Capital Formation, Technical Change and Labour Productivity Improvement: An Analysis of a Cross-Section of Irish Manufacturing Industries 1953/1967

NOEL J. J. FARLEY*

THE recent economic literature has given a good deal of attention to the analysis of production and technical change. During the second half of the 1950's, Solow published his path-breaking article on the causes of labour productivity improvements in the private non-farm sector of the American economy.[1] Soon thereafter Massell was completing a similar analysis of American manufacturing industries.[2] The introduction of a new production function—the CES—then followed and opened the door to a new generation of studies of production and technical change.[3]

During the 1960's the Irish economic literature had included contributions which filled in some of the preconditions for similar analysis of Irish production activities and Kennedy's excellent essay represented the first major effort to understand the causes and effects of improvements in labour productivity in Irish manufacturing industries.[4] Kennedy proceeded with very aggregated capital stock estimates but lacked them for individual Irish industries, and suggested that such analysis would be greatly enhanced by the use of more disaggregated capital stock estimates.[5] On the basis of his comprehensive analysis, he concluded that improvements in labour productivity could be more readily explained by technical change than by increasing capital to labour ratios.

This paper picks up where Kennedy's analysis leaves off and uses capital, labour and output series to examine the causes of labour productivity improvements in 44 Irish manufacturing industries over the period 1953–1967. In its basic methodological approach this paper is cut from the Solow/Massell cloth which seems to provide a satisfactory operational base from which to proceed, and

*I want to thank K. Kennedy and G. Hughes for comments on an earlier draft of this paper. I, of course, take full responsibility for the final product.

1. R. M. Solow [11]
2. B. F. Massell [7]
3. *See*, for example, K. J. Arrow et al (1); B. Minhas (8).
4. K. Kennedy [6].
5. K. Kennedy [6], pp. 132–133.

although there would be great value in experimenting with other approaches to interpreting the behaviour of labour productivity, the basic data at hand are not appropriate to the task.

Many of the estimates included in this paper are crude because of the nature of available data, but efforts are made to make procedures of estimation clear at each step so that a healthy scepticism can be maintained at all times. With few exceptions, I am satisfied that the picture that emerges is a good approximation of the realities of the Irish manufacturing experience between 1953 and 1967.

In the next section, the analytical framework is constructed. A presentation of the data follows and a discussion is undertaken of the methods of compilation of the output, labour and capital series. Causes of labour productivity improvements in each of the 44 industries are then sought and the results are put together to find overall patterns of change. A number of sections then seek out causes for the patterns of technical change in groupings of industries. The implications of the findings for the rôle of capital in the process of industrialisation are then discussed and the conclusion puts the findings into perspective and suggests an agenda for future research.

Capital, Technical Change and the Production Function

The starting point for the analysis is a Cobb-Douglas form of the production function:

$$Y = Ae^{rt}K^{\alpha}L^{(1-\alpha)}, \qquad (1)$$

where Y is the level of output, A is the technical coefficient at a moment of time, e^{rt} is an index of technical change where t represents time and r is a parameter to be estimated for each industry, K is the quantity of capital; L the quantity of labour, α $(1 - \alpha)$ the elasticity of output with respect to a 1 per cent change in capital (labour). α $(1 - \alpha)$ can also be interpreted as the share of income going to capital (labour).

In this form of the production function, constant returns to scale are assumed and the elasticity of substitution between labour and capital is assumed to be one. This last assumption has the implication that factor shares in income remain unchanged over time. Also in this form of the function, technical change is simply a function of time and is assumed to be neutral.[6]

Differentiation of the function with respect to time and dividing through by Y gives us the equation:

$$y = r + \alpha k + (1 - \alpha)\, l \qquad (2)$$

where y, k and l are the annual rates of growth of output, capital and labour respectively. r is the contribution of technical change to the annual rate of growth of output.

6. For this kind of model see Solow [11] and Massell [7].

To get the annual rate of growth of output per man, subtract l from each side and then:

$$(y - l) = \alpha(k - l) + r. \qquad (3)$$

The annual rate of improvement of labour productivity depends on the rate of increase of the capital to labour ratio, the importance of capital in the production process as indicated by α, and the rate of technical change as reflected in r.

As Solow would put it, it is necessary to distinguish between a movement along the function and a shift of the function. The movement along the function is reflected in α $(k - l)$. If α is constant over time because of a unitary elasticity of substitution the success of moving along the function to raise labour productivity depends solely on rising capital to labour ratios. The shift of the function occurs through r and provides a second explanation for improving labour productivity through time. Which forces are paramount in raising labour productivity cannot be indicated on *a priori* grounds and can only be judged by an examination of industry data which the later analysis of this paper will undertake.

Technical know-how and technical change, of course, cover a multitude of forces which influence the level and rate of growth of output and which are not accounted for under labour and capital. For present purposes, improvements in the quality of labour caused, as examples, by better on-the-job training and education are not included under labour and show up under technical change. More advanced technology embodied in new capital equipment also shows its influence under technical change rather than under increases in the physical volume of capital.

A useful if not all-encompassing distinction has been drawn by Denison.[7] He distinguishes between improvements in technological and managerial knowledge, or put another way, between more advanced technological methods and better managerial and organisational know-how. For present purposes, it will be useful to distinguish between technical change which is unrelated to changing quantities of factors and technical change which depends on changes in the quantities of factors in individual industries. The first type of technical change encompasses improved efficiency in the production process caused by managerial improvements, by an up-grading of the quality of labour already engaged in production and by improved quality of labour and capital caused by the replacement of these factors. The second type of technical change covers the important category of improvements caused by the addition of new labour and capital to the total of factors already in use. In particular, new technical knowledge embodied in capital equipment can be most easily achieved by industries which are increasing the quantities of capital in use. Whether increasing quantities either of labour or of capital or of both has a part in bringing about technical change can only be determined by the examination of industry data and a

7. E. F. Denison [5] ch. 20.

number of hypotheses are tested statistically in this regard for the 44 manufacturing industries.

Finally, no account has yet been taken of the possibilities of returns to scale. By making the incomes shares of equation (2) equal to one, this kind of possibility has been precluded. Both the scale factor and technical change can be readily incorporated into equations (1) and (2) as follows:[8]

$$Y = (AE^{B_1+B_2T}K^{a}L^{(1-a)})^{s} \tag{1A}$$

where $T = ak + (1 - a)\,l$

and

$$y = B_1s + sa\,(1 + B_2)k + ls\,(1 - a)(1 + B_2)l \tag{2A}$$

where B_1 is the level of technical change with $T = 0$, B_2 is the contribution of a 1 per cent change in T to r, and s is the scale factor (if $s = 1$ there are constant returns to scale etc.).

Improvements in labour productivity are then equal to:

$$(y - l) = B_1s + sa(1 + B_2)k + l(s(1 - a)(1 + B_2) - 1) \tag{3A}$$

so that improvements in labour productivity depend on not alone the importance of capital in the production process and the rise in the capital to labour ratio but also the importance of the scale factor and the way technical change is introduced (as reflected in the values of B_1 and B_2).

This analysis, then earmarks the forces which go into improving labour productivity. Statistical procedures must now be developed to measure the impact of these forces on the level of labour productivity in individual manufacturing industries.

The Data for 44 Manufacturing Industries

The immediate tasks are to present output, labour and capital series and to arrive at estimates for the shares of labour and capital in total income for the 44 industries.

