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The Measurement of Capacity Utilisation in Irish Manufacturing Industry

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Précis: This paper estimates capacity output for Irish manufacturing industry using the Wharton School linked-peaks method, updating an index produced in McMahon and Smyth (1974). It then presents a capacity output series using a production function approach. This approach involves estimating a production function and then replacing the actual values of the inputs with estimated full capacity levels. The estimated production function is of Cobb-Douglas form, using electricity consumption as a measure of capital input. The two capacity output series are then compared and are found to show similar fluctuations. Finally, some suggestions are made for improving the estimates of the production function.

I INTRODUCTION

As the gap between potential and actual output narrows, expansionary monetary or fiscal policy may cause balance of payments and inflation problems. Because of this it is important in the short run for policymakers and forecasters to know when demand pressures are putting a strain on existing resources of productive capacity. Measures of the level of capacity utilisation – defined here as the ratio of actual to potential output – also have useful applications in the study of investment, price changes and foreign trade.

McMahon and Smyth (1974) in this Review presented quarterly capacity utilisation indices for Ireland for eleven industrial groups, for manufacturing industry as a whole, and for transportable goods industries. These indices were constructed by the Wharton School "linked-peaks" method and covered the period from 1959 to the first quarter of 1973. Their capacity

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utilisation indices for manufacturing and for transportable goods industries were constructed in two different ways: by weighted aggregation of the indices for the individual industries, which is the method used by the Wharton School, and by direct application of the trend-through-peaks method to the output series for total manufacturing industries and transportable goods industries. They also present "adjusted" Wharton indices, obtained by eliminating the Wharton peaks which seemed least likely to be capacity output peaks.

This paper re-examines the topic of capacity utilisation in Irish manufacturing industry, first using the linked-peaks method as did McMahon and Smyth, but then using the production function approach and comparing the results of the two methods.

There is no general agreement on a full and unambiguous definition of potential or capacity output; indeed the Federal Reserve Board (1978, p. 22) has stated that it is impossible to arrive at such a definition, "let alone to measure capacity with great accuracy". Various concepts are discussed in detail in such papers as Klein (1960), Klein and Preston (1967), Artus (1977), Okun (1962), Hilton and Dolphin (1970) and OECD Occasional Studies (1973). Perhaps the most widely used concept of capacity output (at least implicitly) is the output corresponding to full employment of the labour force and maximum sustainable[1] utilisation or intensity of use of capital and labour inputs. This approach is used in an attempt to measure the amount of spare productive capacity in the economy at various points in time. It must be stressed that the potential output concept involved is a *production* concept and is not intended to give an optimal or equilibrium level of output for the economy.

The three principal methods of measuring potential output are the surveying of firms, the fitting of trend-through-peaks, and the estimation of production functions. The production function method has the advantage that it takes directly into account the available productive resources in the economy in estimating potential output. A relationship between actual output and inputs is estimated, and this relationship is then used to estimate the level of output corresponding to "full utilisation" of the inputs. This method is the most theoretically satisfactory of the three and is the method on which this paper concentrates. First, though, estimates for the linked-peaks method are discussed and presented. This method estimates potential output by selecting and joining peaks in actual output. The direct surveying of firms is generally felt to be more useful as a way of measuring *capital,* rather than

1. It may be possible to use both labour and capital inputs for a short period at a level of intensity which is not sustainable – the employees may not be willing to work at this level of intensity permanently, and machinery may break down.

capacity, utilisation (Artus, and Hilton and Dolphin). For this reason the CII/ESRI Industrial Survey is used to derive a measure of capital utilisation only, and this is tried as a variable in the estimation of a production function in Section III below.

All the measures of potential output in this paper relate to manufacturing industries. Thus the services, agriculture, mining and gas and electricity sectors are excluded for a number of reasons. The primary reason is that no data are available for the other sectors on a quarterly basis. Secondly, the manufacturing sector is such an important and dynamic element in the Irish economy that pressures on potential output in this sector will have effects throughout the whole economy. Also, manufactured goods, relatively speaking, form a fairly homogeneous group and this increases the efficiency of estimation of production functions.

II FITTING OF TREND-THROUGH-PEAKS

The trend-through-peaks, or "Wharton School", method has the advantage of computational ease and has been widely used[2]. The method involves constructing a series for capacity output by selecting peaks in actual output, which are taken to represent full capacity output, and joining the peaks by linear interpolation to get capacity output for non-peak periods. If the first or last observations are not peaks, then the linear segments between the two previous peaks are extrapolated[3]. The ratio of actual output to full capacity output gives the index of capacity utilisation.

In Table 1, we present Wharton and "adjusted" Wharton indices from the first quarter of 1954 to the fourth quarter of 1977 for total Irish manufacturing industries. Significant differences exist between these results and those of McMahon and Smyth in respect of both the unadjusted and adjusted indices. The differences between the unadjusted indices are partly due to different methods of seasonal adjustment[4]. Revisions in the data also account for some of the differences between the indices. The differences

2. The method was developed by Klein at the Wharton School Econometric and Forecasting Unit, University of Pennsylvania, and is described in Klein and Summers (1966). Various "Wharton" indices for the UK have been constructed – for example, by Briscoe, O'Brien and Smyth (1970), Taylor, Winter and Pearce (1970), and by Hilton and Dolphin.

