Table 2. The rates of adjustment are those derived from estimating equation (2) for the twenty-year period. Through use of a zero-one variable (0 in the 1956-65 period, 1 in the 1966-75 period) the elasticities of production were estimated separately for the whole period and for the 1966-75 decade. While only one of the dummy variables (that for interest and depreciation of machinery) was significant at the 5 per cent level, it appeared that there was a general shift in factor shares between the two decades (Table 2).

In general, the rate of adjustment of factor shares to equilibrium in Irish

Table 2: *Rate of adjustment of factor shares and measured elasticities of production for Irish agriculture, 1956-75.*

Input Category		Rate of adjustment	Measured elasticities	
			1956-75	1966-75
1.	Fertiliser and lime	.0616	.0807	.0745
2.	Feed and seed	.4556	.1569	.1668
3.	Labour	.3744	.3792	.3729
4.	Machinery: Interest and depreciation	.0699	.0725	.1453
5.	Real estate: Interest on investment	.2975	.0440	.0326
6.	Repairs, petrol, oil, etc.	.7547	.0395	.0402
7.	Misc. operating expenses	.1691	.0570	.0584
8.	Cattle: Interest on investment	.2482	.0546	.0703
9.	Real estate taxes (rates)	.0749	.0186	.0243
	Total		.9030	.9853

agriculture was much slower than that reported by Tyner and Tweeten (TT-65) for US agriculture. Slowest adjustment in Ireland was found for fertiliser and lime, machinery interest and depreciation and real estate taxes, whereas in the US slowest adjustment occurred with feed and seed and repairs, petrol, oil, etc. The measured elasticities differed most from those found for the US in real estate interest on investment.

The sum of the measured elasticities was less than unity although not so convincingly as in the earlier study by Rasmussen with Sandilands (1962), who found considerable evidence of decreasing returns to scale in Irish agriculture. The sum of the elasticities for the 1966-75 decade although not significantly different from that for the whole period, was closer to, but still less than unity, suggesting that returns to scale may be becoming constant.

Measures of the elasticities of substitution between factors at equilibrium can also be derived from Table 2. The elasticity of substitution of factor i for factor j is defined as the percentage change in X_i associated with a one per cent change in X_j, given that output is unchanged. It is equal to the negative of the ratio of the production elasticities for i and j. From among many possible ratios that could be calculated we note here some of the more interesting. The elasticity of substitution of fertiliser and lime for real estate interest on investment was $-1{\cdot}82$. The elasticity of substitution of feed and seed for real estate interest on investment was even higher, $-3{\cdot}57$. The elasticity of substitution of machinery interest and depreciation for labour was low, —·19, although this is not surprising given the orientation to livestock of the Irish agricultural economy.

The measured elasticities for the 1966-75 decade are also presented in Table 2. Although not statistically different in the individual coefficients from the 20-year average, taken together they do indicate a consistent pattern of reduction in the relative importance of land and labour and increase in importance of other inputs. Griliches (1963) has pointed out that factors such as improvements in the technical efficiency of machinery, better seeds, pest and disease preventatives and other qualitative factors which cannot be separately measured may account for some of the changes in production elasticities. Since experience prior to 1965 was not considered particularly relevant to the future of Irish agriculture, only the 1966-75 elasticities are used in the remaining analyses.

IV AGGREGATE PRODUCTION FUNCTION

By assuming a production function of the Cobb-Douglas type and using the measured elasticities one can estimate the constant term for any period so that all parameters of the production function for that period can be quantified. The constant term can be estimated assuming that the error term is either additive or multiplicative, whichever gives the higher R^2. For the period of greatest interest to our analysis, 1966-75, and after deflating values of all inputs and output by the agricultural price index, base 1953 = 100, the multiplicative approach gave the best fit and yielded a constant term of 9·4319.

The estimated production function was first used to compare the least cost combination of inputs with the actual combination used to produce the 1966-75 average level of output (Table 3). The results suggest that the same output could have been achieved with one quarter less inputs. Of the £55·6 million deflated that could have been saved, almost 60 per cent could have come from the labour and real estate inputs. Forty-five per cent more labour was used than would have been needed in the least cost situation. Only machinery interest and depreciation expenditure would have been increased in the least cost situation.