With regard to the output, labour and capital series, I must acknowledge a great debt to Mr. Eamon Henry of the Central Statistics Office, Dublin. He made available these series for 50 manufacturing industries and without them the current work would have been impossible.[9]

The output series for these industries are measured in 1958 prices and unlike the published CIP gross output series, beginning work in progress is subtracted from the gross output figures in order to provide an output series which we can call "gross output less beginning inventories." This has great advantages for our

8. The idea for this technical change function comes from: B. Balassa and T. Bertrand [2].

9. These statistics compiled by Mr. Henry are unpublished and unofficial.

present purposes, although as has been noted by many scholars of Irish industrial series, the ideal type of output series would be one of value added measured in constant prices.[10] This "gross output less beginning inventories" series covers all costs of production (in the broadest sense) including depreciation of capital.

The labour series is measured on a man-year basis. Ideally, a man-hour series would have been preferable but this was impossible to derive for all the industries in the groupings examined here. Not too much is lost, however, as man-hour labour series and man-year series provide similar results in these kinds of production studies,[11] and Kennedy has shown that in the Irish context there is a strong and significant relationship between changes in man-hours and man-years for a cross-section of Irish manufacturing industries between 1953 and 1967.

As compiled by Mr. Eamon Henry, the capital stock data are for fixed assets including land and have been compiled on what Henry calls an "equivalent new" basis.[12] In his presentation of the data, Henry provides an extended discussion of the difficulties of measuring capital and critically appraises Nevin's estimates as well as providing new estimates of the capital stock in the post-1945 period using Nevin's procedures.[13] Nevertheless, his "equivalent new" series is by far his most valuable contribution not alone because it is estimated on more firmly based procedures and data than were used in Nevin's work but also because these estimates are broken down into six categories of fixed assets for each industry and provide fixed capital stock information for each of 50 industries.

With these equivalent new series for 50 industries at hand, a number of procedures were followed:

(*a*) The equivalent new series were transformed into a written down replacement cost series of the fixed capital stock for each of the 44 industries examined in the study. The major corrections used were to write down the asset to between 20 per cent and 25 per cent of its original value rather than the 80 per cent for new assets used by Henry.[14] There were some gaps in information in the process of undertaking this task. Some approximations in measurement were therefore necessary but nevertheless the series that emerged seemed worthy of a high degree of confidence.

(*b*) The resulting written down replacement series were viewed as estimates of capital available to each industry. For the purpose at hand, of greater significance is capital in use in each industry. The estimation of capital in use was the most difficult procedure of all. The chosen one was somewhat similar to that used by

10. As an example, see Kennedy [6].

11. See, as examples: E. F. Denison [5], E. F. Denison [4].

12. The method of compiling these data has been described in a mimeographed paper written by Mr. Henry.

13. The reference here is to: E. Nevin [10].

14. Henry's procedures for dealing with the depreciation of assets are described well in his immeographed paper.

Massell.[15] The first step was to find a capital in use to labour ratio for 1953 in each series. This was done for each industry by multiplying the capital available by the ratio of labour use for 1953 to peak labour use (for 1953 or a previous year).[16] The next step was to compute for each industry the annual rate of change of the ratio of capital-in-use to labour over the period 1953 to 1967. In many cases, the year of peak labour use was 1967 and then it was a simple matter to compute the annual rate of change of the ratio of capital-in-use to labour and to estimate capital-in-use in 1967. In other cases, the year of peak labour use was before 1967 and then the annual trend of capital-in-use to labour was computed between 1953 and that year. With extrapolative procedures, the resulting trend value was used to find the capital-in-use to labour ratio applicable to 1967 and as a final step to estimate capital-in-use in that year.

Most certainly, this method of estimating capital-in-use is only a crude approximation of the reality but the choice of procedures serves to highlight the difficulties involved. Nevertheless, while it is necessary to proceed with care in the use of these data, examination of the basic data seems to indicate that, with a few exceptions, the estimates of capital-in-use are close to the reality.

Once estimates are found for output, labour and capital-in-use in 1953 and 1967, it is a simple matter to estimate annual rates of change of these variables and these are included in table 1A.

The other immediate statistical task was to find values for the shares of labour and capital in the value added of the 44 chosen industries. The basic material to fulfil this task is to be found in the 92 sector input-output table for Ireland in 1964.[17] From this table it is possible to estimate value added before depreciation and to break down the distribution of the value added into labour income and capital income (profits plus depreciation). The choice of value added including depreciation is dictated by the nature of the output series, which is computed without a subtraction for depreciation. Conceptually, it would be preferable to compute both of these series net of depreciation but this is not possible.

A number of difficulties arose in completing this step of the estimation procedure. First, the industry breakdown in the capital output and labour series was not exactly the same as that used in compiling the input-output table. On this front, however, the difficulties were few and with minor exception were easily overcome. Secondly, a good question was whether the factor shares for 1964 were a good reflection of factor shares through the whole period 1953–1967. Unfortunately, the input-output tables for 1956 and 1960 provided little help in answering this question, because of the degree of aggregation involved in their construction. The only course of action left was to examine the data in the annual Census of Industrial Production for the period. Results for the years 1953, 1964 and 1967 were analysed and in many cases it was noted that the average

15. See Massell [7].

16. See Massell [7].

17. Industry classifications changed in 1953 and thus there were some difficulties in achieving this task. Some of the estimates had to be approximations and subject to a a degree of error.

of the ratio of wages and salaries to net output in 1953 and 1967 was different to the same ratio in 1964. The assumption had now to be made that percentage changes in the wages and salaries to net output ratio derived from CIP data provided a fair reflection of the changes in labour's share in value added as compiled from input-output tables.[18] On this basis, an allowance was added to or subtracted from the 1964 estimates derived from the input-output table to bring the 1964 estimate more into line with the average of the estimates for 1953 and 1967.[19]

The 1964 weights are included in table 1A. Values for $\alpha(k - l)$ are included in table 2A. These are based on 1964 values of α. An adjustment for changes in the value of α is made and recomputed values for $\alpha^*(k - l)$ are also included.

The Characteristics of the Industries under Review

Before we proceed to examine the main statistical results of the paper, a look at the industries under review is in order. The 44 industries picked out for analysis are similar in most cases to those published in the Census of Industrial Production as seen in the *Irish Statistical Bulletin* and the *Statistical Abstract of Ireland*. There are eleven food industries with flour mill and animal feeding stuffs handled as separate industries and with fish dealt with as an individual industry. The five drink and tobacco industries, the four textiles, the eight leather shoe and clothing industries, nine wood, furniture, minerals, chemical industries and the seven metal paper and publishing industries all fit the categories of industries published annually in the Census of Industrial Production.

An overall review of the performance of these 44 industries provides some interesting insights:—

(*a*) The unweighted mean rate of growth of output for these industries between 1953 and 1967 was 4·98 per cent. With a standard deviation of 3·91, this provided for a variety of experiences regarding the rate of growth of output. Such industries as men's clothing, flour mills and tobacco experienced decreases in output while annual rates of growth of over 10 per cent were enjoyed by the electrical machinery, fertiliser and chemical industries.

(*b*) As could be expected, capital grew at a faster rate than labour. The 4 per cent difference between these unweighted mean growth rates was substantial but hid a great diversity of experience among these industries. Only miscellaneous clothing and made-up textiles had labour growing faster than capital, and the rate of growth of capital exceeded that of labour by 6 per cent or more in soft drinks, wood, brooms and brushes, fertiliser and non-electrical machinery.