3. The basic decision rule for selecting output peaks has been put succinctly by McMahon and Smyth as follows: output Y has a peak at period t when $Y_{t-1} < Y_t > \max(Y_{t+1}, Y_{t+2})$ – that is, when output in period t is greater than that in the previous period or the next two periods.

4. McMahon and Smyth state that their aim was "simply to smooth out the worst of any obvious seasonal variation" (p. 86) and use a simple multiplicative method with the trend defined by a five-point weighted moving average. However, this paper adopts the more usual approach of adjusting the data fully for seasonality using the US Bureau of the Census X–11 method. This more refined method results in a "smoother" series, so fewer Wharton peaks are identified.

Table 1: *Wharton and adjusted Wharton capacity utilisation indices*

		Output in manufacturing industries(a) (1)	*Capacity output – Wharton* (2)	*Capacity output – adjusted Wharton* (3)	*Utilisation index – Wharton* (4) (1) ÷ (2)	*Utilisation index – adjusted Wharton* (5) (1) ÷ (3)
1954	Q1	42.4	45.5	45.5	.932	.932
	2	44.0	45.7	45.7	.963	.963
	3	45.9	45.9	45.9	1.000	1.000
	4	43.8	46.1	46.1	.950	.950
1955	Q1	44.5	46.3	46.3	.961	.961
	2	45.8	46.5	46.5	.985	.984
	3	46.6	46.7	46.7	.998	.997
	4	46.9	46.9	46.9	1.000	1.000
1956	Q1	46.7	46.8	47.5	.998	.983
	2	44.5	46.7	48.1	.953	.925
	3	43.6	46.6	48.7	.936	.895
	4	43.8	46.5	49.3	.942	.888
1957	Q1	43.5	46.3	49.9	.940	.872
	2	43.8	46.2	50.6	.948	.866
	3	44.0	46.1	51.2	.954	.859
	4	46.0	46.0	51.8	1.000	.888
1958	Q1	45.6	46.9	52.4	.972	.870
	2	45.4	47.8	53.0	.950	.857
	3	45.5	48.7	53.6	.934	.849
	4	45.7	49.6	54.2	.921	.843
1959	Q1	46.5	50.5	54.8	.921	.848
	2	49.1	51.4	55.4	.955	.885
	3	50.7	52.3	56.1	.969	.904
	4	51.4	53.2	56.7	.966	.906
1960	Q1	52.5	54.1	57.3	.970	.916
	2	53.4	55.0	57.9	.971	.922
	3	54.4	55.9	58.5	.973	.930
	4	54.7	56.8	59.1	.963	.925
1961	Q1	57.5	57.7	59.7	.997	.963
	2	58.6	58.6	60.3	1.000	.972
	3	59.0	59.5	61.0	.992	.967
	4	59.3	60.4	61.6	.982	.963
1962	Q1	60.8	61.3	62.2	.992	.977
	2	61.0	62.2	62.8	.981	.971
	3	61.5	63.1	63.4	.975	.970
	4	64.0	64.0	64.0	1.000	1.000
1963	Q1	62.8	65.4	65.3	.962	.962
	2	63.3	66.7	66.7	.949	.949
	3	65.9	68.1	68.1	.968	.968
	4	68.0	69.4	69.4	.980	.980
1964	Q1	68.7	70.8	70.7	.972	.972
	2	70.3	72.1	72.1	.975	.975
	3	70.5	73.4	73.5	.960	.959
	4	71.3	74.8	74.8	.953	.953

1965	Q1	72.5	76.1	76.2	.952	.952
	2	73.2	77.5	77.5	.944	.944
	3	73.0	78.8	78.8	.925	.925
	4	73.6	80.2	80.2	.918	.918
1966	Q1	74.4	81.6	81.6	.913	.913
	2	71.7	82.9	82.9	.865	.865
	3	78.0	84.2	84.2	.925	.925
	4	77.7	85.6	85.6	.908	.908
1967	Q1	80.6	86.9	86.9	.927	.927
	2	81.3	88.3	88.3	.920	.920
	3	81.3	89.6	89.7	.906	.906
	4	82.7	91.0	91.0	.909	.909
1968	Q1	86.4	92.4	92.4	.936	.936
	2	89.5	93.7	93.7	.955	.955
	3	91.5	95.1	95.0	.962	.962
	4	92.7	96.4	96.4	.962	.962
1969	Q1	89.4	97.8	97.8	.915	.915
	2	99.1	99.1	99.1	1.000	1.000
	3	97.7	99.9	100.6	.978	.971
	4	97.5	100.7	102.0	.968	.956
1970	Q1	96.7	101.5	103.5	.953	.934
	2	97.6	102.3	104.9	.954	.930
	3	103.1	103.1	106.4	1.000	.967
	4	102.2	104.8	107.8	.975	.947
1971	Q1	102.0	106.5	109.3	.958	.933
	2	103.1	108.2	110.8	.953	.930
	3	104.1	109.9	112.2	.947	.928
	4	105.1	111.6	113.7	.942	.924
1972	Q1	104.3	113.3	115.1	.921	.906
	2	106.8	114.9	116.6	.930	.916
	3	108.8	116.6	118.0	.933	.921
	4	113.2	118.3	119.5	.957	.947
1973	Q1	119.9	120.0	121.0	.999	.991
	2	121.4	121.7	122.4	.998	.992
	3	122.8	123.4	123.9	.995	.991
	4	121.3	125.1	125.3	.970	.968
1974	Q1	126.8	126.8	126.8	1.000	1.000
	2	123.8	128.5	128.3	.963	.965
	3	122.7	130.2	129.7	.942	.946
	4	119.2	131.9	131.2	.904	.908
1975	Q1	115.0	133.6	132.6	.861	.867
	2	112.4	135.3	134.1	.831	.838
	3	113.8	137.0	135.5	.831	.840
	4	117.8	138.7	137.0	.849	.860
1976	Q1	123.5	140.3	138.5	.880	.892
	2	127.0	142.0	139.9	.894	.908
	3	127.8	143.7	141.4	.889	.904
	4	129.1	145.4	142.8	.888	.904
1977	Q1	132.7	147.1	144.3	.902	.920
	2	138.1	148.8	145.8	.928	.948
	3	135.8	150.5	147.2	.902	.922
	4	140.4	152.2	148.7	.922	.943

