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Capacity Utilisation in Irish Manufacturing

by

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Introduction[1]

Capacity Utilisation (CU) measures play an important role in economic theory and practical analysis. Variation in the extent to which existing capacity is being utilised provides an indication of how the supply side of a particular industry, sector or economy is evolving relative to its demand side. Such measures have been used to explain changes in investment flows and the general economic environment. However, the primary significance of CU measures stems from their usefullness in uncovering upward pressure on the price level. Garner(1994) recently produced evidence that CU measures continue to provide a reliable indicator of inflationary pressure in the US. Despite the increased openness of the US economy, the estimated non-inflationary rate of capacity utilisation has remained very stable at about 82%. While such a stable and robust relationship is unlikely to hold in the context of a small open economy, measures of economic slack should nonetheless form part of a battery of economic indicators that are available for assessing potential inflationary pressures.

Several CU measures are widely quoted in the business and economic literature. However, no unanimous consensus exists over how to measure CU nor over what is in fact being measured. In addition, while most of these widely quoted measures can be used to indicate a change in CU, they offer little explanation of *why* capacity utilisation may have changed. The economic analyst is in fact left in the unenviable position of having to guess at or express a *gut-feeling* as to the probable cause of such movements. As a results, the attempt to draw conclusions which could somehow inform policy is often frustrated. The purpose of this paper is to review some of the widely used methods from which numerical CU measures can be computed for the manufacturing sector. In addition, an economic measure of CU - one which can be interpreted in terms of changes in a host of exogenous variables - is described and empirically applied to the Irish manufacturing sector. The paper is divided into four sections. Section I presents a brief overview of the concept of capacity utilisation from

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[1] The author would like to acknowledge the very helpful comments of Tom O’ Connell, John Frain and participants at an internal Central Bank seminar. Any errors or omissions remain the personal responsibility of the author.

an empirical point of view and provides a selective discussion of available measures. Section II outlines the basic rationale underlying an *economic* measure of CU based on the theory of cost minimisation. This methodology is applied to the Irish manufacturing sector in Section III and the constructed CU measure is examined as an indicator of inflationary pressure. I conclude in Section IV with a brief summary, an assessment of the methodology employed and a review of the empirical results.

Section I : Available Measures of CU

The purpose of this section is to weigh up the alternative CU measures from a practical point of view. An exhaustive survey of the various means of computing numerical CU ratios is beyond the scope of this paper. Instead, three of the most common methodologies are briefly reviewed in terms of underlying rationale, advantages/disadvantages, data requirements and feasibility. These measures can then be usefully compared with the methodology adopted in Sections II and III.

1.1 The Peak-to-Peak Measure

This method is originally associated with the work of Klein and Summers(1966). For the Irish manufacturing sector, peak-to-peak CU estimates have been computed by O'Reilly and Nolan(1979). However, there are no officially published measures for Ireland based on this methodology though they would be quite simple to compute. The approach attempts to measure the degree of utilisation of all inputs by examining a plot of the realised level of output (Y) through time. On a plot of output, relative periodic peaks are (arbitrarily) taken to be points of full utilisation of all resources. The peaks are then connected with a straight line which can be extrapolated beyond the most recent peak in order to represent the path of capacity output (Y*). A numerical CU measure can then be computed as the ratio of actual to capacity output, i.e. $CU = Y/Y^*$. By construction, this CU measure can never exceed unity.

The primary advantage associated with this approach is the ease with which a relevant economic indicator can be derived. An official index of industrial production is available for most countries at least on a quarterly, if not on a monthly, basis[2]. Conveniently, the approach does not require data on inputs which might only be available at a much lower frequency and often only with a considerable time lag. This limited data requirement coupled with the extreme ease of calculation represents the primary advantage associated with this methodology.

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[2] For Ireland, the Industrial Production Index is available on a monthly basis for 49 NACE Industrial Sectors and groupings.

Unfortunately, this must be weighed up against some serious theoretical and practical difficulties which undermine the usefulness of the peak-to-peak approach. For example, the method requires a large degree of subjectivity in the choice of major peaks. This leaves it open to the critique that it is entirely arbitrary. Secondly, the chosen peaks may not in fact represent points of the full-utilisation of resources. If, for example, capacity output is higher than the chosen peak output level, the resulting CU measure will be biased upwards. Another serious deficiency associated with the choice of peaks is that the most recent CU measures will require recalculation whenever a new peak is *deemed* to have occurred. The measures which are most relevant to the prevailing economic climate are therefore perhaps the most unreliable. Unfortunately, however, the peak-to-peak approach does not (and cannot) offer a means by which the error associated with the above can be quantified.

Another significant and problematic feature of the peak-to-peak methodology is the underlying assumption that capacity output grows at a constant arithmetic rate between peaks. As a result, most of the variation in CU is associated with variation in actual as opposed to capacity output[3]. Yet surely - given the strong variation in the determinants of capacity (e.g. investment expenditures) - a higher proportion of the variability in CU is due to variation in capacity. In order to allow for this, the measure of capacity output is often adjusted to reflect the observed variation in investment spending. While this does constitute a reasonable extension, capacity output necessarily depends on other exogenous variables (e.g. energy prices) in the economic system. These criticisms significantly undermine the extent to which capacity utilisation measures based on the peak-to-peak approach can be interpreted at all. However, prudence would suggest that the measure should be weighed up in the light of available alternatives. Certainly, the undemanding data requirements associated with this method would permit the construction of a relevant economic indicator in a timely manner. The constructed CU ratio could than be compared for consistency with other available cyclical indicators.

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[3] This contrasts with the short-run cost minimisation concept of capacity output developed in Section II.

Figure 1(Appendix I) graphs a CU ratio calculated under the peak-to-peak methodology using the quarterly index of industrial production[4]. By definition, the CU ratio equals unity at all chosen peaks. On the basis of this methodology, CU increased steadily during the latter half of the 1970s. However, between 1980 and 1987, capacity utilisation in Irish manufacturing dropped dramatically, reaching a low of about 80.8% in 1987. Since 1987, CU trended upwards signalling an erosion of the spare capacity that had accumulated during the earlier half of the 1980s. Nonetheless, there is clear evidence of some periodic slack in the manufacturing sector during the 1990s. The above measures are, however, completely ad hoc and sensitive to the chosen peaks. The confidence one should choose to place in them should not exceed the degree of confidence one can have that the chosen peaks represent points of full-utilisation of resources.

1.2 Survey Based Measures

The most direct and obvious means of obtaining numerical CU ratios is to ask firms for their own assessment of the extent to which they are using available capacity. Almost all industrialised countries now include this question in monthly surveys of business. For Ireland, the IBEC-ESRI Monthly Industrial Survey(MIS) undertaken on behalf of the EU provides information on capacity utilisation for a number of industrial sector and sub-sector classifications. The two questions relating to capacity utilisation are given below.

> *(16) For the coming year do you consider your present capacity is: Excessive(+): Adequate(=): Insufficient(-)*
>
> *(17) During the month, you were operating at about what percent of capacity - please indicate to the nearest 10%, e.g. 50%, 60%, 70% etc.*[5]

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[4] Based on a visual inspection of the plotted time series, the chosen peaks were 1976Q3, 1978Q4, 1979Q3, 1989Q4, 1992Q3, 1995Q1.

[5] MIS(April 1995), p 14. Christiano(1981) has drawn a distinction between Type #1 and Type # 2 surveys. Question 16 resembles his definition of Type #2 while question 17 is analogous to Type # 1.

While the responses to question 16 cannot yield exact CU ratios, they can provide an overall indication of the direction of change in CU. The number of negative responses gives an indication of the percentage of firms operating at or above full capacity. AS a result, the trend in capacity utilisation can be inferred from the month-on-month change in the balance of positive over negative (or vice versa). Question 16 is forward looking in its orientation. Question 17, on the other hand is retrospective in that it refers to the previous months operating period. The responses to 17 can also provide a numerical CU ratio which can be aggregated to provide industry or sectoral measures.

Apart from the normal sampling and measurement error associated with any survey, there are some other important difficulties which relate specifically to surveyed CU. One problem relates to how individual respondents will choose to define the term “capacity” in both questions. Firms may interpret it in the narrow sense of capital utilisation or in the broader sense which includes all inputs (labour and materials). Similarly, respondents may confuse the concept of economic capacity with their own subjective or preferred capacity level of operations. Christiano(1981) has found that surveyed measures tend to indicate a higher level of excess capacity than do data based measures. He also notes that respondents tend to find capacity when demand is strong and lose it when demand is weak. If this is so, both Y and Y* will tend to move together and, as a result, surveyed CU ratios can display significant inertia (i.e. lower variation).

A time series plot of surveyed capacity utilisation for the Irish manufacturing sector is given in Figure 2(Appendix I). The sample period ranges from the last quarter of 1984 to the beginning of the second quarter of 1995. One evident feature is the strong seasonality which accounts for a substantial component of the variation inherent in the data set. Capacity utilisation generally peaks at the end of the second quarter and drops dramatically in the last quarter. The seasonality in surveyed CU is only to be expected given the seasonal variation in manufacturing output in Ireland[6]. Such a high level of seasonal variation also conflicts with Christiano's observation that firms find capacity when demand is strong. During a seasonal peak in demand, firms do not appear to adjust upwards their assessment of capacity and consequently there is a seasonal pick-up in surveyed CU. However, Christiano's observation is primarily in reference to the inertia in cyclical CU. To examine this, Figure 2 also presents a seasonally adjusted series (cusa)[7]. While the seasonally adjusted series clearly shows some cyclical variation in the surveyed data, this cyclical variation would appear relatively small. The sample mean is approximately 73.14 and is therefore indicative of a substantial degree of excess capacity in the Irish manufacturing sector. The extent of excess capacity is in fact substantially greater than that implied by the CU ratios calculated under the peak-to-peak methodology. However, there is evidence that the level of excess capacity in Irish Industry is declining. The surveyed CU ratio, in a manner consistent with the peak-to-peak measure - shifted upwards between 1986 and 1990[8]. In interpreting this movement, however, it is impossible to know how much of it is due to underlying economic fundamentals and how much (if any) is due to non-economic factors, e.g. changes in the manner in which the survey is administered and interpreted by respondents. The investigation of the economic determinants of surveyed CU ratios represents a potentially useful direction for future research.

Notwithstanding the difficulty associated with correctly decomposing the surveyed series into trend, cyclical and seasonal components, the task of interpreting changes in CU reported in Industrial Surveys is extremely difficult. What, for example is driving the recent (seasonally adjusted) rise in CU to over 80%? Does it, for example, reflect a temporary cyclical movement in demand or a more permanent shift in capacity? In

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[6] For many of the questions in the MIS, respondents are asked to adjust their responses *for the time of year*, i.e. to allow for seasonal variation. However, this is not the case in question 17.