18. This assumption is unfortunately necessary. CIP net output figures include more than factor incomes but the annual breakdown of the published data permits no further sorting out of the components of the net output series for individual industries.

19. The resulting estimates for α and for $(1-\alpha)$ for individual industries are averages of the values of these factor shares over the period.

(*c*) Looking at the individual components of the capital to labour ratio it is to be noted that the rate of growth of labour showed greater variation across these industries than the rate of growth of capital. In fact eleven industries had negative rates of growth of labour, while fish and electrical machinery had an annual rate of growth of labour of 8 per cent or more.

(*d*) The unweighted mean rate of growth of labour productivity was 3·05 per cent and this rate of growth also showed great diversity across industries. The unweighted mean rate of growth of capital productivity was negative over the period indicating a decline in the average and marginal productivities of capital. As reflected in the coefficient of variation, it is also clear that besides a lower rate of growth of capital productivity as contrasted with the rate of growth of labour productivity, the rate of change of capital productivity was also subject to a greater diversity of experience across these industries than was the change in labour productivity.

(*e*) Finally, α, the elasticity of output with respect to a 1 per cent change in capital, had an unweighted mean of ·317. The equivalent statistic for $(1 - \alpha)$, the elasticity of output with respect to a 1 per cent change in labour, was ·683 and by the nature of the limits (0 to 1) in which each could operate, the coefficient of variation for α was greater than for $(1 - \alpha)$. Great diversity in production techniques is reflected in the standard deviation and coefficient of variation for α and $(1 - \alpha)$, ranging from ·612 for α in brewing to ·044 for α in motor and other vehicles. This has great significance for the kind of conclusions that can be drawn from cross section analysis of these industries and we will have reason to return to this question shortly.

The Analysis of Improvements in Labour Productivity

The basis of our point of departure for this analysis is equation (3):—

$$(y - l) = \alpha (k - l) + r$$

For each of the 44 industries values of y, l, k, and α are included in tables 1A and 2A and table 3A includes measures of annual improvements in labour productivity for each industry, the part of it that can be explained by a rise in the capital to labour ratio and the residual part that can be explained by technical change. Neither in equation (3) nor in tables 1A, 2A, 3A is the influence of scale factors given explicit recognition (as in equation 3A) and as a result its effects are implicit in both $\alpha (k - l)$ and r. Finally, table 3A shows the percentage of the improvement in labour productivity which can be accounted for by technical change and a summary of these results for the 44 industries is included in table 2.

These results are striking in many respects. Most important of all is the finding that across these 44 industries the unweighted mean of the percentage of labour productivity improvement accounted for by technical change was 52 per cent but the diversity of individual industry experience is reflected in a coefficient of variation of 135·2 per cent. If we assume, arbitrarily by necessity, that 30 per cent is a dividing line between significant and insignificant contributions of technical change to the improvement of labour productivity, then we find that

TABLE 1: *Summary Statistics for the 44 Industries*

	Unweighted Means	*Standard Deviation*	*Coefficient of Variation*
k	5·94	4·4	74·1
l	1·91	2·8	146·6
$k-l$	4·02	2·8	69·6
y	4·98	3·9	78·5
$y-l$	3·05	2·2	71·1
a	·317	·134	42·2
$(1-a)$	·683	·134	19·6
$a^*(k-l)$	1·49	1·1	75·0
r	1·56	2·2	135·2
$y-k$	—·96	3·2	328·1

Sources: Tables 1A and 2A.
*Adjusted as described on page 30.

29 of the 44 industries (or approximately 66 per cent) gain significant help from technical change in improving labour productivity. Leaving out the food industries which appear to have problems of their own, we discover that the same conclusion can be drawn for 25 out of 33 industries (or 75 per cent).

Travelling the further step of asking the frequency with which technical change is more important than the growth of factors in raising labour productivity, the answer is 24 out of the 44 cases (55 per cent approx.). Leaving out the food industries again, the answer is 21 out of the 33 cases (63 per cent).

Looking at the nine industrial groupings included in table 2, a dramatic result is the apparent lack of technical change in the food, drink and tobacco industries. Eight of the eleven food industries, tobacco and brewing received negative contributions from technical change to the improvement of labour productivity. Explanations for the behaviour of r in these 10 as well as in men's clothing and other vehicles will be sought later in the analysis. Important also is the performance of the clothing group where vigorous technical change was in operation.

In its statistics for the 44 industries, table 2 seems to say that there was a great diversity of experience with technical change. When the results for the 12 industries with negative residuals are left aside, the pattern becomes somewhat more uniform. In that case, 29 out of 32 industries have r's contributing over 30 per

TABLE 2: *Frequency Distribution of Weight of Technical Change in Improving Labour Productivity in Nine Industrial Groupings*

Industry	*Percentages* 100+	90–99	80–89	70–79	60–69	50–59	40–49	30–39	20–29	10–19	0–9	*Negative*	*Total*
Food	0	0	0	1	1	1	0	0	0	0	0	8	11
Drink and Tobacco	0	0	0	1	0	1	0	1	0	0	0	2	5
Textiles	1	0	0	1	1	1	0	0	0	0	0	0	4
Clothing, Leather, Shoes	2	0	2	1	1	0	0	0	0	0	1	1	8
Wood and Wood Products	0	0	0	0	0	1	1	0	0	1	0	0	3
Chemicals	0	0	0	0	2	0	0	1	0	0	1	0	4
Minerals	0	1	0	0	0	1	0	0	0	0	0	0	2
Metals	1	0	1	0	0	1	0	1	0	0	0	1	5
Paper and Printing	0	0	1	0	1	0	0	0	0	0	0	0	2
Total	4	1	4	4	6	6	1	3	0	1	2	12	44

Source: Table 3A.

cent to $(y-l)$ and 26 out of 32 finding technical change quantitatively more important than a rising capital to labour ratio in improving labour productivity.

To reinforce the findings of this section, we will make use of rank correlation analysis. Rank correlation coefficients were sought between (1) $(y-l)$ and $(k-l)$, (2) $(y-l)$ and r and (3) $(y-k)$ and $(y-l)$. Data for the 44 industries were used to derive these coefficients. The results were as follow:—

Dependent Variable	*Independent Variable*	*Kendall's Tau*	*Remarks*
$(y-l)$	$(k-l)$	·119	not significantly different from 0 at the 5 per cent level
$(y-l)$	(r)	·636	significantly different from 0 at the 1 per cent level
$(y-k)$	$(y-l)$	·298	significantly different from 0 at the 1 per cent level

Source: Table 3A.

The first two of these results underline the unimportance of rising capital to labour ratios and the vital significance of technical change in improving labour productivity in these industries. The third result adds fuel to the fire of suspicion that technical change has a lot to do with determining the behaviour of the productivity of both labour and capital.

Industries with Negative Residuals

As indicated above, a cluster of twelve industries experienced negative residuals. What kinds of possible explanations can be provided for these results?

It is important at the beginning to pull out the cases where the negative residuals are associated with decreases in labour productivity. These cases were bacon, vegetable canning, men's clothing, and other vehicles, and in these cases the negative residuals are strong enough to decrease labour productivity. In three cases the factor input (T) is growing as is total output. The exception is men's clothing. In all of these four cases, however, rising capital to labour ratios make positive contributions to raising labour productivity. The remaining eight cases have improving labour productivity and thus the negative residuals are less dominant in influencing the sign attached to $(y-l)$.