a Base 1970 = 100, seasonally adjusted.

between the "adjusted" Wharton indices are caused by, in addition to these factors, the subjective nature of the selection of "true" cyclical peaks.

Actual output and capacity output as measured by the adjusted Wharton index are graphed in Figure 1 below for ease of comparison. These results are analysed and compared with the results of the production function approach in Section IV.

The following drawbacks of the linked-peaks method must be stressed:

(a) the rates of growth of the inputs – capital and labour – are not taken into account in deriving capacity output;

(b) the joining of peaks by linear interpolation to get capacity output in non-peak periods assumes that capacity output grows linearly between adjacent peaks;

(c) as pointed out by Klein and Preston (1967), a principal objection to the method is that some output peaks may be marked off as full capacity utilisation peaks when in fact there may have been considerable under-utilisation of capacity. They use production functions to estimate

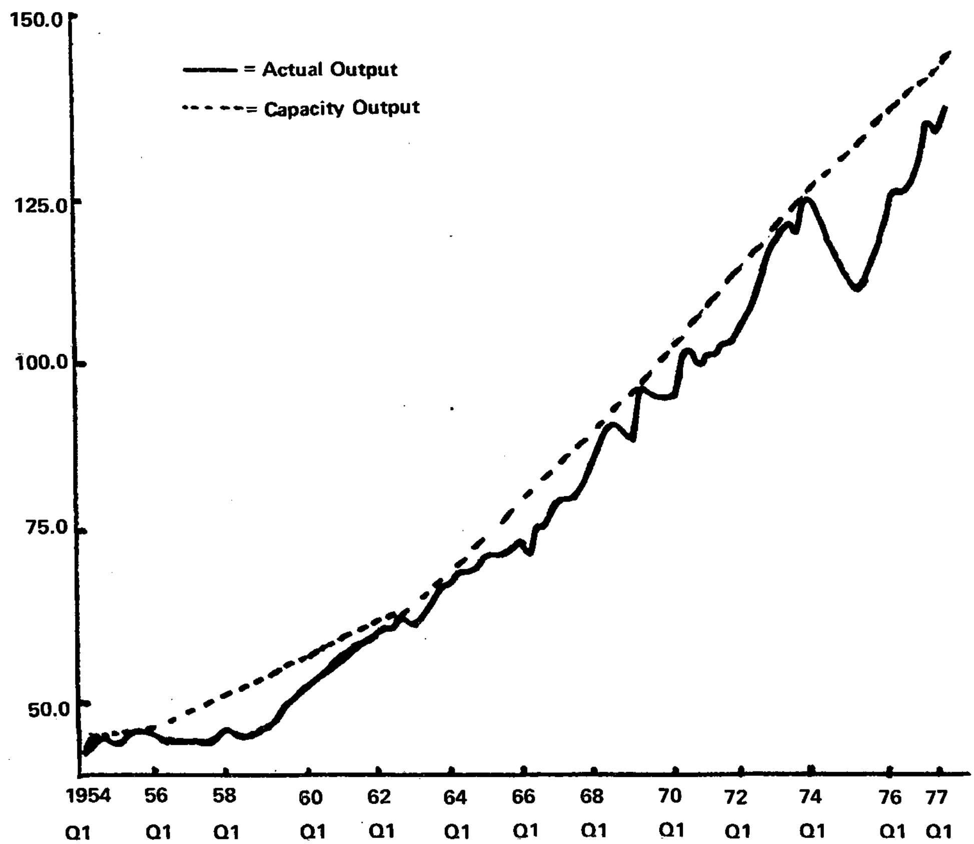

Figure 1: Actual and Capacity (Adjusted Wharton) Output, 1954-77.

alternative indices of capacity utilisation for a number of industries, and then adjust their industry and aggregate Wharton indices in the light of the results;

(d) the extrapolation of the rate of growth of capacity output from the last observed peak to the present assumes that capacity output has continued to grow as rapidly during this period as it did between the last two peaks. This seems unlikely to provide a reliable estimate of capacity output when the last observed peak was some time ago and was followed by a recession – as in the case for Ireland in the present exercise;

(e) the linked-peaks method was applied in this case to the aggregate output index for manufacturing industry, whereas the Wharton School method proper involves the calculation of capacity utilisation indices for the different industries, and the aggregation of these indices to form an index for manufacturing industry as a whole. The latter method has the advantage that the aggregate index cannot be at 100 per cent utilisation unless all the individual industry indices are at 100 per cent.