[7] The surveyed data is seasonally adjusted by fitting a variety of exponential smoothing models as implemented in the RATS package. Without any *a priori* conviction to the contrary, we allow for the possibility of a trend in the data. On the basis of goodness of fit (minimum sum of squares criterion) a linear trend model with multiplicative seasonality was selected. The parameter estimates were $\alpha = 0.240$, $\gamma = -0.044$ and $\delta = -0.148$ (see Gardner(1985) for notation).

[8] Taking the entire sample period, surveyed CU has risen from a low of below 65% in 1984 to over 80% in 1995. The seasonally adjusted figure for the second quarter of 1995 for the Total Manufacturing sector in Ireland was 80.1%. See European Commission, Business and Consumer Surveys(April 1995, No. 4).

contrast, the measure to be developed in section II allows the analysis of changes in CU in terms of changes in a set of exogenous variables. This greatly enhances the understanding of and applicability of CU ratios. The above points do call for a degree of caution in interpreting survey-based CU measures. However, from a practical point of view they are currently the most accessible and timely indicators of CU available for Ireland. There is therefore good reason to further test their determinants and usefulness in explaining economic behaviour.

1.3 The Production Function Approach

The Production Function approach represents an attempt to take the economic theory of production and apply it at a sectoral or industry level in order to derive a measure of CU. Artus(1977) applied a production function methodology to measure capacity output for eight industrial countries for the period 1955-1978. For the UK, Harris and Taylor(1985) adopted a more disaggregated approach to derive measures of capacity utilisation for four UK industries. O’ Reilly and Nolan(1979) also applied this approach to the manufacturing sector in Ireland.

The production function approach shares with the peak-to-peak methodology the common objective of trying to measure the level of output that could be produced if all available inputs were being fully utilised. However, the approach requires the specification and estimation of some functional relationship between inputs (e.g. capital and labour), the state of technology and output. Once a production function for an individual industry or sector has been estimated, capacity output can then be calculated by evaluating it at the point where all resources are fully utilised. One significant by-product of this type of approach is that changes in capacity output can be decomposed into its respective components: capital stock growth, technological progress and growth of potential labour supply. This contrasts with the peak-to-peak and survey based measures which do not allow any such decomposition.

CU measurement based on a production function should represent a significant improvement over the two previous measures. Yet, it is not without its shortcomings.

Many of the assumptions associated with the underlying production relationship are often untenable. The homogeneity of inputs and outputs that must be assumed in the estimation is a clear simplification of reality. Similarly, there is the problem of which functional form is the best representation of economic behaviour. There are also the serious econometric issues associated with the application of production functions to time series data. It is, for example, often the case that the parameter estimates are either statistically insignificant, unstable over the sample period chosen or signed incorrectly.

Perhaps the most important shortcoming (from a practical point of view) associated with this approach is its much larger data requirements. Capital stock estimates for Ireland are subject to a large margin of error and are only available annually. In general, this reduces the frequency with which CU ratios can be calculated. There is also a serious conceptual problem associated with the labour input when the approach is applied at a sectoral level. Given that some workers will migrate between different sectors of the economy, it is difficult to define what the potential available labour supply to a particular sector is. This problem becomes even more acute when trying to evaluate production functions for individual industries at the potential supply of labour. From a theoretical point of view, the production function approach should constitute a significant advance in terms of our understanding of what CU ratios actually mean. In practice, as a result of some of the issues raised above, this may not be the case.

Section II: An Economic Measure of CU

Both surveyed and peak-to-peak measures discussed in Section I lack a firm theoretical basis. However, a lot of progress has been made in relating the concept of CU to the economic theory of production and costs. A continuation of this process is essential if a better understanding of CU measures and their applications is to be obtained. This section provides a brief and general exposition of the rationale behind cost function based economic measures of capacity utilisation.

2.1 A Cost Function Based Approach

Klein(1960), Berndt and Morrison(1981) and others have made the intuitively appealing suggestion that capacity output is inherently a *short-run* concept conditional on the level of quasi-fixed inputs available to producers[9]. Capacity output can then be defined as the *optimum* level of output for given levels of quasi-fixed factors. In this context, the producers technology can be represented by the production function (F) below,

$$Y = F(V, X, t) \tag{2.1}$$

where V is an n x 1 vector of variable inputs and X a j x 1 vector of quasi-fixed inputs. Time, t, is included as an argument in the production function to act as a proxy for technological advance. Subject to certain regularity conditions (Diewert(1974), if costs are minimised with respect to the variable inputs V conditional on the level of

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[9] Other authors who have employed this short-run notion of capacity output include Morrison (1985a, 1985b, 1986) and also Lee and Kwon(1994). For Ireland, Bradley et al(1993) have extended this notion to an open-economy setting using the Leontief variant of the restricted cost function.

output (Y) and the quasi-fixed inputs (X), then there exists a variable or restricted cost function (C_V) which is dual to 2.1[10]

$$C_V = G(Y, P_V, X, t) \qquad (2.2)$$

where P_v is the 1 x n vector of prices of the variable inputs. Short-run average total costs (SRAC) can be defined as the sum of average variable costs and average fixed costs.

$$SRAC = \frac{C_V}{Y} + \frac{P_X X}{Y} \qquad (2.3)$$

where P_x is the 1 x j price vector for the quasi-fixed inputs. Capacity output, defined as the optimal level of output for given level of the quasi-fixed factors, is that level of output which minimises SRAC. Thus, at the point where actual and capacity output are equal, i.e. Y = Y*, equation 2.3 is minimised. Differentiating 2.3 with respect to Y and setting equal to zero yields:

$$\frac{dSRAC}{dY^*} = \left(\frac{1}{Y^*}\right)\left(\frac{dC_V}{dY^*}\right) - \left(\frac{C_V}{Y^{*2}}\right) - \left(\frac{P_X X}{Y^{*2}}\right) = 0 \qquad (2.4)$$

For many functional forms for C_v, an exact analytical solution can be obtained for Y* from (2.4). However, by simple inversion, it is clear that Y* will depend on the arguments of the variable cost function(P_v, X, t) and the price vector of the quasi-

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[10] Bradley and Fitzgerald(1988) note that this type of optimisation, i.e. one which treats output as exogenous may be inappropriate in the context of small open economies like Ireland. They show that the endogeneity of domestic output in the productive process is likely to be more crucial the smaller the economy. In particular, they illustrate that changing this assumption can have a substantial impact on both the sign and size of the estimated elasticities. These important issues are being overlooked in the short-run optimisation framework being employed here.

fixed factor.

$$Y^* = Y^*(P_V, X, P_X, t) \tag{2.5}$$

In this setting, capacity output is therefore directly related to variable input prices, the level of the fixed factors, the prices of the fixed factors and the state of technology[11]. From the solution to (2.4), the rate of capacity utilisation can then be defined as actual output, Y, over capacity output, Y*, i.e. CU = Y / Y*.

2.2 A Diagrammatic Illustration

This section presents a simple diagrammatic exposition of the above CU measure[12]. We assume i) a single quasi-fixed factor (e.g. capital) and ii) long-run constant returns to scale. Under long-run constant returns to scale, the firms long-run cost function is homogenous of degree one in output. As a result, long-run *average* costs do not depend on the level of output and are represented by the horizontal line LRAC in Figure I. We can also define two short-run average cost curves ($SRAC_o$ and $SRAC_1$) for different levels of the quasi-fixed capital stock (K_o and K_1). For $K_1 > K_o$, $SRAC_1$ will lie to the right of $SRAC_o$. Since average fixed costs tend to fall with output and average variable costs tend to rise, both $SRAC_o$ and $SRAC_1$ will be U-Shaped as depicted in Figure I. Capacity output, (i.e. the value of Y which solves equation 2.4) for different levels of the quasi-fixed capital stock is given by the minimum points on $SRAC_0$ and $SRAC_1$. Furthermore, the long-run cost function is just the short-run cost function evaluated at the optimal level of the quasi-fixed factors and therefore capacity output will also correspond to the point of tangency between SRAC and LRAC. With only one quasi-fixed factor, this measure of CU strictly corresponds to the narrower concept of *capital utilisation* rather than the broader *capacity utilisation* which refers to the utilisation rate of all inputs (labour and materials). Under this theoretical framework, there is no rationale for variation in the utilisation rates of the other factors

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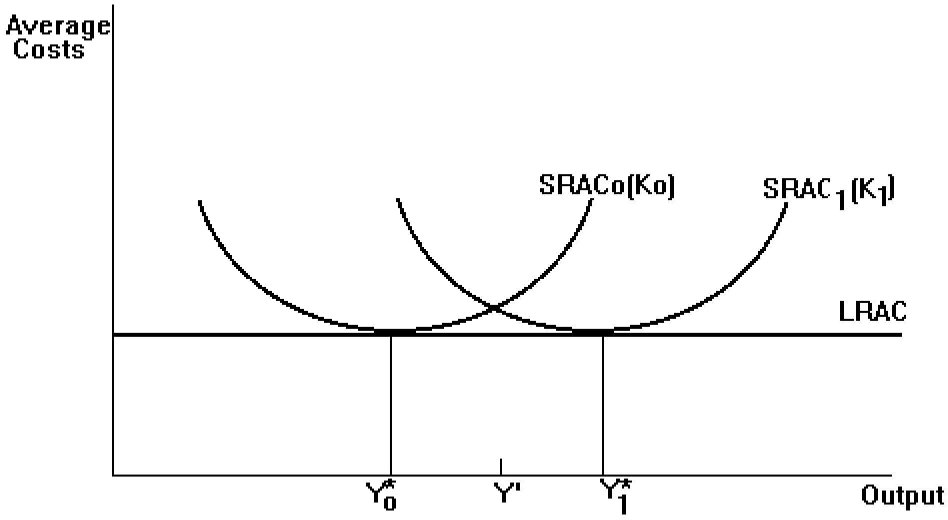
[11] The econometric application employed in Section III below enables the calculation of the elasticity of capacity output with respect to changes in these exogenous variables.