With regard to these negative residuals, a number of possible explanations were explored:—

(a) Failures to Measure Appropriately Capital-in-Use

As was described earlier, an effort was made to adjust the figures of available capital so that appropriate measures would be found for capital-in-use. This was done by seeking out for each industry the rate of change in the ratio of capital-in-use to labour. This was easily achieved when labour-in-use was subject to some fluctuations over the period, although even here the possibility of error was always present, but it was a much more difficult procedure when an uninterrupted trend in labour use existed as reflected in peak labour use falling in either 1953 or 1967. In these cases, there was a possibility that the chosen statistical procedure would fail to pick up the emergence of excess capacity in individual industries.[20]

The year of peak labour use in each of the industries was as follows:—margarine, etc. 1953; flour milling 1953; sugar and sugar confect. 1963; other food 1964; bread 1953; bacon 1967; vegetable canning 1965; milk and milk products 1967; brewing 1965; tobacco 1967; men's clothing 1953; other vehicles 1967.

Those with peak year use of labour occurring in 1953 and 1967 were then picked out and $(y-k)$, k and y were compared for the periods 1953–1967 and 1964–1967. The results are included in table 3.

TABLE 3: *Rate of Change of Capital Productivity, Output and Capital*

	1953–1967 $y-k$	*1964–1967* $y-k$	*1953–1967* y	*1964–1967* y	*1953–1967* k	*1964–1967* k
Margarine etc.	−3·0	1·2	·8	4·3	3·8	3·1
Flour Milling	−3·0	−1·0	−1·1	2·0	1·9	3·0
Bread	−4·2	−2·6	−·2	1·3	4·0	3·9
Bacon	−4·0	−7·6	1·8	1·6	5·8	9·2
Milk and Milk Products	−3·7	−3.8	5·5	11·2	9·2	16·0
Tobacco	−4·9	−6·4	−·7	·8	4·2	7·2
Men's Clothing	−2·9	−2·4	−·9	1·7	2·0	4·1
Other Vehicles	−6·7	−16·6	2·5	2·6	9·2	19·2

Sources: Unpublished data provided by Mr. Eamon Henry of the Central Statistics Office, Dublin.

On the basis of these results, it was decided to sort out bacon, milk and milk products, tobacco, men's clothing and other vehicles and to use an annual rate of growth of capital-in-use which was more an approximation to the rate of growth of capital-in-use over the period 1953–1964. The contributions by rising capital to labour ratios and by technical change to the improvement of labour productivity are then recomputed and the results are included in table 4.

It is seen that the adjustment of k makes little difference to the results except in the case of milk and milk products where the percentage contribution of r to the

20. This possibility of course existed for all industries and on the basis of the results, there was a suspicion that it might apply to the fertiliser industry.

TABLE 4: *Re-estimated Capital Growth Figures and the Change in Labour Productivity (Recomputed)*

	k	$a^*(k-l)$	r
Bacon	4·9	·5	−1·0
Milk and Milk Products	7·3	1·3	·4
Tobacco	3·4	1·9	−1·6
Men's Clothing	1·4	·2	−·5
Other Vehicles	6·5	·1	−2·0

Source: As for table 3.

improvement of labour productivity switched over from being negative to making a positive contribution of 23·5.

b) Failure to Make an Appropriate Choice of the Form of the Production Function

A serious possibility of error was in the choice of the form of the production function. In the chosen form, a key assumption has been that the elasticity of substitution between the factors is equal to one and that technical change has been neutral in its impact. We thus have avoided any kind of measure of α, the elasticity of substitution. Could this have seriously distorted the reported results?

Unfortunately, because of the nature of the available data, we are unable to measure the magnitude of the elasticity of substitution along the lines suggested by Minhas and others. What we can do, however, in the case of these industries with negative residuals is to ask what value of α could wipe out the negative residuals in these industries.

The procedure to meet this objective is a refined version of an equation suggested by R. R. Nelson[21] as appropriate to the measurement of technical change in industries where the elasticity of substitution (σ) can take on a variety of values:

$$r \approx y - \alpha k - \beta l - \tfrac{1}{2}\alpha\beta\left(\frac{\sigma-1}{\sigma}\right)(k-l)^2 + l \qquad (4)$$

In our case we assume that $\beta = (1-\alpha)$ so that the equation reduces to:

$$r \approx (y-l) - \alpha(k-l) - \tfrac{1}{2}\alpha(1-\alpha)\left(\frac{\sigma-1}{\sigma}\right)(k-l)^2 \qquad (5)$$

For each of these twelve industries we can conduct the exercise of assuming that $r = 0$, and as values are available for all the other variables, we can find the required value of σ. These results are included in Table 5.

21. R. R. Nelson [9].

TABLE 5

	Required σ
Margarine etc.	·66
Flour mills	·88
Sugar and sugar confect.	1·17
Other food	·86
Bread	·73
Bacon	·44
Vegetable Canning	·54
Milk and Milk Products	1·35
Brewing	·53
Tobacco	·60
Men's Clothing	·39
Other Vehicles	·19

Note: 1964 values of α have been used in these computations.

An examination of the required values of σ, in association with the change in income shares as reflected in Table 2A suggests that diminishing returns may have some importance in the following cases: bread, bacon, vegetable canning, other food, brewing and tobacco. The decline in the technical coefficient continues to be important for margarine, flour milling, sugar and sugar confectionery, milk and milk products, men's clothing, and other vehicles. For the former group, diminishing returns provides us with explanatory power only in the absence of technical change, and technical change of a size equivalent to that achieved in other industries would have permitted more substantial improvements in the average productivities of labour and capital.

(c) Failure to Account for Changes in the Sex and Age Composition of Labour-in-Use

Another distinct possibility is that the composition of the labour force was shifting in favour of female labour and the under-18 age group. When this is so, we assume that the lower weekly earnings for these two groups in contrast to that for men over 18 years of age is a reflection of the lower productivity levels of these units of labour. Industries with negative residuals which were tending to use increasing proportions of female and under 18 years old labour would tend to attribute too much of the drag on their labour productivity improvement to a decline in their technical coefficient and too little to difficulties with the labour force. Whether this possibility has any explanatory value for these twelve industries must now be examined empirically.

A procedure by which to do this is to examine the changes in the composition of labour and to adjust the rate of growth of labour figures for changes in composition. This is done by creating equivalences for various kinds of labour by using relative weekly earnings as weights for computing these growth rates.