However, since we are only interested in the aggregate index and since the individual industry indices are not required for their own sake, it was decided not to calculate the aggregate index from individual industries. Thus we used the direct method, as did Briscoe, O'Brien and Smyth in their study of the UK.

III PRODUCTION FUNCTION APPROACH

The production function approach to estimating potential output has been used for other countries by, among others, Klein and Preston, Briscoe, O'Brien and Smyth and OECD. These studies use a Cobb-Douglas production function of the form

$$Q = A\,(E\,H)^{\alpha}\,(K\,X)^{\beta}\,e^{\rho t}\,e^{u} \tag{1}$$

where Q = output in manufacturing industries,[5]
E = employment in manufacturing industries,
H = hours worked in manufacturing industries,
K = capital stock,
X = a measure of capital usage,
t = time, and
u = a stochastic term, assumed to be normally and independently distributed $(0, \sigma^2)$

5. Original data for Q, and also for E and H, were obtained from the Irish Statistical Bulletin and seasonally adjusted using the X–11 method of seasonal adjustment. The derivation of K and X are explained in the text.

In the production function approach, the method is to estimate the above relationship using actual data and then insert full employment and "full utilisation" values for hours worked and capital usage as the independent variables to produce potential output.[6]

III.1 Data Problems

A number of data problems arise in estimating this production function. The first problem is with Q and concerns the fact that Q, as measured in the Quarterly Industrial Inquiry, is a gross, and not a net, output concept. This is because Q is an aggregate of the number of units of goods produced and does not net out the cost of the inputs (see McCarthy, 1966). Since Q is a gross output concept, another variable should appear in Equation (1) for the input of materials (M),

$$Q = A\,(E\,H)^{\alpha}\,(K\,X)^{\beta}(M)^{\gamma}\,e^{\rho t}\,e^{u} \qquad (2)$$

Two measures of this variable (derived from the Census of Industrial Production and from import data) were tried, but with little success. Thus it had to be assumed that M was a constant proportion of output (i.e., $M = \omega Q$). This leads to the revised specification,

$$Q = A^{*}\,(E\,H)^{\alpha}\,(K\,X)^{\beta}\,e^{\rho t}\,e^{u} \qquad (3)$$

where $A^{*} = \dfrac{A}{1-\omega}$.

This, to all intents and purposes, is the same as Model 1 in Equation (1) except for the redefinition of the constant, A.

The second problem relates to obtaining data for K and X on a quarterly basis. Annual capital stock estimates were available[7] for the years 1953–1973. The data were extended to 1977 using capital formation data[8] and a capital stock series derived by Slattery (1975, Tables 9–12)[9]. The annual estimates for K were interpolated on a quarterly basis using a variation of the Boot, Feibes and Lisman (1967) method of interpolation.

Given that capital stock figures are available, the major difficulty encountered in estimating a production function is finding information on the rate

6. The variables EH and KX are assumed to be exogenous to the economic system studied here. This is indeed a heroic assumption and an obvious extension to this study would be to study the determinants of the inputs – in particular, factor prices.

7. These figures were kindly provided by Richard Vaughan (ESRI).

8. Obtained from National Income and Expenditure and internal Central Bank estimates.

9. The capital stock series derived by Slattery (SK), which was available up to 1972, was extended to 1977 using capital formation information from the national accounts. Vaughan's series, K, was then extended to 1977 using the regression relationship, K = 73.2 + .938 SK, estimated using data on K and SK from 1953 to 1972.

of utilisation of capital, X[10]. In most studies, some relationship between the utilisation rates of capital and labour is postulated, the utilisation rate of labour being measured as some function of the unemployment rate. However, McMahon and Smyth point out that this procedure is unsatisfactory for Ireland for a number of reasons. The most important of these is that unemployment may change because of external factors and may not reflect variations in utilisation rates. In particular, this is because of the sensitivity of emigration and hence unemployment rates in Ireland to earnings and unemployment in the UK.

Another reason why unemployment is not used here is that it is an indirect measure of capital utilisation and more direct measures are available. Smyth (1974) suggests one direct measure,

$$X = f(P)$$

where P = the proportion of respondents in the CII/ESRI Quarterly (pre-March 1974) and Monthly (post-March 1974) Industrial Surveys who said their production was constrained by insufficient capacity.

Various functional forms of this variable are discussed by Smyth. However, in this study no satisfactory results were obtained when using this variable in estimating regressions. There are *a priori* reasons for thinking it to be unreliable. First, there is a break in the series in 1974 when the new monthly survey was instituted. Secondly, a previous study of the survey variables by O'Reilly (1977b) did not find any relationship between the survey and the real economy. Because of the break in the series, it was decided to estimate the relationship using the sample period from 1967 up to the first quarter of 1974, but this approach did not produce any useful results.