[12] The analysis draws heavily on Berndt and Hesse(1986) and Morrison(1985a, 1985b).

of production since they will always adjust instantaneously to their optimal levels. Furthermore, under this short- run interpretation, measures of CU

Figure I



can be either greater than, equal to or less than one[13]. If the firm has $SRAC_o$ and if actual output is given by Y ¢then short-run CU given by Y ¢/Y_o* is greater than 1. If such a firm expected output to remain at Y ¢it would have an incentive to invest in productive capital in order to lower average costs. Alternatively, if the firms short-run cost curve is given by $SRAC_1$, then CU given by Y ¢/Y_1* is less than one and the firm has an incentive to disinvest if it expects that output will remain at Y ¢

Econometric evidence presented by Morrison (1985) suggests that the above CU measure tends to be greater than one when producers expect all exogenous variables to remain constant (static expectations). A similar result was obtained by Lee and Kwon(1994) who applied Morrison’s approach to Korean data. However, when producers are modelled as forward looking with anticipatory (adaptive or near

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[13] This contrasts with peak-to-peak and survey based measures which are always less than or equal to one.

rational) expectations, the relevant CU measures tend to be less than one. Morrison rationalises this phenomenon on the grounds that forward looking agents will tend to have an incremental level of capital due to anticipatory expectations. However, the issue may also depend on the functional form of C_v adopted for econometric analysis. Berndt and Hesse(1986), for example, applied the above concept of CU to a translog restricted cost function under a static expectations assumption and found most measures of CU to be less than unity for nine industrial countries. This sensitivity of these CU measures to the underlying functional form and expectational assumptions makes the task of applying them for policy purposes more difficult.

Section III: Econometric Implementation

This section applies the cost function based concept of capacity utilisation to the Irish manufacturing sector using the restricted version of the translog variable cost function employed by Berndt and Hesse*(op. cit.)* and Brown and Christensen(1981). Annual capacity utilisation measures between 1970 and 1990 are derived. This period covers the accession of Ireland into the EU and therefore constitutes a particularly interesting period of industrial development in Ireland. In addition to the total manufacturing sector (TMAN), the model is applied to the two contrasting sub-sectors classifications (Hi-Technology(HI-TECH) and Traditional(TRAD)) in Irish manufacturing which have been noted by Bradley et al. (1993) and others. The results therefore represent a further contribution to the debate surrounding the dichotomy which exists in Irish manufacturing.

3.1 An Econometric Framework

In order to implement the measure of CU outlined in Section 2, some functional form corresponding to equation 2.2 is required. In a manner analogous to Berndt and Hesse*(op. cit.)* and Brown and Christensen*(op. cit.)*, the partial equilibrium variant of the flexible translog specification is adopted under a capital, labour, energy, materials (KLEM) framework. Capital is assumed to be the single quasi-fixed input. The translog variable cost function is given in (3.1) below.

$$\begin{aligned}
LnC_V = {} & a_o + a_y \ln Y + a_L \ln L + a_E \ln E + a_m \ln M + b_k \ln K + a_t t + a_{tt} t^2 \\
& + \tfrac{1}{2} g_{yy} (\ln Y)^2 + \tfrac{1}{2} g_{LL} (\ln P_L)^2 + g_{LE} \ln P_L \ln P_E + g_{LM} \ln P_L \ln P_M \\
& + \tfrac{1}{2} g_{EE} (\ln P_E)^2 + g_{EM} \ln P_E \ln P_M + \tfrac{1}{2} g_{MM} (\ln P_M)^2 + \tfrac{1}{2} g_{KK} (\ln K)^2 \\
& + r_{YL} \ln Y \ln P_L + r_{YE} \ln Y \ln P_E + r_{YM} \ln Y \ln P_M + r_{YK} \ln Y \ln K \\
& + r_{KL} \ln K \ln P_L + r_{KE} \ln K \ln P_E + r_{KM} \ln K \ln P_M + r_{tY} t \ln Y + r_{tK} t \ln K \\
& + r_{tL} t \ln P_L + r_{tE} t \ln P_E + r_{tM} t \ln P_M
\end{aligned} \tag{3.1}$$

where K, L, M, E represent Capital, Labour, Material and Energy input quantities with respective input prices P_i where $i \in \{K, L, M, E\}$. The translog specification is useful in that it places no a priori restrictions on substitution elasticities between the factors of production and yet it can easily be made consistent with the constraints which are traditionally imposed by economic theory[14]. Two significant differences exist between (3.1) and the more common translog representation of total costs. Firstly, the left-hand side represents the log of variable costs ($C_V = P_L L+P_E E+P_M M$). Under Shephard's Lemma, and by logarithmically differentiating (3.1) with respect to variable input prices, three variable cost share equations for each of the three variable factors (L, E M) can be derived.

$$\frac{d\ln C_V}{d\ln P_i} = \frac{\partial C_V}{\partial P_i} \cdot \frac{P_i}{C_V} = S_i \qquad \forall_i \in \{ E,L,M \}$$

S_i denotes the cost minimising share in variable costs for each of the variable inputs. Logarithmically differentiating 3.1 with respect to $\ln P_L$, $\ln P_E$ and $\ln P_M$ gives the following three variable cost shares for labour, energy and material inputs.

$$\begin{aligned}
S_L &= \alpha_L + \gamma_{LL} \ln P_L + \gamma_{LE} \ln P_E + \gamma_{LM} \ln P_M + \rho_{YL} \ln Y + \rho_{KL} \ln K + \rho_{tL} t \\
S_E &= \alpha_E + \gamma_{EL} \ln P_L + \gamma_{EE} \ln P_E + \gamma_{EM} \ln P_M + \rho_{YE} \ln Y + \rho_{KE} \ln K + \rho_{tE} t \\
S_M &= \alpha_M + \gamma_{ML} \ln P_L + \gamma_{ME} \ln P_E + \gamma_{MM} \ln P_M + \rho_{YM} \ln Y + \rho_{KM} \ln K + \rho_{tM} t
\end{aligned} \tag{3.2}$$

Note also the adding up restriction that $\sum S_i = 1$, i.e. the sum of variable cost shares must equal unity. The other significant difference between 3.1 and the more common total cost representation relates to the inclusion on the right-hand side of a variety of linear and quadratic forms of the quantity of fixed capital (K) instead of its price. As a result of this second feature, the shadow value of capital (R_K) can be calculated as the change in variable costs associated with having an additional unit of capital($\delta C_V/(\delta K$).

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[14] Specifically, for a cost function to be well behaved it must be homogenous of degree one (hd1) in prices for a given state of technology(t) and level of output(Y). The variable cost function must be hd1 for given t, Y *and* K.

Logarithmically differentiating 3.1 with respect to lnK gives

$$\frac{d\ln C_V}{d\ln K} = \frac{dC_V}{dK} \cdot \frac{K}{C_V} = \frac{R_K K}{C_V} = M_K$$

where, from 3.1

$$M_K = b_K + g_{KK} \ln K + r_{YK} \ln Y + r_{KL} \ln P_L + r_{KM} \ln P_M + r_{KE} \ln P_E + r_{tK} t \tag{3.3}$$

M_k gives the shadow value share of capital in variable costs. While the left hand side ($R_K K$) cannot be observed directly, Berndt and Hesse*(op. cit.)* have shown that it can be inferred - under the assumption of marginal cost pricing and long-run constant returns to scale - from the quasi-rents to the capital fixed input.

$$-R_K \cdot K = P \cdot Y - C_V \tag{3.4}$$

In order to solve for capacity output, the translog specification for the short-run cost minimisation condition must be derived. Berndt and Hesse(op. cit.) have shown that, for the translog, the short-run average cost minimisation condition (2.4), is given by 3.5 below[15].

$$-M_K \cdot C_V - P_K \cdot K = 0 \tag{3.5}$$

It can also be easily shown that when the firm is producing its capacity output, i.e. at Y=Y*, 3.5 implies that the ex-post user cost of capital equals the shadow cost of capital. Additionally, C_V and M_k are functions of Y and lnY respectively. Therefore 3.5 cannot be solved analytically for Y*. However, once all the parameters of the restricted

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[15] See Berndt and Hesse(1986), p. 966 for derivation.

cost function have been estimated, numerical iteration can be employed in order to find the value of Y which satisfies (3.5).

3.2 Estimation

In order to solve for capacity output in (3.5), all parameters from the restricted cost function(3.1) need to be estimated. However, as has been pointed out by numerous authors, gains in econometric efficiency can be obtained by estimating a system of variable cost share equations (3.2). Given the loss in degrees of freedom associated with the large number of right hand side variables in 3.1, it was decided not to include the Translog in the system of estimable equations[16]. Instead, the following two-step estimation procedure was employed. Firstly an additive disturbance term is appended to each of the variable (3.2) and shadow cost shares (3.3) and the resulting system was estimated using Zellner's seemingly unrelated estimator. The additive error terms are assumed to be multivariate normally distributed with mean vector zero and constant non-singular residual covariance matrix (Ω^*). Following Brown and Christensen*(op. cit.)*, homogeneity and constant returns to scale imply the following restrictions on the estimated parameters.

Table I: Parameter Restrictions

Homogeneity	**Constant Returns To Scale**
$\alpha_L+\alpha_E+\alpha_M = 1.0$	$\alpha_Y+\beta_K = 1.0$
$\gamma_{LL}+\gamma_{LE}+\gamma_{LM} = 0$	$\gamma_{YY}+\rho_{YK} = 0$
$\gamma_{LE}+\gamma_{EE}+\gamma_{EM} = 0$	$\gamma_{KK}+\rho_{YK} = 0$
$\gamma_{LM}+\gamma_{EM}+\gamma_{MM} = 0$	$\rho_{YL}+\rho_{KL} = 0$
$\rho_{tL}+\rho_{tE}+\rho_{tM} = 0$	$\rho_{YE}+\rho_{KE} = 0$
$\rho_{KL}+\rho_{KE}+\rho_{KM} = 0$	$\rho_{YM}+\rho_{KM} = 0$
$\rho_{YL}+\rho_{YE}+\rho_{YM} = 0$	$\rho_{tY}+\rho_{tK} = 0$

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[16] Inclusion of the Cost function along with the share equations does not allow for an internally consistent stochastic specification of homoskedastic error terms. Additionally, a lot of the information from the cost function is totally redundant insofar as it is entirely captured by the share equations.