It should again be pointed out that these results are influenced by the definitions and method of measurement of inputs described in an earlier section. For example, it is possible that Irish farm labour input is overvalued, or vice versa. Tentatively one can say that these results suggest that the 1966-75 output could have been produced more efficiently by greater emphasis on the machinery input, given the method used to value all inputs.

Table 3: *Deflated values of actual and least cost combinations of inputs used to produce 1966-75 average level of output*

Inputs		Actual (£ million)	Least-Cost (£ million)
1.	Fertiliser and lime	17.0	12.8
2.	Feed and seed	40.6	28.7
3.	Labour	93.1	64.2
4.	Machinery: Interest and depreciation	20.9	25.0
5.	Real estate: Interest on investment	6.6	5.6
6.	Repairs, petrol, oil, etc.	9.8	6.9
7.	Misc. operating expenses	13.9	10.1
8.	Cattle: Interest on investment	16.4	12.1
9.	Real estate taxes (rates)	7.2	4.2
	Total inputs	225.5	169.6

A further interesting use of the aggregate production function is to examine the least cost combination of inputs needed to generate given increases in output specifically 20 per cent and 40 per cent above 1975 levels. Use of the 1966-75 average production function to make projections implies constant technology, whereas there is evidence that the production function of Irish agriculture has not been constant over the 1956-75 period. Accordingly, projections must be interpreted with the caution that they do not allow for possible changes in technology. Many alternative assumptions could be made about the future volume and prices of inputs and the price of output. Only a few are presented here (Table 4). Output price is in all cases assumed to remain at the same level as in 1975, and all results are presented at 1975 prices. Input volume is generally allowed to vary except for the case of real estate which is in some examples assumed fixed at 3·9 per cent above 1975 levels. Input prices are with one exception assumed constant at 1975 levels. In one example the real price of labour is assumed to rise by 50 per cent.

1975 output could have been achieved with a least-cost combination of inputs 18·7 per cent below that actually used (Table 4). This is less than the possible savings indicated for the average output of the 1966-75 decade in Table 3. However, increases in output above the 1975 level call for almost equivalent increases in the least-cost combination of inputs under the cases studied. The potential savings in labour costs and real estate taxes in 1975

Table 4: *Least cost combinations of inputs required to generate selected output levels under varying assumptions about input volume and price, at 1975 levels (£ million)*

	Actual	*LEAST-COST*				
Assumptions	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
(a) Output level	1975 actual	1975 actual	1975 x 1.20	1975 x 1.40	1975 x 1.40	1975 x 1.40
(b) Input level	1975 actual	All variable	Real Est. x 1.039	Real Est. x 1.039	All variable	Real Est. x 1.039
(c) Input price	1975 actual	1975 actual	1975 actual	1975 actual	1975 actual	1975 actual (exc. labour x 1.50)
Target output	909.0	909.0	1090.8	1272.6	1272.6	1272.6
Inputs required						
1. Fertiliser, etc.	68.8	48.7	56.6	66.8	66.9	84.0
2. Feed and seed	127.0	109.0	126.7	149.6	149.8	188.0
3. Labour	281.9	243.7	283.2	334.3	335.0	420.2
4. Machinery inv.	97.7	95.0	110.3	130.3	130.5	163.7
5. Real estate inv.	36.6	21.3	37.5	37.5	29.3	37.5
6. Repairs, etc.	38.4	26.3	30.5	36.0	36.1	45.3
7. Misc. exp.	52.8	38.2	44.4	52.4	52.5	65.8
8. Cattle inv.	72.2	45.9	53.4	63.0	63.1	79.2
9. Real estate taxes	16.5	15.9	16.9	16.9	21.8	16.9
Total inputs	791.9	644.0	759.5	886.8	885.0	1100.6
Ratio: Inputs/Output	.871	.709	.696	.697	.695	.865

is relatively much smaller than for the 1966-75 decade. This may have arisen because these resources were actually being more fully utilized in 1975 or because the prices of these inputs had grown less rapidly than that of other inputs. Both influences may have been at work.