Fortunately, data exist on another variable, called industrial consumption of electricity (C)[11], which can be used as a proxy for capital usage. Using this variable assumes that the capital stock is totally electricity-based or at least that the variation in utilisation of total capital stock is the same as that of the electricity-based capital stock. Two approaches can be made to the use of this variable from which two models, set out in Equations (4) and (5), emerge to be tested.

First, C can be used, as in Heathfield (1972), to estimate a variable, X, for capital usage. The idea is that C as a proportion of total electricity consumable (CK) should be some measure of capital usage. The question then arises as to how to measure electricity consumable. Such a series was available to Heathfield for the UK, but unfortunately it is not available for

10. The rate of utilisation or intensity of use of labour, a concept discussed by Artus, is assumed to be perfectly collinear with hours worked.

11. This variable was derived from data sent to the Central Bank from the Electricity Supply Board; details of how this variable is derived are available in O'Reilly (1977a).

Ireland. However, it could be postulated that electricity consumable should be some function of the trend in electricity consumed (S)[12],

$$CK = f(\mu,S)$$

where μ = a non-linear parameter.
Therefore, it could be said that

$$X = f(\frac{C}{CK}).$$

It is desirable that this variable X be between 0 and 1, so the functional form suggested for $f(\frac{C}{CK})$ is

$$X = (1 - \exp(-C/\mu S)).$$

Thus, the derived model to be estimated is

$$Q = A^* (EH) \ K(1-\exp(-C/\mu S))^{\beta} e^{\rho t} e^{u} \qquad (4)$$

The second way in which industrial consumption of electricity can be used is as follows: if the capital stock is looked upon as being measured in units of electricity consumable rather than in millions of constant Irish pounds, then the variable C can be looked upon as a measure of total capital input (i.e., C = KX). Thus, the alternative specification is

$$Q = A^* (EH)^{\alpha} C^{\beta} e^{\rho t} e^{u}. \qquad (5)$$

III.2 ESTIMATION OF THE PRODUCTION FUNCTION

Preliminary investigations showed that the inclusion of time led to a high degree of multi-collinearity and, because of this, time as a proxy for technological change was dropped from the model.

When Equation (4) is estimated in log form, there is one non-linear parameter present — μ. This parameter is estimated using the maximum likelihood search procedure in the EAS package (see Just and Fletcher, 1975). The following is the result of the estimation:

$$\log Q = -5.296 + .813 \log(EH) + .582 \log(KX) \qquad (4)\ E$$
$$(-7.13) \quad (9.34) \qquad (49.58)$$

where $X = 1 - \exp(-C/1.0595S)$

$R^2 = .988 \qquad DW = 1.03$

As can be seen, the t-values in this equation are highly significant. The sum of the parameters for labour and capital are higher than those found in a number of studies relating to other countries (cf. Artus), and indicate some degree of increasing returns to scale. (The addition of the estimated para-

12. Several trend lines were fitted for C. A double-log trend, $\hat{C} = S = de^{bt}$, was the most satisfactory.

meters is significantly greater than 1 at 1.395.) However, it is questionable as to how much meaning can be given to this latter statistic at the level of aggregation and heterogeneity at which this equation is estimated. A particularly undesirable characteristic of the equation is that the Durbin-Watson statistic indicates either some degree of positive auto-correlation and/or mis-specification.

When Equation (5) is estimated (also in log form, but in this case with no non-linear parameters), the following is the result:

$$\log Q = -2.544 + .672 \log (EH) + .350 \log (C) \qquad (5)E$$
$$(-3.113) \quad (7.190) \qquad\qquad (47.017)$$
$$\bar{R}^2 = .988 \qquad DW = .912$$

All the statistics indicate the same degree of fit for this equation as for (4)E. The sum of the parameters (1.022) are of the same order as those found in other countries (Artus) and indicate constant returns to scale. As with equation (4)E, the Durbin-Watson is very low.

When deciding between Equation (4)E and (5)E, there is very little to choose between them on the basis of the statistics. However, the variable C has more meaning on a quarterly basis than KX because of the high degree of "construction" necessary to derive both K and X (K having to be forecasted and interpolated and X having to be derived by a maximum likelihood search method). Thus it was decided to drop Model (4) and pursue Model (5).

Because of the low value of the Durbin-Watson statistic, it was decided to check if there was any mis-specification by estimating a CES production function,

$$Q = A(\alpha(EH)^{-\rho} + (1-\alpha)\, C^{-\rho})^{\frac{1}{\rho}} + u_t \qquad (6)$$

Since this expression is highly non-linear in the parameters, it was decided to use maximum likelihood search methods to estimate α and ρ. However, unsatisfactory results were obtained, presumably because the grid in the maximum likelihood search method available on EAS for the two-parameter case is very coarse. Further progress in the estimation of CES production functions thus awaits the application of other more efficient estimation programmes.