Since the three variable cost shares sum to unity, the S_m equation was deleted from the estimable system. However, the above estimation procedure ensures that the estimated parameters are invariant with respect to which variable cost share equation is deleted from the system. Most of the remaining parameters(α_M , γ_{MM}, ρ_{tM}, ρ_{KM}, ρ_{YM} α_Y , ρ_{YK}, ρ_{tY}) were then computed by rearranging the above restrictions in terms of the directly estimated parameters. In the second step, the remaining intercept (α_o,) and technology parameters (α_t, α_{tt}) are estimated from the following equation using OLS.

$$LnC_V = \alpha_o + \alpha_t t + \alpha_{tt} t^2 + \alpha_{X*} X^* \tag{3.6}$$

The slope coefficient on X* is constrained to equal one. The variable X* is defined in the following manner using the estimated parameters from step one:

$$\begin{aligned} X^* = {} & \alpha_y \ln Y + \alpha_L \ln L + \alpha_E \ln E + \alpha_m \ln M + \beta_k \ln K + \tfrac{1}{2}\gamma_{yy}(\ln Y)^2 \\ & + \tfrac{1}{2}\gamma_{LL}(\ln P_L)^2 + \gamma_{LE}\ln P_L \ln P_E + \gamma_{LM}\ln P_L \ln P_M + \tfrac{1}{2}\gamma_{EE}(\ln P_E)^2 \\ & + \gamma_{EM}\ln P_E \ln P_M + \tfrac{1}{2}\gamma_{MM}(\ln P_M)^2 + \tfrac{1}{2}\gamma_{KK}(\ln K)^2 + \rho_{YL}\ln Y \ln P_L \\ & + \rho_{YE}\ln Y \ln P_E + \rho_{YM}\ln Y \ln P_M + \rho_{YK}\ln Y \ln K + \rho_{KL}\ln K \ln P_L \\ & + \rho_{KE}\ln K \ln P_E + \rho_{KM}\ln K \ln P_M + \rho_{tY} t \ln Y + \rho_{tK} t \ln K + \rho_{tL} t \ln P_L \\ & + \rho_{tE} t \ln P_E + \rho_{tM} t \ln P_M \end{aligned} \tag{3.7}$$

The reasoning behind this two step estimation procedure is to avoid the econometric difficulties associated with inclusion of the cost function in the system of estimable equations, while - at the same time - ensuring that the estimated intercept and technology parameters are at least numerically consistent with the efficient estimates taken from the fitted cost share equations.

3.3 Parameter Estimates

The above estimating procedure was applied separately to both Traditional and Hi-Technology sectors as well as to the Total Manufacturing Sector using annual data between 1970 and 1990[17]. The estimated parameters are given in Table II below.

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[17] Definitions of variables and data sources are given in Appendix II.

Table II

Parameter Estimates: Translog Variable Cost Function(t-stats in parentheses)

	TMAN	TRAD	TECH
α_o	-0.38897	-0.52164	-0.49758
	(-11.24)	(-18.21)	(-7.40)
α_t	0.03022	0.00275	0.03401
	(4.41)	(0.48)	(2.55)
α_{tt}	-0.00508	-0.00132	-0.00836
	(-8.74)	(-2.73)	(-7.40)
α_L	0.23413	0.38329	0.27807
	(39.58)	(29.47)	(29.35)
γ_{LL}	0.12099	0.1251	-0.01236
	(7.37)	(4.26)	(-0.38)
γ_{LE}	-0.00336	-0.01645	-0.00845
	(-0.66)	(-2.36)	(-1.03)
γ_{LM}	-0.11763	-0.10865	0.02081
	(-6.85)	(-3.44)	(0.61)
ρ_{YL}	-0.00231	-0.09725	-0.00824
	(-0.18)	(5.86)	(-0.40)
ρ_{KL}	0.00231	0.09725	0.00824
	(0.18)	(5.86)	(0.40)
ρ_{TL}	-0.00515	-0.00541	-0.00297
	(-7.18)	(-4.97)	(-2.04)
α_E	0.04441	0.06054	0.036
	(15.30)	(10.34)	(10.93)
γ_{EE}	0.01223	0.03443	0.00634
	(4.06)	(10.19)	(1.96)
γ_{EM}	-0.00887	-0.01798	0.00211
	(-1.49)	(-2.39)	(0.24)
ρ_{YE}	-0.03908	-0.03044	-0.03331
	(-6.125)	(-4.09)	(-4.67)
ρ_{KE}	0.03908	0.03044	0.03331
	(6.125)	(4.09)	(4.67)
ρ_{TE}	.000151	.000679	0.00184
	(0.600)	(-2.15)	(4.25)
β_K	-0.11165	-0.18287	-0.11876
	(-8.39)	(-9.03)	(-6.61)
ρ_{KM}	-0.04139	-0.12769	-0.04155
	(-3.01)	(-7.25)	(-2.201)
ρ_{YK}	-0.20311	-0.14706	-0.30855
	(-6.88)	(-5.57)	(-7.73)
γ_{KK}	0.20311	0.14706	0.30855
	(6.88)	(5.57)	(7.73)
ρ_{tK}	-0.01042	-0.01310	-0.01200
	(-14.06)	(-12.59)	(-8.28)

Adj. R^2s	TMAN	TRAD	TECH
LnVC	0.99	0.99	0.99
S_L	0.35	0.59	0.76
S_E	0.91	0.83	0.68
M_K	0.93	0.79	0.97

In general, the fit of the labour share equation is lower than the other estimated equations. However, in the Hi-technology sector, the labour share equation has a slightly better fit than the energy share equation. For all three sectors to which the model was applied, the estimated cost equation can be shown to be monotonically increasing in variable factor prices but decreasing in the level of the fixed factor. In terms of significance, the parameter estimates for the Traditional manufacturing sector tend to outperform both the High-technology and the Total Manufacturing sectors. In the Hi-Tech sector, the significance of the parameters in the labour share equations is particularly disappointing.

The *partial equilibrium* price and substitution elasticities implied by the fitted share equations and parameter estimates are given in Tables 1 and 2, Appendix I[18]. As noted by Brown and Christensen*(op. cit.)* these substitution elasticities do not provide any information as to the substitution possibilities between the fixed and variable factors[19]. Additionally, the estimated elasticities are stochastic and in some cases - given the standard errors on the associated parameter estimates - are subject to a large margin of error. In particular, the γ_{ij} parameter estimates in the Hi-Technology sector are not well determined. For all three sectors, all own price and substitution elasticities are negative for each annual observation as is required by theory. In comparing Table 1 with Tables 2, it can be seen that while the substitution elasticities are all symmetric ($\sigma_{ij} = \sigma_{ji}$), the price elasticities are not ($\varepsilon_{ij} \neq \varepsilon_{ji}$). Of the three sectors examined, the Hi-technology sector exhibits the greatest own price response for labour, energy and materials. This is consistent with the findings of Bradley et al.(1993). Also consistent with these previous results for the Hi-technology sector is the finding that labour displays the greatest own price response, followed by energy and then by materials.

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[18] The partial equilibrium elasticities of substitution are computed from the restricted cost function and its first and second partial derivatives, i.e. $s_{ij} = \frac{C_V \cdot C_{V_{ij}}}{C_{V_i} \cdot C_{V_j}}$ where $C_{V_i} = \frac{d\,C_V}{d\,P_i}$ etc. The price elasticities are then computed as the product of the fitted cost share equation and the estimated elasticities of substitution, i.e. $e_{ij} = S_j \cdot s_{ij}$. See Brown and Christensen(1981).

[19] Brown and Christensen(1981) go on to illustrate the procedure for calculating the long-run or full-equilibrium elasticities of substitution. Additionally, some inferences concerning long-run substitution between the fixed and variable factors can be made using the elasticity of capacity output with respect to variable input prices calculated below in section 3.3.

There also appears to be a moderate upward trend in the labour own-price elasticity in the Hi-Technology Sector. The own-price elasticity of labour in the Traditional sector is approximately half that in the High-technology sector. Again, in all three sectors, labour and materials and energy and materials appear to be weak short-run substitutes. In the Hi-Tech sector, there is a greater degree of substitutability between labour and materials and energy and materials than either the Total or Traditional manufacturing sectors. There is no significant substitution for any sector between energy and labour in the short-run.

3.4 Capacity Utilisation in Irish Manufacturing: 1970 - 1990

Together with the parameter estimates from the restricted variable cost function, input and output quantity and price series are employed to calculate by numerical iteration the capacity output implied in (3.5). From this the implied CU ratio is calculated for each sector over the 1970 - 1990 period. The results are given in Table III below[20]. For the purpose of comparison, the annual averages from the peak-to-peak and surveyed measures are also reproduced. The resulting CU measures are all less than unity and thus are similar to those obtained by Berndt and Hesse(*op. cit.*) for eight other industrialised countries. The results contrast with Morrison's CU measures under static expectations which tended to be greater than one in general. The CU ratio relating to the Total Manufacturing sector is given in the first column of Table III. The results indicate that a substantial degree of excess capacity existed in the Irish manufacturing sector between 1970 and 1990. Relative peaks in capacity utilisation occurred in 1973, 1978, 1981 and 1988. CU in the Total Manufacturing sector reached its lowest level of 49% in 1986. The results suggest that the extent of excess capacity was much greater than that implied by either the survey results (MIS) or the peak-to-peak (PP) measures. The extent of excess capacity in the Hi-Technology component of Irish manufacturing has been somewhat lower. In this sector, capacity

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[20] A graphical presentation of the CU ratios is given in Figures 3, 4 and 5 in Appendix I.

Table III: Capacity Utilisation, Irish Manufacturing Sector: 1970 - 1990

	TMAN	*TECH*	*TRAD*	*MIS*	*PP*
1970	0.539256	0.675492	0.621715	-	-
1971	0.555282	0.64426	0.563575	-	-
1972	0.595904	0.62732	0.67754	-	-
1973	0.637503	0.715719	0.703229	-	-
1974	0.619636	0.764848	0.697873	-	-
1975	0.59726	0.680427	0.637671	-	0.963701
1976	0.611627	0.697151	0.637125	-	0.977472
1977	0.656957	0.723697	0.674067	-	0.978843
1978	0.683094	0.749335	0.570202	-	0.987695
1979	0.644159	0.74534	0.688446	-	0.993016
1980	0.589432	0.751446	0.623758	-	0.910016
1981	0.654867	0.776766	0.665106	-	0.890793
1982	0.64192	0.722335	0.612035	-	0.819184
1983	0.617793	0.734001	0.542715	-	0.832229
1984	0.602106	0.759099	0.520198	0.66050	0.858337
1985	0.565784	0.643192	0.55379	0.68417	0.84929
1986	0.49127	0.567633	0.433829	0.69292	0.826229
1987	0.578105	0.686593	0.534282	0.71067	0.863616
1988	0.732682	0.816938	0.701001	0.72492	0.924227
1989	0.705642	0.860027	0.593846	0.75283	0.984057
1990	0.602864	0.695811	0.586627	0.75542	0.973354

utilisation peaked at over 86% in 1989. The Traditional Sector has on average had a greater buffer of excess capacity than the Hi-Technology component. CU peaked at over 70% in 1973 and 1988 in the Traditional Sector. In all three sectors, capacity utilisation dropped substantially between 1980 and 1986. Consistent with the survey results, there was a significant rise in CU between 1986 and 1988/89. However, the economic measures record a substantial drop in CU in 1990 which is not reflected in the surveyed data.