An examination of Table 6 suggests that, in the light of this possible explanation

TABLE 6: *Changes in the Age and Sex Composition of the Labour Force in the Negative Residual Grouping of Industries*

	Year	*Females Labour force*	*Under 18 Labour force*	*Year*	*Females Labour force*	*Under 18 Labour force*
Margarine etc.	1952	33·2	3·4	1967	39·3	5·9
Flour*	1953	9·1	3·9	1966	11·8	4·5
Sugar and sugar confect.	1953	49·7	16·8	1967	49·3	8·2
Other food*	1953	52·6	15·1	1966	43·8	8·8
Bread	1953	28·9	12·9	1966	33·1	11·6
Bacon	1954	30·4	5·1	1966	27·5	6·2
Vegetable Canning	1953	67·5	14·3	1966	58·9	7·0
Milk and Milk Products	1953	12·1	·9	1966	13·9	2·9
Brewing	1954	10·8	4·3	1966	15·5	3·4
Tobacco	1954	54·8	7·3	1967	50·5	·5
Men's Clothing	1953	78·1	28·8	1966	76·3	24·9
Other Vehicles	1953	12·3	14·8	1966	10·6	4·3

	Ratio of Female Ratios at the beginning and end of the period	*Ratio of Under 18 Ratios at the beginning and end of the period*
Margarine etc.	118	173
Flour*	130	115
Sugar and sugar confect.	99	49
Other Food*	83	58
Bread	115	89
Bacon	90	122
Vegetable Canning	87	49
Milk and Milk Products	115	322
Brewing	143	79
Tobacco	90	7
Men's Clothing	98	86
Other Vehicles	86	29

Notes: *Flour here covers grainmilling and animal feeding stuffs; other food includes fish but fish is a small part of the total. The nature of the published data forced an acceptance of these categories.

Source: Irish Trade Journal and Statistical Bulletin (Irish Statistical Bulletin for later issues)—various issues.

of the negative residuals, we should pick out margarine etc., flour milling, bread, bacon, milk and milk products and brewing for further examination.

The procedures indicated above have been used to recompute the rate of growth of labour and the results are included in Table 7. In each of these six cases the negative residual now falls in magnitude and in the cases of milk and milk products and flour milling, *r* now makes a positive contribution to the rate of improvement of labour productivity.

TABLE 7: *Re-estimation of r for the Six Industries with Negative Residuals*

	l	*k*	(*k* – *l*)	(*k* – *l*)	*r*	(*y* – *l*)
Margarine etc.	–·8	3·8	4·6	2·3	–·6	1·6
Bread	–·8	4·0	4·8	1·6	–1·0	·6
Bacon	1·8	5·8	4·0	·8	–·8	0
Milk and Milk Products	1·9	9·2	7·3	2·7	·9	3·6
Flour Milling	–3·7	1·9	5·6	2·2	·5	2·7
Brewing	·4	6·0	5·6	3·4	–3·1	·3

Note: The method of computation of *l* is described above. Sources are indicated on page 39. The remainder of the basic figures are taken from tables 1A and 2A. When the re-estimated values of *k* are taken from table 4, and substituted in for the values of *k* in this table, the sign of *r* in bacon and milk and milk products is not changed.

(d) Possible Errors in the Computation and Use of α and the Output Series

Two possible sources of error arise in this regard. First, the adjusted values of α may be subject to a margin of error. In so far as this adjustment was erroneously positive, the contribution of technical change to the improvement of labour productivity would be underestimated. An examination of the adjustments as contained in Table 2A suggests that this possibility takes on importance in causing negative residuals in only two cases. These are sugar and sugar confectionery, etc. and milk and milk products. The removal of the adjustment causes these industries to have small but not significantly large positive residuals. Secondly, the output series used may tend to underestimate the rate of growth of value added measured in constant prices. The way to catch this kind of bias is to examine the change in the ratio of net to gross output over the period. This provides no certain procedure with which to determine whether the bias in question does in fact exist. But given the nature of available data it may give us some help. In all twelve industries with negative residuals, the ratio of net to gross output increases over the period and this opens the possibility that anyone of the negative residuals might disappear in the face of new output series based on the value added concept measured in constant prices.[22]

What then can be concluded about the causes of the decline in the technical coefficient? A number of findings can now be reported: (*a*) If we bring together the adjustments to the capital stock and make allowance for the changes in the age and sex composition of the labour force in computing the rate of growth of labour, we find that two industries out of the twelve now have a positive rather than negative residual. These are milk and milk products and flour milling. (See Table 7.) (*b*) When we examine the remaining industries, we find a cluster of four where performance has been caused by the decline in the level of technical know-how and another grouping of six where the explanation lies with either the decline in technical know-how or the strength of diminishing returns. Even if the required σ values could be achieved after adjustments have been made for k and l, it is clear that technical change is making little contribution in these cases to the improvement of labour productivity.

(*c*) It is possible that decreasing returns to scale could be in operation in all of these industries except for miscellaneous clothing. It is unfortunate that scale factors could not be singled out for separate examination.

(*d*) The character of the output series may be responsible for the negative residuals. A series based on value added at constant prices might tend to turn negative into positive residuals although it seems likely that most of these twelve industries would still have only small contributions by technical change to the improvement of labour productivity.

Probably the most notable feature of this cluster of twelve industries is that the labour input declines over the period for six of the twelve industries and $(k-l)$ is above the unweighted mean average for the 44 industries in 75 per cent of these cases. Brewing's labour also has an annual rate of growth of only 0·5 per cent. Thus a high degree of capital deepening was in process in these seven cases with apparent efforts to cut out unnecessary labour. Despite the possible role of diminishing returns, we can speculate with good reason that the process of capital deepening involved major readjustments in production lines and at least a temporary loss of effectiveness had come to bear on both labour and capital. The capital deepening process involved therefore, not a movement along a production isoquant with given technology, but a shift from an isoquant in one field to another isoquant in a field involving more sophisticated technology. For these more advanced methods to reflect themselves in strong positive residuals required a probation period which had not been completed by 1967. The declining average productivity of capital in the face of substantial capital deepening can be explained then either

22. An examination of the statistics would suggest that even if we were to double y, margarine etc., bread, brewing and tobacco would still have negative residuals. Flour milling, sugar and sugar confectionery, etc., men's clothing and other vehicles would make a small, to average contribution by technical change to the improvement of labour productivity. Only other food, and milk and milk products would possibly have a significant contribution by technical change to the improvement of labour productivity.

by mistakes in company decisions and/or by government policies which subsidised heavily the process of capital deepening and/or by expectations that major gains in both labour and capital productivity could be achieved after a probationary period of "learning by doing".

While other explanations for these results may be possible and a number of these have been examined in the process of researching this paper, the conclusions just drawn, while necessarily speculative seem plausible and worthy of further examination. The advance of the science in providing tools to handle production function analyses is limiting in that 'residuals' are found and the judgment of the research becomes vital in explaining the results. This has happened as is inevitable in studies of this kind.

Industries with Positive Residuals

Leaving aside the twelve industries with negative residuals, we are now led to ask whether any causal explanations can be found for the level of technical change achieved in the remaining 32 industries. The temptation was strong to seek, by means of regression analysis, for parametric relationships between r and k, and/or l and/or T. Let us pursue this avenue of attack for a moment.

In his work on labour productivity improvements in Irish manufacturing industries, Kennedy had recourse to the so-called Verdoorn Law equation relating changes in labour productivity to the rate of growth of output. We ran the same analysis on the output and labour series used in this essay and came up with similar results to those of Kennedy:

$$(y-l) = \underset{(\cdot 04)}{1\cdot 08} + \underset{(\cdot 062)}{\cdot 394y} \qquad r = \cdot 717 \qquad \text{(A)}$$

(all results significant at the 1 per cent level)

As Kennedy pointed out, and added further evidence to make his case, this suggested strongly that improving labour productivity was caused by technical change which occurred with the rate of growth of output.