At output 40 per cent above 1975 levels, when real estate inputs are assumed fixed, the use of all other inputs and total inputs increases slightly over the situation when all inputs are allowed to vary. In contrast to the average situation in the 1966-75 decade, this suggests that almost all the land currently in agriculture would be needed at higher levels of output. The same fuller utilisation appears to be ahead for labour if output is to increase markedly over 1975 levels. When the price of labour was allowed to increase by 50 per cent at 40 per cent higher output, actual expenditure on labour rose by 25·7 per cent while the real input of labour fell by 16·2 per cent. Total input costs also rose substantially when expenditure on labour rose, and the ratio of total inputs to output rose sharply. This suggests that any increase in price of inputs faster than the increase in the price of output, will reduce the economic return to farmers from any given level of output.

Some other interesting measures can be derived from the average Cobb-Douglas production function for 1966-75. Assuming all other factors fixed, the elasticity of use of factor X_i associated with a 1 per cent change in product price (called the cross-elasticity, following Tyner and Tweeten (TT-66)) is set out in the first column of Table 5. The elasticity of factor use with respect to factor price is simply the negative of the cross-elasticity

Table 5: *Cross-elasticities of demand and supply elasticities for nine input groups, 1966-75*

Input		*Cross-elasticity*[a]	*Simple supply elasticity*[b]
1.	Fertiliser and lime	1.0805	.0805
2.	Feed and seed	1.2002	.2002
3.	Labour	1.5946	.5946
4.	Machinery: Interest and depreciation	1.1700	.1700
5.	Real estate: Interest on investment	1.0337	.0337
6.	Repairs, petrol, oil, etc.	1.0419	.0419
7.	Miscellaneous operating expenses	1.0618	.0618
8.	Cattle: Interest on investment	1.0756	.0756
9.	Real estate taxes (rates)	1.0249	.0249

[a] Cross-elasticity is defined as the elasticity of demand for the ith input (X_i) with respect to product price P_y. In symbols, $(dX_i/dP_y)\ (P_y/X_i) = 1/(1-b_i)$.

[b] Simple supply elasticity is defined as the change in output (Y) associated with a change in only one input (X_i) as the result of a change in product price P_y, thus $(dY/dP_y)\ (P_y/Y) = (dY/dX_i).\ (dX_i/dP_y)\ (P_y/X_i) = b_i/(1-b_i)$.

and so is not listed separately. By definition, since all b_i are greater than zero, all cross-elasticities are greater than one and all direct elasticities less than minus one. Labour, feed and seed and machinery are most responsive to a change in either product or factor price.

The simple supply elasticities, that is, the change in output associated with a change in only one input as the result of a change in product price, is also reported in Table 5. All other inputs are assumed fixed. However, as Tyner and Tweeten point out, the simple supply elasticity indicates not that only one input would normally react at any one time to a change in price, but what would happen *if* only one input reacted. Accordingly, they arbitrarily divided inputs into four groups based on the length of time required for an input to be varied. Using the same grouping, we estimated supply elasticities for four lengths of run, short, intermediate, intermediate-long and long (Table 6). Given time for fertiliser and lime, feed and seed, repairs and miscellaneous operating expenses to adjust to a 1 per cent change in product price, supply would increase by about one half per cent. Given additional time for investment in machinery and livestock to adjust, supply would increase by more than 1 per cent. Given time for labour to react to a price stimulus, supply would respond by almost 13 per cent. However, as Tyner and Tweeten suggest (TT-66), "It is quite unlikely that such a phenomenon would ever be observed because of the changes occurring in 'short-run' variables."

Table 6: *Supply elasticities for four lengths of run, derived from 1966-75 coefficients*[a]

Length of run	*Inputs variable*	*Supply elasticity*
Short	1, 2, 6, 7	.5149
Intermediate	4, 8 (plus above)	1.2497
Intermediate-long	3 (plus above)	12.9665
Long	All	67.0272

[a] The elasticity for more than one input variable equals $\Sigma b_i / (1-\Sigma b_i)$.

V CONCLUSIONS

Very little is known about the aggregate behaviour of the Irish agricultural sector. Yet it is important for policymakers to have some conceptual framework in which to evaluate the impact either of exogenous shocks or of proposed policy measures. A method developed by Tyner and Tweeten which permits examination of a large number (nine in our case) of groups of inputs without risking multicollinearity was applied to Irish data for the years 1956-75. It was possible to use published estimates of measures of most input categories. However, some gross assumptions had to be employed in developing time series for labour, investment in real estate and investment in livestock inventory. The author recognises the limitations of these series. Accordingly, the results reported here are conditional pending more precise data on these inputs. It is hoped that they will stimulate further data collection and analysis of this important field.