Figure 3 (Appendix I) also illustrates that the calculated CU ratio provides a reasonable indicator of the Irish business cycle: changes in the CU rate for the total manufacturing sector accord well with the recessions which have been identified by

Fagan and Fell(1992) for the Irish economy[21]. During the 1970s, two recessions have been identified using a composite coincident indicator approach and these occurred in the periods 1973-1975 and 1979 -1980. From Figure 3, it is clear that during both of these recessions the calculated CU ratio declined substantially. The first half of the 1980s was also characterised by two severe recessions and these are captured in the significant decline in measured CU between 1981 and 1986. The rebound in economic activity which occurred subsequently is captured in the surging capacity utilisation rate between 1986 and 1988. Lastly, the recessionary period identified by Fagan and Fell between 1990 and 1992 would appear to be reflected in a sharp decline in CU in 1990.

As noted in the discussion of equation 2.5, an important dimension to the above CU measure, is that it allows one address the issue of how changes in variable input prices, the cost of capital and technological progress affect capacity output (Y*). Some insight into what is driving the above CU ratios can be obtained from an examination of the elasticity of capacity output with respect to variable input prices. Berndt and Hesse*(op. cit.)* have shown that - for the Translog - this elasticity is given in 3.7 below:

$$e_{Yi} = \left(\frac{S_i M_k + r_{Ki}}{g_{YY} + M_K^2 - M_K} \right) \qquad (3.8)$$

Since the above measure depends on the fitted factor shares and the estimated parameters (ρ_{ki} γ_{yy}), it is itself stochastic and will vary for each annual observation. Berndt and Morrison(1981), referring to the work of Rasche and Tatom(1977), rationalise the sign of ε_{yi} in terms of the degree of substitutability/complementarity between the variable input and the fixed factor. If variable input i and the fixed factor K are long-run substitutes, then an increase in P_i will raise the long-run optimal (K/Y) ratio. This implies that for a given fixed capital stock, in the short-run capacity output Y* must be lower. Consequently, a negative ε_{yi} is consistent with long-run substitution

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[21] Fagan and Fell(1992) deem a recessions to have occurred when there have been two consecutive quarters of period to period negative growth in their co-incident index of the Irish business cycle. The exact periods which satisfy this criterion over the sample period are 1973(M9) - 1975(M4), 1979(M7) -1980(M7), 1981(M9) - 1983(M5), 1985(M5) - 1986(M6), 1990(M10) - 1992(M1).

between the variable and the fixed factor. Conversely, a positively signed ε_{yi} is consistent with long-run complementarity.

The ε_{yi} elasticity measures are given for each sector in Table 3 in Appendix I. In all three sectors a similar pattern emerges. Capacity output is negatively related to the price of labour and materials but positively related to energy prices. Traditional sector capacity output is substantially less sensitive to variation in the price of labour. In all three sectors, capacity output is seen to be most sensitive to the price of material inputs. Capacity output in the Traditional sector exhibits the greatest sensitivity to material input prices. As outlined in the preceding paragraph, the negative sign on the ε_{YL} and ε_{YM} elasticities is consistent with some measure of capital-labour, capital-materials substitution in the long-run. In contrast, Bradley et al.(1993) found evidence of significant long-run complementarity between capital and labour in the traditional sector. The positively signed ε_{YE} is consistent (as also outlined above) with long-run capital-energy complementarity. For three of the nine countries analysed (including the UK), Berndt and Hesse*(op. cit.)* also uncovered positively signed ε_{YE}. However, the responsiveness of short-run capacity output to an energy price increases is positive but generally weak. There also appears to be a trend decline in the sensitivity of capacity output in Irish manufacturing to increases in the price of energy. Berndt and Hesse*(op. cit.)* also note that ε_{YE} is equivalent to the negative of the long-run price elasticity of capital with respect to the price of energy. Energy price increases thus tend to reduce the long-run demand for capital.

The elasticities of Y* with respect to changes in the cost of capital and technological change are also given in Table 3(Appendix I). Consistent with the results obtained in Berndt and Hesse*(op. cit.),* capacity output is *positively* related to increases in the cost of capital. This occurs because the own price elasticity of capital is negative. As a result, an increase in the cost of capital will lower the long-run optimal (K/Y) ratio. Thus, for a given capital stock, short run capacity output must be higher. In general, the ε_{YK} elasticity is greater than unity though it varies substantially over the sample period. Lee and Kwon(op. cit.) employed the Morrison(1986) quadratic cost function approach and found a negative relationship between Y* and P_K. Table 4 also shows how capacity output varies with the level of technology. In the Total and Hi-Technology sectors capacity was positively related to the level of technology in 1990. However, in the Traditional sector, there is a weak negative relationship. In effect, capacity output in Traditional manufacturing appears to be relatively independent of the level of technology.

It is possible - given the above elasticity estimates - to analyse some of the primary turning points in the CU ratios in terms of exogenous price changes. As noted previously, the above capacity output measure is most sensitive to changes in the cost of capital and the price of raw materials. Capacity output is not in general very sensitive to energy and labour price changes over the period analysed (see Table 3). Materials prices - for all sectors - have exhibited significantly less fluctuation than the cost of capital. Material prices are therefore likely to account for a smaller component of the short-run variation in CU. However, the sensitivity of capacity output to changes in the cost of capital is particularly useful in explaining changes in CU. One period which is interesting to analyse corresponds to the trend decline in CU that was observed for all three sectors during 1980-86. From Table 5, it is clear that - in all three sectors - capacity output grew at a substantially faster rate on average than actual output. This period is associated with a substantial rise in the cost of capital and therefore - consistent with the observed positive sign on the ε_{YK} elasticity - gave rise to a decline in the recorded level of CU. Conversely, the large rise in measured CU in 1988 corresponds to a period when the user cost of capital declined substantially. The subsequent decline in CU between 1989/90 coincides with a period in which the cost of capital increased significantly.

3.5 Capacity Utilisation and Inflation: 1970 - 1990

Recently, it has been argued that the current environment in which monetary policy must be carried out has increased the need to examine the usefulness of different variables as indicators of inflation[22]. In an open economy - which possesses both a

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[22] See McGettigan(1994)

traded and a non-traded sector - it is necessary to consider both external and internal sources of inflation. External sources - which are generally agreed to be significant in the case of Ireland - have been investigated by (among others) Geary(1976) and Callan and Fitzgerald(1989). Other research has, however, sought to emphasise the domestic influences on Irish inflation which may be of particular importance over the short-run. In a recent survey, Leddin(1995) - in weighing up the evidence - concludes " . . . that domestic variables have an important bearing on Irish inflation. Even in monetarist models, where PPP is assumed, the importance of domestic variables cannot be discounted." We briefly outline below why a capacity utilisation series may be of use in uncovering inflationary impulses in the Irish economy. We argue that this is true no matter what view one takes of the ultimate determinants of inflation in either the short or long-run. Following this, some tentative regression results are presented in order to test whether the constructed capacity utilisation series are significantly related to Irish inflation.

CU measures the extent to which a nation's industrial sector is operating at its capacity level of output. Finn(1995) has remarked that the theory supporting the view that high (low) rates of utilisation are inflationary(deflationary) would appear not to have been fully articulated. Furthermore, insofar as the theory has been articulated, it primarily relates to a closed-economy specification of economic activity. What, therefore, exactly is the justification for positing a relationship between variation in utilisation rates and inflation? One rationale for the relationship hinges on the possibility that there exists a certain operating rate above which a firm's costs will begin to rise. When the economy is growing strongly, demand pressures may emerge which force firms to operate above this threshold rate of utilisation. At this point, firms may be forced to pay workers overtime. Furthermore, as the derived demand for labour increases, firms may only be able to hire additional workers at higher wages. An increase in plant and machinery maintenance costs may also be associated with operating at higher rates of utilisation. Under the assumption that output prices can be expressed as a constant mark-up on input costs, such upward pressure on costs will feed into higher output prices and may, ultimately, give rise to inflation. It is clear, that for this cost-push factor to be relevant, firms cannot behave purely as price-takers in output markets: they must be able to pass on higher costs into higher final output prices.

CU may also be interpreted as being *proximately* related to inflation in manner which reflects the ultimate role of money in determining price increases in the long-run. For example, CU rates may capture the impact on demand of domestic monetary aggregates. In so far as it results in a rightward shift in the aggregate demand curve, a positive shock to the domestic money supply will be associated with a rise in utilisation rates. Thus, an inflationary shock to demand may be reflected in a contemporaneous rise in the utilisation rate. In practice, it has, however, been noted that monetary policy operates primarily through financial prices (short-term interest rates) as opposed to financial quantities. In this regard, the deflationary impact of higher short-term interest rates may also be reflected in lower rates of capacity utilisation[23]. In short, positing a relationship between CU and inflation does not rule out monetary explanations of inflation.

The inflation-CU nexus noted above combines elements of traditional cost push and demand pull theories of inflation. Consequently, CU may capture some of the “domestic variables” that Leddin(*op. cit.*) identifies as being potentially significant in the case of Ireland. However, it is also possible that we might observe a positive correlation between CU and inflation *even if* domestic factors were completely insignificant in the inflationary process in Ireland. Most of the output of the Irish manufacturing sector is internationally traded. Variation in CU will, therefore, largely reflect the impact of stochastic *external* demand[24]. A positive shock to the external demand for Irish goods will be associated with a rise in short-run rates of utilisation.

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[23] This is particularly true of the measures constructed above. In the preceding analysis, capacity output was found to be positively related to changes in the user cost of capital. A rise in the cost of capital - driven by an increase in short rates - would immediately be reflected in a decline in the rate of utilisation.

[24] This is true of many widely available measures of capacity utilisation - however, it may not be true of the measure constructed in this paper. A large portion of the variation in these CU measures (as noted in section 3.4) can be attributed to variation in Y* as opposed to Y. A significant component of CU variation is therefore due to changes in the cost minimising level of output which is not directly related to the impact of stochastic demand (captured by Y) but rather reflects the impact of exogenous variable input prices, technology and the level of the fixed factor.

Irish firms which possess market power may pass on the increased costs associated with such higher rates of utilisation into higher output prices. The vast majority of Irish firms, however, constitute only a small fraction of total world supply. Consequently, they would tend to operate as price-takers on international markets. Under the small open economy (SOE) model of price setting behaviour, assuming purchasing power parity(PPP), Irish prices will tend to converge (in the long-run) to a weighted sum of the prices of a range of other countries (abstracting from any change in the exchange rate). However, even under this version of events, domestic CU measures may exhibit the expected positive correlation with inflation. With a fixed nominal exchange rate, a rise in domestic CU may largely reflect the erosion of economic slack in our main trading partners. Under the SOE model, unless the exchange rate is allowed to appreciate, foreign inflation would be transmitted to the Irish economy via the goods market (PPP). In summary, rising CU in the Manufacturing sector in Ireland may provide a good local indication of a build up of international inflationary pressures which may ultimately be transmitted to the Irish economy. As a result, manufacturing sector CU - as an indicator of inflation - cannot be interpreted as isolating domestic sources of inflation.