At the next stage, a similar equation was set up with $(y-k)$ as the dependent variable and y as the independent variable. The results were as follows:

$$(y-k) = \underset{(\cdot 41)}{-2\cdot 31} + \underset{(\cdot 131)}{\cdot 272y} \qquad r = \cdot 344 \qquad \text{(B)}$$

(r is significant at the 2 per cent level; the regression coefficient at the 5 per cent level, and the intercept at the 1 per cent level)

These equations seemed to indicate systematic parametric relationships across the 44-industry clustering, although equation (B) provided statistically weaker results than did equation (A). The major conclusion, however, was that the rate of growth of output had something to do with influencing the pace of change of the productivity of both labour and capital. The rôle of technical change had thus come to the fore.

Working with the 32 industries that had experienced positive residuals, regression analysis was applied to these 32 industries using *r* as the dependent variable and using *k*, *l* and *T* in turn as the independent variable. Multiple regression analysis was also tried as well as non-linear forms of the equation. No significant parametric results were derived but there seemed good reason for this to be the case.

It is a relatively uncomplicated matter to relate labour productivity improvements to technical change, but as indicated earlier, technical change is measured as a residual in the statistical procedures and its value tends to reflect the influence of all the factors not already accounted for in the analysis. The probability seems low then of discovering a statistically significant causal link between *r* and (say) *k* for these 32 industries. Each industry does or does not go about the process of improving labour productivity, and if it does, has a multitude of methods with which to achieve it. In addition, the production processes of these industries as reflected in the value of *a* are different and the degree to which increasing returns to scale can be achieved depends again on the production processes of the individual industry. Another procedure was therefore sought which involved breaking down the sample of 32 industries into clusterings of industries where a selected group seemed to have some common vehicle for achieving technical change.

The chosen method was to rank the 44 industries according to the magnitude of *r* and then to rank them again according to the magnitude of *T*.[23] The rankings were then compared for each industry. The predominant clustering was one in which the rankings were apart by 10 or less. A second clustering was of those industries where the *T* ranking exceeded the *r* ranking by more than 10 and this was classified as the "*R* biased" group. The third clustering was of those industries where the *r* ranking exceeded the *T* ranking by more than 10 and this grouping was called the "*T* biased" group.[24] Industries were then divided into the following groupings:

R—T Group Positive Residuals	*R Biased Group Positive Residual*	*T Biased Group Positive Residual*
Animal feeding stuffs, soft drinks, made-up textiles, cotton, jute, woollen, tanning, wood, furniture, brooms, chemicals, paints, non-electrical machinery, electrical machinery, pottery, motor vehicles, paper.	Clay, printing, distilling, malting, shirts, women's clothing, boots and shoes, leather, hosiery, soap, miscellaneous clothing.	Fish, slaughter, fertiliser metals.

23. The procedure was repeated for *r* and *k* and then for *r* and *l*.

24. The procedures which were repeated for *r* and *k* and *r* and *l* produced *R–K*, *R* biased and *K* biased categories, and the same principle was followed in classifying the results of the *r* and *l* analysis. The results of classification were very similar under all three methods.

R—T Group Negative Residuals	*R Biased Negative Residuals*	*T Biased Negative Residuals*
Flour milling, sugar and sugar confect., bread, tobacco, men's clothing	None	Brewing, milk and milk products, vegetable canning, bacon, other food, other vehicles, margarine etc.

(Similar groups were derived from the ranking of r and k and r and l)

The *T* biased group has been largely handled in the earlier discussion of industries with negative residuals. The fish, slaughtering and fertiliser industries are also included, however, and these are industries which experienced positive residuals but which also had substantial increases in the volume of their factors.

Most attention will be focussed on the $R-T$ group. The particular quality of this grouping is that there seems to be a systematic relationship between the magnitude of *R* and *T* suggesting that the process of growth of output seems to be associated with the embodiment of technical change in new and replacement capital and also improvement in the quality of the labour force. Linear regression analysis was therefore used to seek out the nature of the parametric relationship between *r* and *k* and the data for the 17 industries with positive residuals were submitted to this statistical procedure. The following equation was found:

$$r = -\cdot 26 + \cdot 44k \qquad r = \cdot 68 \qquad \text{(C)}$$
$$(\cdot 7) \quad (\cdot 11)$$

(all the results were statistically significant at the 1 per cent level except for the intercept).

These results indicate the plausibility of asserting a relationship between the magnitude of *r* and the growth of the factors as reflected in *k*. The same conclusion followed when a similar equation was set up between *r* and *T*:

$$r = \cdot 09 + \cdot 61T \qquad r = \cdot 83 \qquad \text{(D)}$$
$$(\cdot 36) \quad (\cdot 10)$$

(all the results were statistically significant at the 1 per cent level except for the intercept).

Adding in *l* and using *T* as the dependent variable seems to improve the fit of the equation and thus *T* is the most appropriate variable to observe as it includes improvements in the quality of the labour force and scale factors in explaining the causes of technical change. With either *k* or *T* as the dependent variable, the limited size of the intercept and its statistical insignificance indicates that the achievement of technical change is linked directly to the growth of *k* or *k* and *l*.

A warning must be entered about the use of these statistical results. They are applicable only to the industries in the grouping and to the range of values of k (and T) included for these industries. Used beyond that framework results derived from them must be viewed as unacceptable.

Let us turn to the industries in the R biased group. This small grouping enjoyed the benefits of technical change to a larger degree than the $R-T$ grouping and thus either had the benefit of a larger intercept and/or a higher regression coefficient. Let us thus perform the experiments of assuming a regression coefficient of ·61 and recompute the intercept for each industry and then assume the intercept is given and re-estimate the value of the regression coefficient. The results are as follows:

	Regression coeff. (intercept = ·09)	*Intercept (regression coeff. = ·61)*
Clay and cement	1·428	3·0
Printing	1·765	2·1
Distilling	10·000	1·0
Malting	*	4·6
Shirts	1·666	2·0
Women's clothing	1·324	1·8
Boots and shoes	*	3·2
Leather	1·428	1·2
Hosiery	1·129	2·7
Soap	1·642	1·5
Miscellaneous clothing	*	2·7

*T values were negative and thus growth of factors had nothing to do with the magnitude of r.

These results pull out a number of probable changes in the process of production. It seems clear that in the case of malting, boots and shoes, miscellaneous clothing where T is negative and in the case of distilling where a regression coefficient of 10·0 seems impossible the large magnitude of the residual can be attributed largely to technical change—management improvements, reorganisation of production, etc.—which is unrelated to the level of production. One suspects also that this same kind of technical change is in operation in the other cases, too, with the possible exception of hosiery where the growth of factors may have been responsible for a greater degree of technical change than was in evidence in the case of the $R-T$ group.

Implications of the Analysis for the Role of Capital

Analyses of this kind seem to downgrade the role of capital in improving labour productivity over time. The works of Solow, Denison and Massell provided this implication at the aggregate level and this analysis also seems to do the same for this cross-section study of industries through time.[25]

Have we paid too much attention to capital in the analysis of the process of industrialisation? The appropriate answer seems to be that some of our notions about the impact of capital are overstated but, nevertheless, many of these notions still stand and other avenues of analysis come to the fore because of studies of this kind.