Thus, the problem of the Durbin-Watson statistic still remains. Other forms of mis-specification could be (a) the validity of the use of C as a measure of KX and (b) unusual events which have caused aberrations in the data. The two most important events which could have done so are the maintenance men's strike in early 1969 and the oil crisis effect on production in 1973 and 1974. For the time being, it is assumed that mis-specification is

Table 2: *Estimated autocorrelations of residuals*

Lag	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Auto-correlation value	.53	.14	–.10	–.06	.06	–.04	–.02	–.11	–.08	–.13	–.07	–.07
Standard error	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17

not the problem, but pure autocorrelation in the u term. The autocorrelations of the residuals of Equation (5)E were estimated and are set down in Table 2 above. As can be seen, only the first autocorrelation value seems significantly different from zero. Thus Model (5) was re-estimated, this time with a correction for first order autocorrelation.

The following is the revised model:

$$Q = A^* (EH)^{\alpha} C^{\beta} e^{v} \qquad (7)$$

where $v_t = \rho v_{t-1} + u_t$.

The following is the estimated result:[13]

$$\log Q - \hat{\rho} \log Q_{-1} = \underset{(2.077)}{-1.264} + \underset{(4.575)}{.706} (\log (EH) - \hat{\rho} \log (EH))$$

$$+ \underset{(26.29)}{.344} (\log C - \hat{\rho} \log C_{-1}) \qquad (7)E$$

$$R^2 = .955 \quad \hat{\rho} = .55$$

The estimated parameters have only been altered slightly and though the t values have been reduced (as would be expected), they are still significant at the 95 per cent level. An autocorrelation analysis of the residuals indicates that no systematic variation remains in this series. Thus Model (7) is used to estimate capacity output.

III.3 Deriving Full Capacity Production

In order to derive potential output, values for the full employment level of the labour force (EF) and maximum sustainable utilisation values of labour ($\bar{H}$) and capital inputs ($\bar{C}$) must be obtained to replace E, H and C, respectively, in the production function. This gives rise to the problem of

13. A similar analysis of Model (4) was undertaken. However, the sum of the estimated coefficients were still well above 1 (1.394). Also, the other statistics in the estimated results were similar to those obtained for (5)E.

estimating the "full employment" level of unemployment and the full capacity level of intensity of use of the various factors. For the latter, the approach used by the OECD is followed, namely, that of selecting "some high though not maximum value of utilisation" as the full capacity level of intensity of utilisation. A trend was first fitted to the data for utilisation of labour and of capital by regression. This trend was then shifted upwards to pass through the higher-than-average value of utilisation by the addition to the trend of a selected "high though not maximum" positive residual.

For H, hours worked in manufacturing, the estimated regression equation was

$$H = \underset{(396.998)}{45.23} - \underset{(-19.041)}{.065\,T} \qquad R^2 = .864$$

Call the fitted trend line, HM. To this was added the constant 0.8, a high though not maximum positive residual, to get $\tilde{H}$. This procedure is illustrated in Figure 2 below, and is not repeated for the other inputs.

Thus the high though not maximum value for H is $\tilde{H} = 0.8 + 42.23 - .065T$. For C, electricity consumption used as a measure of total capital input (rather than intensity of capital utilisation), the estimated regression equation was $\log C = 4.423 + 0.034t$. Thus, the underlying trend for C, say S, is $S = \exp(4.423 + 0.034t)$. To this trend line S, a constant 16.0 was added to get $\bar{C}$, full capacity C. Thus $\bar{C} = 16.0 + \exp(4.423 + 0.034T)$.

The interpretation of this "upward shift" may be an actual higher-than-average value of the input of the factor to get potential output or more efficient utilisation of the existing factor input, leading to greater output, or a combination of the two.

Finally, the level of full employment (EF) must be estimated before potential output can be derived. To obtain EF, those who, as Artus put it, "are unemployed for reasons which have nothing to do with a temporary short-fall in aggregate demand" (1977, p. 3) – i.e., the structurally and frictionally unemployed – are subtracted from the total labour force, L. For the purposes of this paper, L = E + U where E is the number of persons employed and U is the number of registered unemployed in manufacturing[14].

The *rate* of unemployment at full employment, r, was estimated using a series constructed by Walsh (1977) which he calls "vacancies". The series, derived from the responses to the CII-ESRI Survey, represents the proportion of firms surveyed in manufacturing industries who said that their production was constrained due to insufficient labour. The series is quarterly, running from the first quarter of 1969 to the second quarter of

14. Thus no account is taken of those who are not registered as unemployed, but would enter the labour force if job opportunities appeared, and those in other industries who are potentially employable in manufacturing.