Given the above reasons for citing a positive relationship between CU and inflation, it is worth assessing the potential information content of the measures constructed in this paper. A preliminary assessment of this can be made from Figures 6, 7 and 8 in the appendix which graph the CU measures together with plots of the annual percentage change in the Consumer Price Index(CPI) and the Manufacturing output price Index (WPI)[25]. From the graphs, there does appear to be some reason to believe that CU can provide information concerning inflationary/deflationary pressures. In Figure 6, for example, the severe reduction in inflation which took place over the 1981-1986 period was associated with a sharp contraction in capacity utilisation in the Total manufacturing sector. From Figure 6, it can also be seen that CU reached its lowest level in a year in which manufacturing output prices actually declined (1986). However, the graph suggests a lack of any stability in the relationship: the marked rise

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[25] The output price index for Manufacturing Industries is employed and not the General Wholesale Price Index which includes the price of both imported and agricultural products.

in CU between 1986 and 1988 did not bring about any proportional increase in prices. This general finding is confirmed in Table IV below where it can be seen that the calculated CU ratios do exhibit the expected positive correlation with inflation. For the CPI, the correlation tends to increase when lagged values of the CU ratios are employed. For the WPI, the correlation is generally highest when the contemporaneous utilisation rate is employed. One notable feature of Table is that the Traditional sector CU ratio exhibits by far the greatest positive correlation with inflation. In fact, given the number of observations used in the sample, only the Traditional sector correlations are significantly different from zero. This is an intuitively appealing finding since these sectors are less subject to international competition than the High-Technology industries. Consequently, the cost-push/demand pull factors identified above might be thought to be most relevant here.

Table IV: Correlation of Capacity Utilisation and Inflation: 1970 - 1990

	TOTAL	**TECH**	**TRAD**
CPI			
CU_t	0.0125	0.0911	0.4572
CU_{t-1}	0.0933	0.1446	0.6040
CU_{t-2}	0.2870	0.2109	0.6310
WPI			
CU_t	0.1850	0.1544	0.5823
CU_{t-1}	0.0480	0.0422	0.6237
CU_{t-2}	0.0350	-0.1142	0.5521

We turn now to the issue of empirically testing for a statistical relationship between CU and inflation. McElhattan(1985) has derived a reduced form inflation equation to test for a relationship between CU and inflation in the US. Under her framework, the inflation rate is determined by changes in the nominal wage rate adjusted for changes in labour productivity and by excess aggregate demand expressed as some function of the capacity utilisation rate. Employing some further simplifying assumptions, McElhattan(1985) proceeded to show that the stable inflation rate of CU can be estimated from the short-run Philips curve given below:

$$p_t = a_o + a_1 p_t * + a_2 CU_t \qquad (3.9)$$

where π_t is the inflation rate and π_t* the current expected rate of inflation. To implement the model, the current expected rate of inflation is replaced by it actual past value π_{t-1} and a supply shock variable (Z_t) is also appended. Furthermore, the coefficient on the current expected rate of inflation (a_1) is assumed to equal unity. This yields the following estimable equation:

$$p_t = a_o + p_{t-1} + a_2 CU_t + a_3 Z_t + e_t$$

$$\text{or,} \quad \Delta p_t = a_o + a_2 CU_t + a_3 Z_t + e_t \qquad (3.10)$$

where e_t is a random disturbance term. Garner(1994) in a recent revision of the McElhattan equation found evidence that the CU rate consistent with stable inflation has exhibited a marked degree of stability despite recent arguments to the contrary. In a less structural interpretation of the CU-inflation nexus, Finn(1995) estimates the following regression to test the power of CU as an indicator of inflation.

$$p_t = a_o + \sum_{i=1}^{n} a_i p_{t-i} + b_o CU_t + e_t$$

(3.11)

A lag length of three was employed (with quarterly data) and the CU rate was indeed found to have significant explanatory power. As emphasised above, Finn(*op. cit.)* places little or no structural interpretation on (3.11). She argues for example that the lagged values of inflation are included only to ensure an “adequate specification” However, she notes of (3.11) that it is also consistent with the static Keynesian theory which permits persistence in the inflation rate. (3.11) might also be viewed as a generalisation of the McElhattan equation where Z_t is set equal to zero and π_t* is set equal to a weighted average of past values of π_t. The lag length is chosen on the basis of F-tests which establish that additional lagged values of the inflation series are statistically insignificant.

To test for a relationship between the constructed CU measures and inflation, the Finn equation (3.11) is employed. The less structural interpretation is appealing. Furthermore, the specification of a short-run Philip’s curve for Ireland would constitutes a complete research agenda in its own right. (3.11) is simply testing the significance of the contemporaneous utilisation rate in explaining Irish inflation in the presence of lagged inflation. While such an analysis is far from conclusive, it is based on the general conclusion in empirical work that the inflation rate is a most potent variable in explaining a significant proportion of its own variance. In the VAR analysis conducted by Howlett and McGettigan(1994), for example, it was shown that prices react very strongly to once of shocks in prices themselves. Over a two year horizon, depending on the specification of the VAR, between 98% and 53% of the squared prediction error of prices is “caused” by prices themselves. Anything which offers additional significant explanatory power may be of potential interest to policy makers.

The estimated parameters from the application of (3.11) to the CU ratio for the Total, Traditional and High Technology manufacturing sectors are reported in Table V below. Regression results are reported for both the Consumer Price Index(CPI) and the output price index (WPI) measures of inflation. For the CPI a lag length of two was found to be significant while a lag length of only one was implied by the F-test for the WPI. Since all regressions include lagged dependent variables, the results of a Lagrange Multiplier test for first and second order autocorrelation are reported in each case. At the normal levels of significance, these statistics provide no evidence of serial correlation in the residuals. For the Total manufacturing sector, the coefficient on the contemporaneous rate of utilisation, while positively signed in both regressions, is not statistically different from zero. This is also true of the CU ratio for the High Technology component of the Irish manufacturing sector. In a statistical sense, neither CU rate is able to explain any of the variation in consumer or manufacturing output

Table V: Regression Output : $p_t = a_o + \sum_{i=1}^{n} a_i p_{t-i} + b_o CU_t + e_t$ **- Eq. (3.10)**

p_t	a_o	a_1	a_2	b_o	**R^2**	**LM**
TMAN						
1. CPI	0.02 (0.22)	1.290 (5.95)	-0.570 (-2.53)	0.014 (0.09)	0.72	$\chi^2(1)$ = 0.859[0.353] $\chi^2(2)$ = 2.920[0.232]
2. WPI	-0.081 (-0.59)	0.783 (4.73)	-	0.161 (0.72)	0.54	$\chi^2(1)$ = 0.437[0.508] $\chi^2(2)$ = 2.520[0.282]
TECH						
1. CPI	-0.048 (-0.56)	1.292 (6.12)	-0.563 (-2.59)	0.106 (0.92)	0.73	$\chi^2(1)$ = 1.237[0.265] $\chi^2(2)$ = 2.486[0.288]
2. WPI	-0.099 (-0.77)	0.791 (4.87)	-	0.163 (0.91)	0.54	$\chi^2(1)$ = 0.428[0.512] $\chi^2(2)$ = 3.777[0.151]
TRAD						
1. CPI	-0.091 (-1.41)	1.136 (5.40)	-0.427 (-1.99)	0.198 (1.92)	0.77	$\chi^2(1)$ = 0.238[0.624] $\chi^2(2)$ = 0.791[0.673]
2. WPI	-0.239 (-2.92)	0.679 (4.97)	-	0.439 (3.18)	0.70	$\chi^2(1)$ = 0.339[0.560] $\chi^2(2)$ = 0.382[0.825]

Note: T-statistics given in (.), Significance level of $\chi^2(n)$ given in [.]

prices. However, the CU measure for Traditional industries is significant in explaining some of the variation in the CPI and the manufacturing output price index. It is also signed correctly in both regressions. This component of the Irish manufacturing sector is relatively more labour intensive and has been subjected less to international competition. As a result the above finding is highly intuitive since one would expect that - if anywhere - it would be in these industries that the cost-push/demand-pull factors associated with the CU rate would be relevant. A comparison of the R^2 reveals that 5% more of the variation in the CPI is explained when the Traditional sector utilisation rate is included instead of the rate for the Total Manufacturing sector. Over

16% more of the variation in output prices can be explained by the Traditional sector CU rate compared to the Total or High-Technology rates. It is also worth noting that the magnitude of the coefficient on the capacity utilisation rate is much larger in the output price equation than it is in the consumer price equation.

The above results are consistent with the hypothesised role of domestic variables in the inflationary process in Ireland. However, as was pointed out above, CU does not isolate the impact of domestic variables. The results suggest the potential usefulness of CU as an indicator of inflationary pressure but fall short of a structural analysis of the determinants of Irish inflation. A more formal investigation would have to extend the analysis to an open economy setting where both the impact of exchange rate variation and foreign prices on the Irish price level are taken into account. One could examine whether the Traditional sector CU ratio had any incremental explanatory power in a regression that includes both the exchange rate and foreign prices. What has been illustrated here is that there may be empirical support for a relationship between a *narrow* measure of CU and consumer/output price inflation. This finding certainly constitutes grounds for further research. Perhaps this could proceed along disaggregated lines with the monthly survey data and the output price series.

Section IV: Concluding Remarks

This paper has reviewed some of the more common methods of calculating measures of capacity utilisation. All methods have their own specific advantages and disadvantages. Peak-to-Peak extrapolation represents a practical option which may be useful in cross checking other measures (e.g. those taken from the monthly IBEC/ESRI survey). The available monthly survey measures are currently the most accessible and perhaps the most useful from a policy viewpoint given the high frequency with which they become available. However, there is a large degree of uncertainty about what these surveyed measures actually mean. Nor is it clear what is driving changes in surveyed CU measures. Methods based on the econometric application of production functions at an industrial level are also subject to a high margin of error. Apart from the econometric pitfalls involved in the estimation of production functions, the extensive data requirements(e.g. capital stock estimates) associated with this approach means that it is unlikely that it could be operationalised with a view to providing a timely economic indicator.