This study indicates that the rate of adjustment of factor shares to equilibrium in Irish agriculture is relatively slow, on average only about half the rate reported by Tyner and Tweeten for US agriculture. The rate of adjustment was slowest in fertiliser, machinery interest and depreciation and real estate taxes (rates) and fastest in repairs, petrol and oil expenditures, feed and seed use and labour.

The sum of the measured elasticities was less than unity and supported Rasmussen's findings of decreasing returns to scale in Irish agriculture. There was some evidence (not statistically significant) that returns to scale had increased in the 1966-75 period relative to the previous decade. The elasticity of substitution of fertiliser for real estate investment over the 20 years studied, 1956-75, was −1·82 and of feed and seed for real estate investment −3·57. That is, a 1 per cent reduction in real estate investment would require a greater than 1 per cent increase in those purchased inputs to maintain constant output. The elasticity of substitution of investment in machinery for labour was quite low, −·19, perhaps reflecting the extensive, livestock-oriented nature of much of Irish agriculture.

The average output for the decade 1966-75 could have been produced at least cost with approximately 75 per cent of the inputs actually used. Labour and real estate accounted for almost 60 per cent of the excess expenditure on inputs. However, different definition of inputs might yield different results. The 1975 output could have been produced at least cost with 81 per cent of the inputs actually used. In 1975, labour and real estate contributed only 37 per cent to excess input use. It appears then that during the period studied, as output has expanded the production function of Irish agriculture has moved closer to equilibrium, relatively fixed resources such as labour and real estate have become more fully utilised, and variable resources have been used more efficiently.

The average production function for the 1966-75 decade was used to examine the least cost combination of inputs needed to generate increases in output over 1975 levels of 20 per cent and 40 per cent. Twenty per cent greater output could be achieved with approximately the level of inputs used to generate 1975 output. A 40 per cent increase in output would require more feed and seed, labour and machinery. Whether real estate was assumed fixed or allowed to vary made little difference to expenditure on real estate or on other inputs for output 40 per cent above 1975 levels. However, it seems clear that above that level of output the limited availability of land would become an effective constraint; it should be noted that no allowance was made in these projections for changing technology or increased productivity of inputs.

For illustrative purposes, we examined the effect of a 50 per cent rise in the real price of labour relative to the price of output and all other inputs. Expenditure on labour would rise 25·7 per cent and volume of labour used would fall 16·2 per cent. However, the substitution of other inputs would not adequately offset the increased cost of labour, so that the least cost combination of inputs would rise by 24·1 per cent and the ratio of inputs to output would deteriorate by the same amount. Similar adverse results could be expected from increases in real costs of feed, fertiliser, machinery or other inputs.

Following Tyner and Tweeten it was also possible to combine inputs to measure the supply elasticity of Irish agriculture by length of run. In the short-run the response of aggregate supply to a 1 per cent increase in product price would be about ·5, in the intermediate run about 1·25, and in the long-run very large. However, only the short and intermediate run measures are ever likely to occur before further exogenous shocks intervene.

The results presented here must be considered tentative since no yardstick exists against which they can be compared. However, they pose a number of intriguing hypotheses about past and future conditions in Irish agriculture. Why are factor share adjustments relatively slow? Can adjustment be speeded up, and if so at what social cost? Are economies of scale really increasing over time, and why? As output increases, will the decline in the agricultural labour force slow or even reverse itself? Will pressure on agricultural land increase as output increases? Is Irish agriculture (and its profitability) particularly sensitive to real increases in input prices? It is hoped that this paper has at least drawn the attention of policymakers to the possible shape of the aggregate production function for Irish agriculture and to the more important relationships that can be derived therefrom.

REFERENCES

GRILICHES, ZVI. 1963. "The Sources of Measured Productivity Growth: United States Agriculture, 1940-60" *Journal of Political Economy*, Vol. 71, pp. 331–346.

RASMUSSEN, KNUD, with M. M. SANDILANDS 1962. *Production Function Analyses of British and Irish Farm Accounts*. Loughborough; University of Nottingham, School of Agriculture, England.