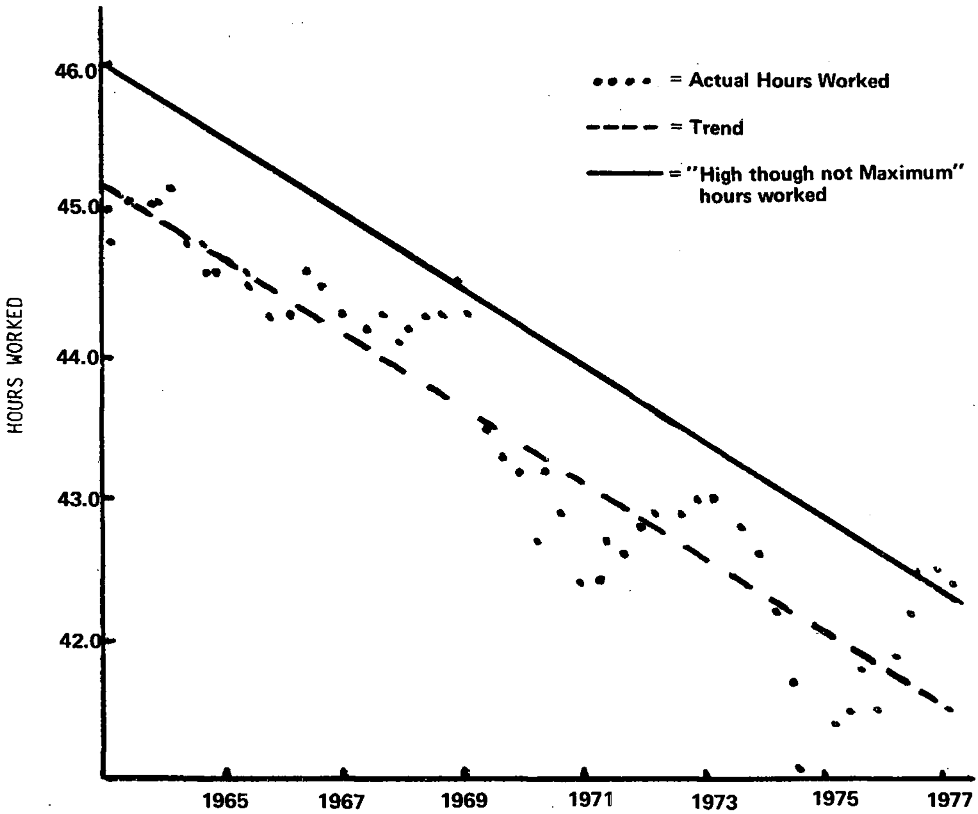

Figure 2: Full Capacity Hours Worked.

1976. From this series it can be seen that "vacancies" were at their highest in the third quarter of 1969 and over the period from the third quarter of 1973 to the second quarter of 1974.

For the purposes of this paper, it was assumed that this high level of vacancies corresponds to "full employment" in the third quarter of 1969 and the first quarter of 1974, and the rate of unemployment in those quarters is, therefore, used as an estimate of the contemporary "full employment rate of unemployment". To find the rate for other quarters, rough interpolation and extrapolation are used. Given this rate, R, the *numbers* unemployed in each quarter at full employment are given by (r x l) and thus the numbers employed at full employment are EF = L – r L.

Figure 3 below shows actual and potential (estimated by the production function method) output graphed against time, and Table 3 shows potential output and the capacity utilisation index. The following section, Section IV, compares potential output estimated by the Wharton School method with potential output estimated by the production function method.

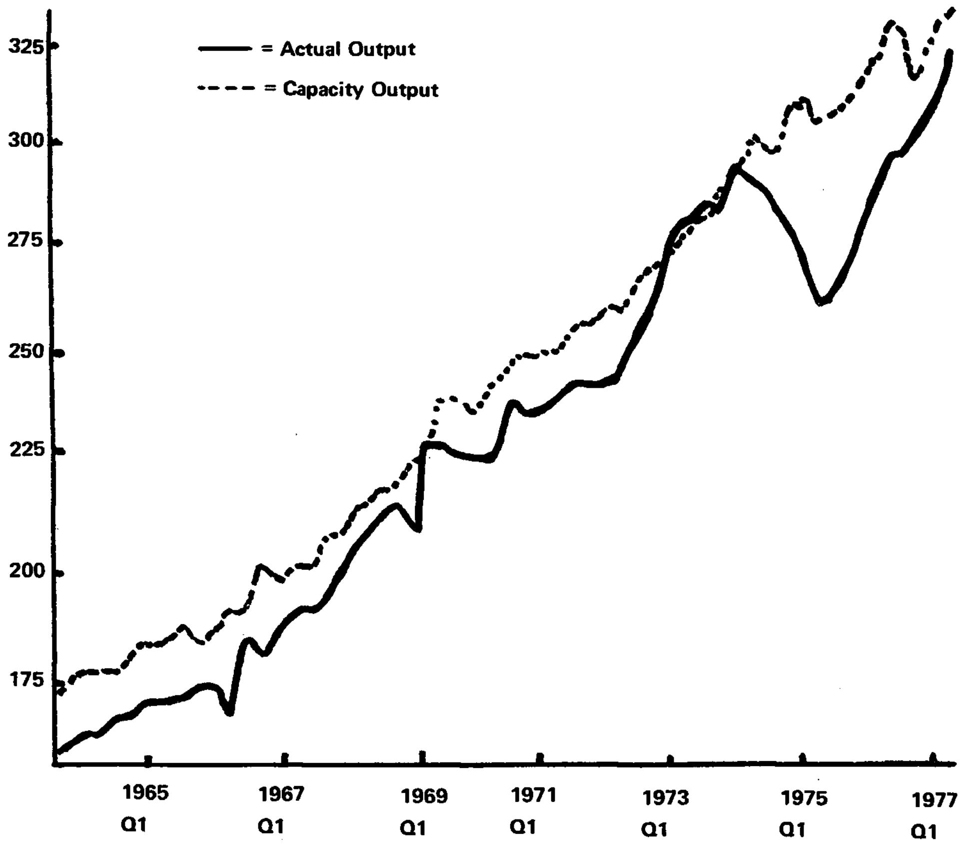

Figure 3: Actual and Capacity (Production Function) Output.