What we have simply shown is that improved labour productivity is linked more to technical change than to higher capital to labour ratios. We are not saying, however, that differing capital to labour ratios across industries at a moment of time may not help to explain different levels of labour productivity in these individual industries. In the case of 40 manufacturing industries in 1967, for example, Kendall's Tau between the average productivity of labour and the capital to labour ratio was statistically significant at a value of ·52 (see Table 4A for basic data).[26] Nor are we saying that capital is unimportant for the growth of output in individual industries. For these 44 industries the unweighted mean of capital's contribution to the growth of output was 40 per cent. Finally, we are not suggesting that the behaviour of the average and marginal productivities of capital (and correspondingly the average and marginal capital to output ratios) is unimportant. This study suggests that in the period 1953–1967, the average productivity of capital appears to have fallen in 28 of the 44 industries and the policymaker has to take account of this in planning decisions.

The new role for capital, of course, is as an agent for transmitting technical change into the production process. This enables capital to play a greater indirect role in improving labour productivity even though the direct role ends up being smaller than has often been thought. Other means of bringing about technical change are also clearly in evidence and the major insight from this kind of analysis is not to ignore the role of capital but to give more weight to understanding how organisational and managerial improvements and human investment influence the process of production.

Conclusions

Further work is clearly in order on the question of what determines labour productivity improvements. The analysis of the causes of technical change produced satisfying results but indicated the need for further research. In this respect, the conviction emerged from this study that the divergence between the experiences of individual industries regarding technical change suggests an emphasis on individual industry studies rather than cross-section analyses of industries.

In general, the findings are consistent also with the Verdoorn equation. The

25. See also A. K. Cairncross [3] pp. 111–114 and other references there.

26. It is also of interest that Kendall's Tau between a and the capital to labour ratio was statistically significant at the 1 per cent level at a value of ·694.

improvement of labour productivity as output grows is now understood in terms of induced technical change and also of increasing returns to scale for the majority of these industries with positive residuals. We noted, of course, that there also appeared to have been some important exceptions where technical change was unrelated to the rate of change of output and also some where technical change was highly limited in its effects. Nevertheless, both this and the Kennedy essay lean to a degree on cross-section analyses and further insight can probably come from detailed examinations of time series for individual industries.

Needless to say, the distorting effects of some of the inevitable approximations in statistical procedures may have been missed and technical knowledge—which this writer did not have—of the operations of individual industries could have enriched further the interpretation of the results. But confidence can be put in the pattern of change and the causes of them that have been identified and analysed in this essay. It is hoped that the essay will spur on further research in this area and encourage the re-evaluation of policy preconceptions regarding the process of industrialisation.

Bryn Mawr College

TABLE 1A: *Basic Industry Data: Output, Capital and Labour Growth Rates and Values.*

Industry	+*y*	*k*	*l*	*in 1964*
Margarine etc.	·8	−3·8	−·4	·555
Slaughtering of livestock	10·8	11·7	7·7	·328
Flour mills	−1·1	1·9	−2·6	·369
Animal feeding stuffs	5·5	5·9	2·0	·206
Sugar and sugar confectionery	1·0	4·8	−·7	·237
Fish	15·7	14·8	11·1	·241
Bread	−·2	4·0	−·7	·275
Bacon	1·8	5·8	2·3	·166
Vegetable canning	2·5	6·5	2·7	·142
Milk and milk products	5·5	9·2	3·8	·194
Other food	6·7	11·5	5·8	·241
Brewing	·7	6·0	·5	·612
Soft drinks	5·1	6·4	·1	·523
Distilling	1·2	1·4	−1·0	·469
Tobacco	−·7	4·2	−1·0	·491
Malting	2·7	·1	−3·6	·354
Made-up textiles	7·3	1·7	3·5	·327
Cotton, linen etc.	7·7	7·2	2·2	·342
Jute	6·1	5·7	2·3	·276
Woollen	4·8	4·1	1·8	·245
Tanning	2·2	5·3	−·3	·355
Shirts	4·9	5·6	1·1	·205

TABLE 1A (*continued*)

Industry	*y*	*k*	*l*	*in 1964*
Women's clothing	5·9	7·0	1·2	·237
Boots and shoes	3·1	3·6	—·7	·242
Leather products	3·5	—·3	2·7	·242
Hosiery	6·9	7·4	1·6	·241
Men's clothing	—·9	2·0	—·6	·172
Miscellaneous clothing	2·4	—4·7	·4	·173
Wood	2·3	4·4	—1·8	·475
Furniture	2·5	4·7	·2	·294
Brushes and brooms	5·4	7·6	1·6	·294
Fertiliser	11·2	20·0	5·4	·557
Chemicals	13·3	9·7	5·4	·510
Paints, oils, etc.	2·2	2·6	1·4	·498
Soap	3·8	3·7	·3	·343
Pottery	6·5	6·2	2·6	·558
Clay and Cement	8·6	5·5	3·3	·316
Non-electrical machinery	8·4	11·2	3·3	·368
Electrical machinery	14·5	11·5	8·0	·318
Metals	8·6	8·2	3·6	·274
Motor vehicles	5·1	4·2	3·1	·044
Other vehicles	2·5	9·2	4·4	·044
Paper	7·5	6·2	1·9	·363
Printing	4·8	3·7	1·0	·247

Sources: Ireland, Central Statistics Office, *Input-output Tables for 1964*: Unpublished and unofficial capital, labour and output series compiled by Mr. Eamon Henry, Central Statistics Office, Dublin.

TABLE 2A: *The Contribution of Rising Capital to Labour Ratios to Improving Labour Productivity*

Industry	$\alpha(k - l)$	*Adjustment*	$\alpha(k - l)$
Margarine etc.	2·3	·1	2·4
Slaughter	1·3	·1	1·4
Flour mills*	1·6	·1	1·7
Animal feeding stuffs*	·8	·2	1·0
Sugar and sugar confect.	1·3	·6	1·9
Fish*	·9	·7	1·6
Bread	1·3	·2	1·5
Bacon	·6	·1	·7
Vegetable canning	·5	·8	1·3
Milk and milk products	1·1	·9	2·0

TABLE 2A (*continued*)

Industry	$\alpha(k-l)$	*Adjustment*	$\alpha(k-l)$
Other food	1·4	·9	2·3
Brewing	3·2	·1	3·3
Soft drinks	3·4	—·3	3·1
Distilling	1·2	—·1	1·1
Tobacco	2·5	—·2	2·3
Malting	1·4	·3	1·7
Made-up textiles	—·3	·1	—·2
Cotton, linen etc.	1·6	0·0	1·6
Jute	1·3	·3	1·6
Woollen	·8	·3	1·1
Tanning	2·0	·2	2·2
Shirts	·9	—·2	·7
Women's clothing	1·4	—·1	1·3
Boots and shoes	1·1	—·5	·6
Leather products	—·8	—·5	—1·3
Hosiery	1·5	·2	1·7
Men's clothing	·3	—·1	·2
Miscellaneous clothing	—·9	·2	—·7
Wood	3·0	·4	3·4
Furniture*	1·3	0·0	1·3
Brushes and brooms*	1·7	0·0	1·7
Fertiliser	8·1	—2·7	5·4
Chemicals	2·1	·5	2·6
Paints, oils etc.	·6	—·1	·5
Soap	1·2	—·1	1·1
Pottery	2·0	—·2	1·8
Clay and cement	·7	—·5	·2
Non-electrical machinery	3·0	—·6	2·4
Electrical machinery	1·2	·1	1·3
Metals	1·2	·1	1·3
Motor vehicles	·1	—·1	0·0
Other vehicles	·2	0·0	·2
Paper	1·6	·2	1·8
Printing	·7	0·0	·7

Sources: Input-output Table for 1964 and (1) *Statistical Abstract of Ireland*, (2) *Irish Trade Journal and Statistical Bulletin* (or *Irish Statistical Bulletin* in later years)—various issues.