TYNER, FRED H. and LUTHER G. TWEETEN 1965. "A Methodology for Estimating Production Parameters." *Journal of Farm Economics*, 47: pp. 1462–67, Dec.

TYNER, FRED H. and LUTHER G. TWEETEN 1966. "Optimum Resource Allocation in US Agriculture." *Journal of Farm Economics*, 48: pp. 613–631, August.

Appendix Table 1: *Time series data, 1956-75*

Item	*Inputs (£ million)* *Fertiliser and lime*	*Feed and seed*	*Labour*	*Machinery dep. and int.*	*Real estate int.*	*Machine op. exp.*	*Misc. op. exp.*	*Cattle ins., int.*	*Rates*	*Gross output (£ million)* *Undeflated*	*Deflated*	*Agricultural price index (1953=1.00)*
1956	8.6	23.7	77.2	8.2	1.4	6.0	8.0	3.2	7.4	175.5	187.7	.935
57	9.1	24.7	77.2	8.4	1.6	6.8	8.4	3.2	7.6	190.3	190.7	.998
58	9.6	26.2	76.8	8.8	1.9	6.9	8.5	4.8	7.7	178.3	174.0	1.025
59	8.5	25.7	79.2	8.5	1.1	7.3	8.7	2.5	8.2	180.2	176.0	1.024
60	8.3	24.0	81.8	8.9	1.6	7.4	9.4	3.6	8.4	191.4	192.2	.996
1961	8.4	28.7	86.1	8.9	1.7	7.7	10.0	3.7	8.9	209.4	209.4	1.000
62	10.2	31.0	74.2	10.7	1.8	7.9	10.2	4.0	7.0	209.0	205.5	1.017
63	11.2	32.0	73.8	11.0	1.2	8.3	10.9	2.7	7.5	211.4	206.8	1.022
64	11.4	33.5	84.0	12.4	2.1	8.8	11.8	5.1	7.2	230.4	203.7	1.131
65	12.4	41.4	90.1	14.4	3.5	9.3	12.6	9.1	8.1	232.4	197.5	1.177
1966	12.6	41.2	102.5	15.7	3.3	9.9	13.5	8.2	9.1	242.5	209.2	1.159
67	15.8	41.5	101.0	17.3	4.4	10.4	14.5	9.5	7.7	272.2	230.1	1.183
68	18.8	47.8	108.5	19.7	7.2	10.9	15.4	15.0	8.6	298.3	228.8	1.304
69	21.6	51.7	122.0	23.9	7.6	12.3	18.3	17.4	9.9	312.5	233.0	1.341
70	23.0	58.6	132.7	29.0	7.7	13.6	20.3	20.2	11.1	330.5	235.6	1.403
1971	28.2	67.1	162.7	33.5	9.0	15.9	23.7	22.1	13.3	381.5	254.2	1.501
72	30.8	71.2	187.2	38.9	8.3	17.6	26.7	21.8	15.4	441.4	242.1	1.823
73	42.0	102.9	206.6	51.2	23.7	20.3	31.5	76.5	15.1	559.1	234.7	2.382
74	55.0	120.2	239.7	73.2	25.5	29.6	39.9	68.4	15.7	646.3	267.5	2.416
75	68.8	127.0	281.9	97.7	36.6	34.4	52.8	72.2	16.5	909.0	293.7	3.095
Mean value	20.74	51.01	122.26	25.02	7.56	12.57	17.76	18.66	10.02	320.08	218.62	1.397
Mean factor share (%)	6.48	15.94 5.36	38.20	7.82	2.36	3.93	5.55	5.83	3.13	100.00	–	–
Ratio 1975/1956	8.00	5.36	3.65	11.91	26.14	5.73	6.60	22.56	2.23	5.18	1.56	3.31
Mean value 56-65	9.82	29.09	80.04	10.02	1.79	7.64	9.85	4.19	7.80	200.83	194.35	1.033
66-75	31.66	72.92	164.48	40.01	13.33	17.49	25.66	33.13	12.24	439.33	242.89	1.761
Mean factor share (%) 56-65	4.89	14.48	39.85	4.99	0.89	3.80	4.90	2.09	3.88	100.00	–	–
66-75	7.21	16.60	37.44	9.11	3.03	3.98	5.84	7.54	2.79	100.00	–	–