The paper has also applied the recently popularised cost function approach which grounds the derivation of a CU measure within a flexible theoretical framework. Specifically, the restricted variant of the Translog cost function was applied to data from the Irish manufacturing sector under the assumption of long-run constant returns to scale. In recognition of the dichotomy that characterises Irish industry, the model was also fitted to two individual sub-sector classifications: Hi-technology and Traditional manufacturing. The results suggest that a substantial degree of excess capacity existed in Irish manufacturing between 1970 and 1990. Traditional industry, relative to the Hi-technology sector, has had a significantly greater “buffer” of excess capacity. The results also suggest that changes in CU are predominantly driven by changes in the user cost of capital and the price of raw materials. While, this measure enriches our understanding of what is driving CU ratios, there are serious difficulties associated with its econometric application over a small sample period. In addition, this technique has extensive data requirements.

We also examined the usefulness of the constructed CU ratios as a possible indicator of inflationary pressure. No significant relationship between CU in the Total or Hi-Technology sectors was found. However, the CU ratio for the Traditional sector was found to be significantly positively related to Irish inflation. This finding while consistent with the belief that domestic variables may play an important role in the Inflationary process in Ireland, does not constitute a validation of that theory.

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APPENDIX I

Figure 1

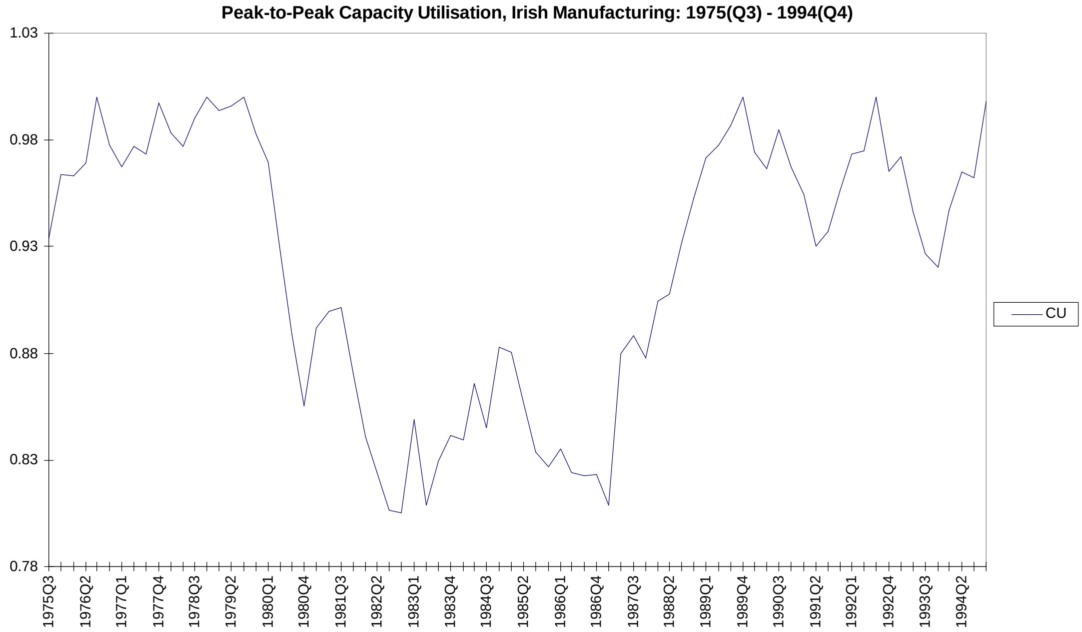


Figure 2

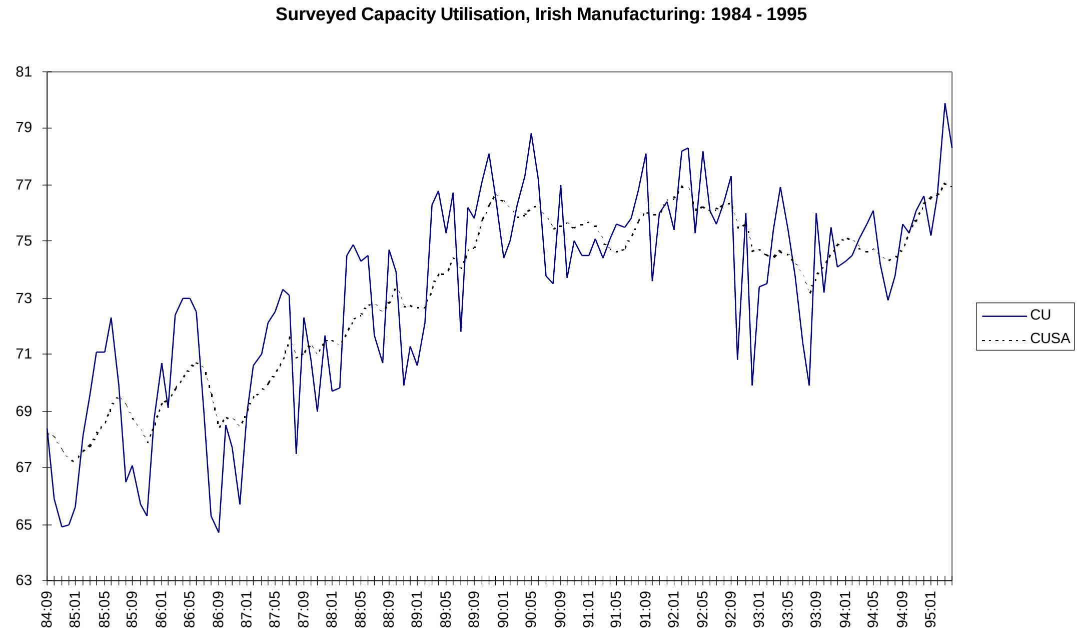


Figure 3

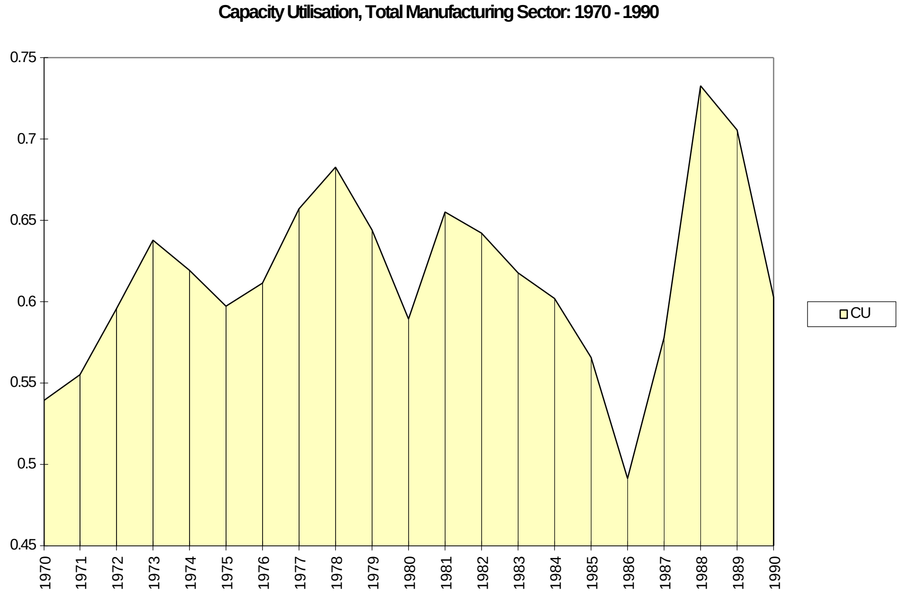


Figure 4

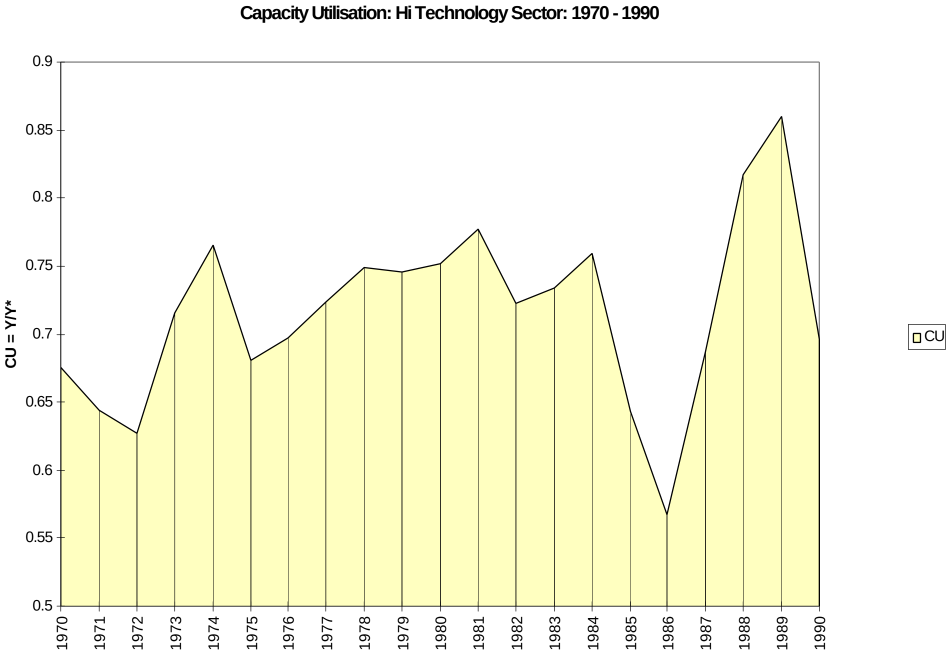


Figure 5

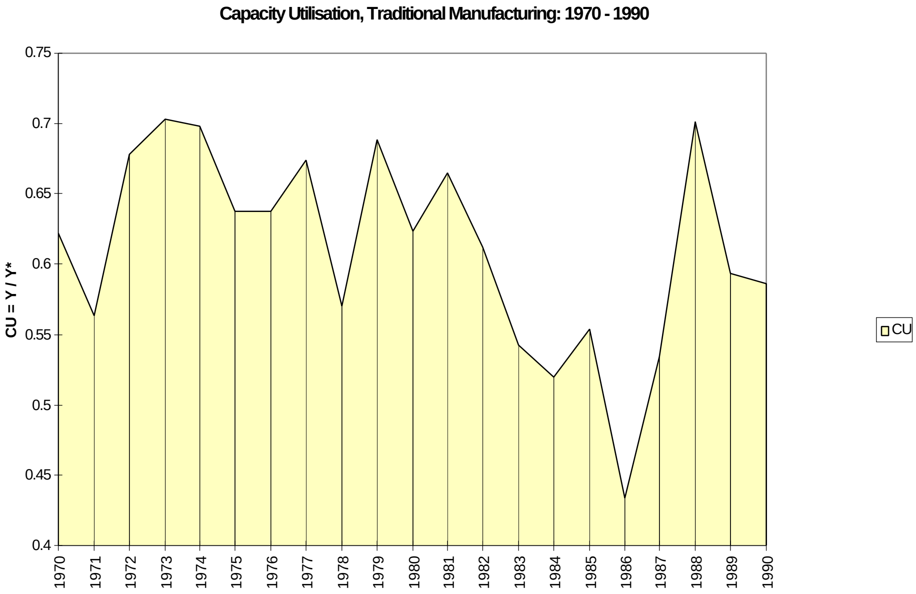


Figure 6

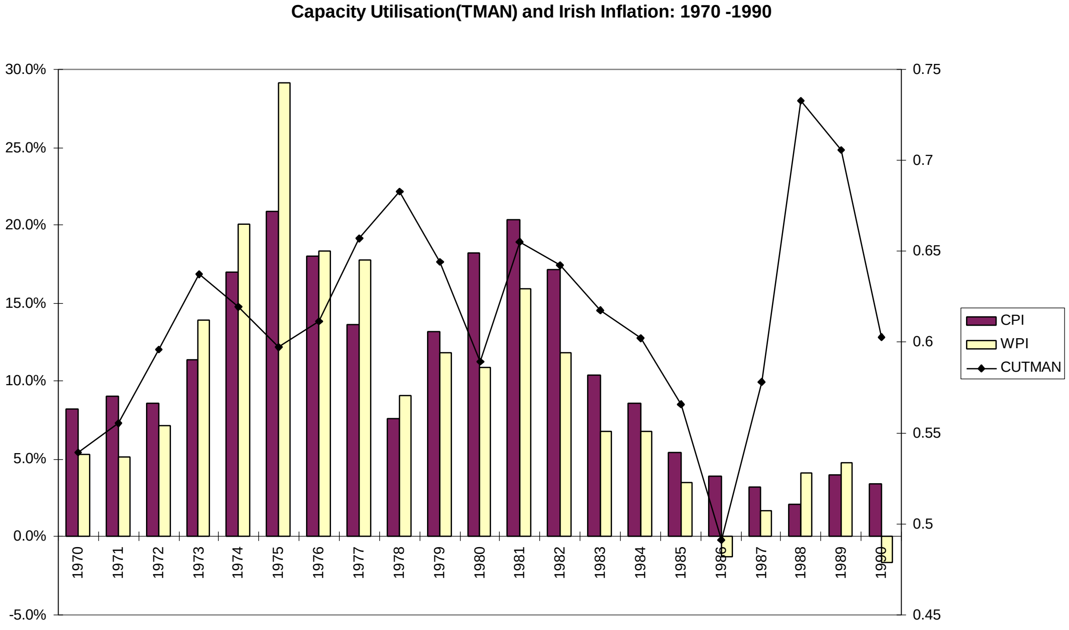


Figure 7

Capacity Utilisation(TECH) and Irish Inflation: 1970 - 1990