*Animal feeding stuffs and flour mills were viewed as one category in the published data, and so the sign of this adjustment may not be in order for *both* of these industries. Fish was included in other food and furniture and brooms and brushes were also viewed as one industry in the published data. Thus in each of these industries the sign of the adjustment and its percentage magnitude may be only a crude approximation for each of these industries.

TABLE 3A: (*1*) *Capital Productivity Improvements,* (*2*) *Increase in Labour Productivity and the Assignment of Responsibility for Them*

Industry	$y - k$	$y - l$	$a^*(k - l)$	r	$\% r$
Margarine etc.	−3·0	1·2	2·4	−1·2	−100·0
Slaughtering	−·9	3·1	1·4	1·7	54·8
Flour mills	−3·0	1·5	1·7	−·2	−13·3
Animal feeding stuffs	−·4	3·5	1·0	2·5	71·4
Sugar and sugar confect.	−3·8	1·7	1·9	−·2	−11·7
Fish	·9	4·6	1·6	3·0	65·2
Bread	−4·2	·5	1·5	−1·0	−200·0
Bacon	−4·0	−·5	·7	−1·2	−140·0
Vegetable canning	−4·0	−·2	1·3	−1·5	−750·0
Milk and milk products	−3·7	1·7	2·0	−·3	−17·6
Other food	−4·8	·9	2·3	−1·4	−155·5
Brewing	−5·3	·2	3·3	−3·1	−155·0
Soft drinks	−1·3	5·0	3·1	1·9	38·0
Distilling	−·2	2·2	1·1	1·1	50·0
Tobacco	−4·9	·3	2·3	−2·0	−666·6
Malting	−6·3	6·3	1·7	4·6	73·0
Made-up textiles	5·6	3·8	−·2	4·0	105·2
Cotton, linen etc.	·5	5·5	1·6	3·9	70·9
Jute	·4	3·8	1·6	2·2	57·9
Woollen	·7	3·0	1·1	1·9	63·3
Tanning	−3·1	2·5	2·2	·3	12·0
Shirts	−·7	3·8	·7	3·1	81·7
Women's clothing	−1·1	4·7	1·3	3·5	74·4
Boots and shoes	−·5	3·8	·6	3·2	84·2
Leather products	3·8	·8	−1·3	2·1	262·5
Hosiery	−·5	5·3	1·7	3·6	67·9
Men's clothing	−2·9	−·3	·2	−·5	−166·6
Miscellaneous clothing	7·1	2·0	−·7	2·7	−135·0
Wood	−2·1	4·1	3·4	·7	17·1
Furniture	−2·2	2·3	1·3	1·0	43·5
Brooms and brushes	−2·2	3·8	1·7	2·1	55·2
Fertiliser	−8·8	5·8	5·4	·4	6·9
Chemicals	3·6	7·9	2·6	5·3	67·1
Paints, oils etc.	−·4	·8	·5	·3	37·5
Soap	·1	3·5	1·1	2·4	68·5
Pottery*	−·3	3·9	1·8	2·1	53·8
Clay and cement	3·1	5·3	·2	5·1	96·2
Non-electrical machinery	−2·8	5·1	2·4	2·7	52·9
Electrical machinery	3·0	6·5	1·3	5·2	80·0
Metals	·4	5·0	1·3	1·7	34·0
Motor vehicles	·9	2·0	·0	2·0	100·0
Other vehicles	−6·7	−1·9	·2	−2·1	−110·5
Paper	1·5	5·6	1·8	3·8	67·8
Printing	1·1	3·8	·7	3·1	81·6

Source: Basic data derived from tables 1A and 2A.

TABLE 4A: *Output per unit of Labour and Capital per Unit of Labour for 40 Manufacturing Industries in 1967*

Industry	*Y/L*	*K/L*	*a*
Brewing	2,335	3,529	·612
Margarine etc.	2,485	1,864	·555
Soft drinks	1,198	1,317	·523
Fertiliser	2,312	5,552	·557
Chemicals	2,728	1,785	·510
Pottery	1,032	1,130	·558
Distilling	1,583	2,412	·469
Tobacco	436	1,595	·491
Wood	887	1,082	·475
Paints etc.	1,675	1,884	·498
Slaughter	1,666	996	·328
Flour mills	1,178	2,409	·369
Malting	1,112	1,387	·354
Clay and cement	2,355	3,123	·316
Cotton etc.	707	931	·342
Tanning	1,110	1,404	·355
Paper	951	982	·363
Soap	1,047	737	·343
Non-electrical machinery	900	1,001	·368
Electrical machinery	1,362	903	·318
Animal feeding stuff	1,322	1,676	·206
Sugar etc.	1,300	709	·237
Fish	532	1,654	·241
Other food	1,183	1,568	·241
Shirts	529	2,110	·205
Women's clothing	758	284	·237
Bread	1,497	2,506	·275
Woollen	1,140	1,143	·245
Boots and shoes	816	400	·242
Leather goods	327	657	·242
Hosiery	996	1,123	·241
Printing	1,129	1,071	·247
Metals	998	1,131	·274
Bacon	995	1,248	·166
Vegetable canning	713	1,180	·142
Men's clothing	559	327	·172
Miscellaneous clothing	429	186	·173
Milk etc.	984	1,903	·194
Motor vehicles	1,026	1,119	·044
Other vehicles	646	1,004	·044

Source of Y figures: These are net output figures for 1967 and are taken from:— Ireland, Central Statistics Office, *Statistical Abstract of Ireland 1968*.

REFERENCES

[1] K. J. Arrow, H. B. Chenery, B. S. Minhas and R. M. Solow, "Capital Labour Substitution and Economic Efficiency," *Review of Economics and Statistics*, XLIII (August 1961).

[2] B. Balassa and T. Bertrand, "Growth Performance of Eastern European Economies and Comparable Western European Countries," *AEA Papers and Proceedings*, LX (May 1970).

[3] A. K. Cairncross, *Factors in Economic Development*, London: Allen and Unwin, 1962, pp. 111–114.

[4] E. F. Denison, *The Sources of Economic Growth in the United States and the Alternatives before us*, New York: Committee for Economic Development, 1962.

[5] E. F. Denison, *Why Growth Rates Differ*, Washington, D.C., The Brookings Institution, 1967.

[6] Kieran Kennedy, "Growth of Labour Productivity in Irish Manufacturing 1953–1967," *Journal of the Statistical and Social Inquiry Society of Ireland*, XXII, Part I (1968–1969).

[7] B. F. Massell, "Capital Formation and Technological Change in United States Manufacturing," *Review of Economics and Statistics*, XLII (May 1960).

[8] B. Minhas, *An International Comparison of Factor Costs and Factor Use*, Amsterdam: North Holland Publishing Co., 1963.

[9] R. R. Nelson, "The CES Production Function and Economic Growth Projections," *Review of Economics and Statistics*, LXVI (August 1965).

[10] E. Nevin, *The Capital Stock of Irish Industry*, Dublin Economic and Social Research Institute, *Publication Series*. No. 17.

[11] R. M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, XXXIX (August 1957).