IV COMPARISON OF RESULTS

It can be seen from Figures 1 and 3 and more clearly from the indices of capacity utilisation in Tables 1 and 3 that both the Wharton method and the production function method show roughly the same upturns and downturns in capacity utilisation over the period. Both show capacity utilisation reaching a low in the second quarter of 1966, rising to a peak in the second quarter of 1969, falling to a low in the first quarter of 1972, rising to an unprecedented level in the first quarter of 1974, and then falling to an exceptionally low point in the second quarter of 1975. Both indices have been rising rapidly since then.

Some similarity between the Wharton and the production function methods is to be expected, since the same output figures are used in each case, and both methods estimate potential output to be roughly a straight

Table 3: *Capacity output and capacity utilisation rate from the production function approach using equation (7)E*

		Capacity output[1]	Rate of capacity utilisation
1963	Q4	173.6	0.910
1964	Q1	174.0	0.918
	Q2	174.6	0.933
	Q3	177.0	0.924
	Q4	181.0	0.917
1965	Q1	182.5	0.921
	Q2	183.5	0.925
	Q3	184.9	0.916
	Q4	183.2	0.933
1966	Q1	187.4	0.919
	Q2	189.2	0.880
	Q3	190.7	0.948
	Q4	199.2	0.906
1967	Q1	197.4	0.945
	Q2	200.4	0.941
	Q3	201.1	0.937
	Q4	206.8	0.928
1968	Q1	208.4	0.961
	Q2	214.3	0.969
	Q3	217.3	0.978
	Q4	219.6	0.979
1969	Q1	225.6	0.919
	Q2	224.9	1.022
	Q3	238.3	0.952
	Q4	238.3	0.949
1970	Q1	237.3	0.945
	Q2	243.7	0.928
	Q3	247.2	0.967
	Q4	249.5	0.951
1971	Q1	249.4	0.948
	Q2	250.0	0.957
	Q3	256.6	0.941
	Q4	258.2	0.944
1972	Q1	261.3	0.926
	Q2	261.7	0.947
	Q3	269.0	0.939
	Q4	271.0	0.969

1973	Q1	275.3	1.010
	Q2	282.6	0.997
	Q3	283.0	1.007
	Q4	290.0	0.971
1974	Q1	290.8	1.010
	Q2	298.8	0.961
	Q3	294.9	0.965
	Q4	305.5	0.906
1975	Q1	309.5	0.862
	Q2	303.8	0.859
	Q3	306.1	0.862
	Q4	311.4	0.878
1976	Q1	316.9	0.904
	Q2	327.7	0.900
	Q3	325.3	0.910
	Q4	314.3	0.954
1977	Q1	323.5	0.952
	Q2	331.2	0.967

(1) Base 1958 = 100.

line. The linked-peaks method produces a straight line because growth in actual output has been linear. The production function does so because the growth in the inputs fed in to produce potential output was also linear (except for C which was exponential, though growth did not vary startlingly from the straight line) and because the production function exhibited constant returns to scale.

The correlation coefficient between the two indices is .81 compared to .66 for a similar comparison between an adjusted Wharton index and a production function based index for the UK by Briscoe, O'Brien and Smyth.

It is interesting to note that the indices show the recent boom and recession to be of exceptionally large amplitude. The production function index shows actual output above capacity output in quarters 1–3 of 1973 and the first quarter of 1974[15] for the only time during the period covered, and the slump shows capacity utilisation falling well below previously experienced levels. It is also interesting that by mid-1977 (the latest data shown by the production function index) and by end-1977 (in the case of the Wharton index) output was still below capacity output, but was tending rapidly towards it.

15. The fall in production in the fourth quarter of 1973 was caused by shortage of materials limiting production; as the supply shortage eased, production rose rapidly in the first quarter of 1974.

V SUMMARY AND CONCLUSIONS

This paper estimates potential output by two methods – the Wharton School and the production function method. The main innovation of the paper is in the estimation of the production function and the estimation of potential output using the production function method for Ireland. The production function may also be of use for other purposes.

Two main production functions were estimated, one with capital stock data and one without. From Section III.2, it was concluded that the equation excluding capital stock gives more reasonable results. However, Equation (4)E could be used to produce a capital usage index, X. Parameter estimates might be improved by respecification – through endogenising capital and labour, investigating the validity of the use of consumption of electricity as a measure of capital input, taking account of unusual events and by a more general production function. In the meantime a first order autoregressive parameter has been used to correct for autocorrelation.

Section IV of the paper compares potential output estimated by the Wharton School method and the production function method. There seems to be very little difference in general between the indices.

The results indicate depressions in 1966, 1972 and 1975. The depression in 1975 was of an exceptional amplitude. A rapid recovery is evident in 1976 and 1977 with actual output tending rapidly towards potential output.

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