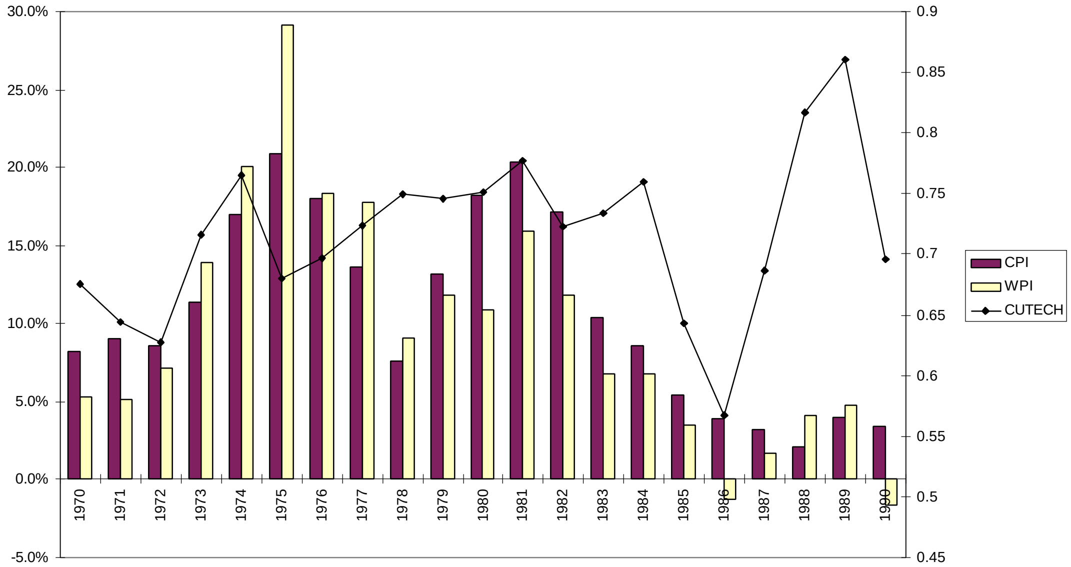
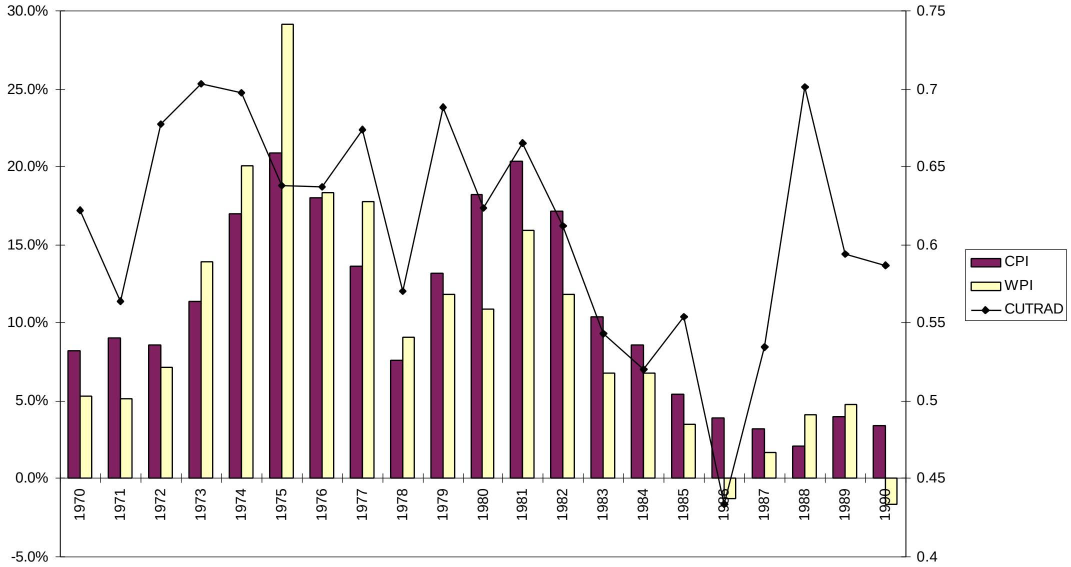


Figure 8

Capacity Utilisation(TRAD) and Irish Inflation: 1970 - 1990



Partial equilibrium elasticities of substitution

$$s_{ij} = \frac{C_V \cdot C_{V_{ij}}}{C_{V_i} \cdot C_{V_j}} \quad \text{,where} \quad C_{V_i} = \frac{d\,C_V}{d\,P_i} \quad \text{etc.}$$

Table 1: Partial Equilibrium elasticities of Substitution

Total Manufacturing:

	s_{LL}	s_{EE}	s_{MM}	s_{LE}	s_{LM}	s_{EM}
1970	-1.06	-19.44	-0.11	0.00	0.17	0.29
1975	-1.03	-18.02	-0.11	0.00	0.15	0.37
1980	-1.04	-15.52	-0.12	0.00	0.15	0.39
1985	-1.05	-16.18	-0.13	0.00	0.15	0.38
1990	-1.03	-19.28	-0.10	0.00	0.16	0.32

Traditional Manufacturing

	s_{LL}	s_{EE}	s_{MM}	s_{LE}	s_{LM}	s_{EM}
1970	-0.93	-1.68	-0.24	0.00	0.20	0.12
1975	-0.90	-4.72	-0.26	0.00	0.19	0.16
1980	-0.89	-6.25	-0.30	0.00	0.17	0.20
1985	-0.87	-6.23	-0.31	0.00	0.17	0.19
1990	-0.92	-3.08	-0.24	0.00	0.19	0.14

Hi-Tech Manufacturing

	s_{LL}	s_{EE}	s_{MM}	s_{LE}	s_{LM}	s_{EM}
1970	-2.87	-35.43	-0.45	0.00	0.56	0.59
1975	-3.18	-25.66	-0.43	0.00	0.58	0.57
1980	-3.62	-21.61	-0.40	0.00	0.61	0.58
1985	-4.06	-22.42	-0.36	0.00	0.65	0.62
1990	-4.55	-25.75	-0.32	0.00	0.69	0.66

Partial Equilibrium Own and Cross Price Elasticities

$$e_{ij} = S_j \cdot s_{ij}$$

Table 2: Partial Equilibrium Own and Cross Price Elasticities

Total Manufacturing.

	e_{LL}	e_{EE}	e_{MM}	e_{LE}	e_{LM}	e_{EM}	e_{EL}	e_{ML}	e_{ME}
1970	-0.24	-0.47	-0.08	0.00	0.129	0.215	0.00	0.039	0.007
1975	-0.22	-0.59	-0.07	0.00	0.115	0.275	0.00	0.033	0.012
1980	-0.22	-0.67	-0.09	0.00	0.109	0.290	0.00	0.032	0.017
1985	-0.23	-0.65	-0.09	0.00	0.114	0.279	0.00	0.035	0.015
1990	-0.22	-0.51	-0.07	0.00	0.121	0.246	0.00	0.034	0.009

Traditional. Manufacturing

	e_{LL}	e_{EE}	e_{MM}	e_{LE}	e_{LM}	e_{EM}	e_{EL}	e_{ML}	e_{ME}
1970	-0.29	-0.07	-0.15	0.00	0.13	0.08	0.00	0.06	0.01
1975	-0.29	-0.22	-0.17	0.00	0.12	0.10	0.00	0.06	0.01
1980	-0.29	-0.41	-0.18	0.00	0.10	0.12	0.00	0.05	0.01
1985	-0.29	-0.40	-0.19	0.00	0.10	0.12	0.00	0.06	0.01
1990	-0.29	-0.13	-0.16	0.00	0.12	0.09	0.00	0.06	0.01

Hi-Tech Manufacturing

	e_{LL}	e_{EE}	e_{MM}	e_{LE}	e_{LM}	e_{EM}	e_{EL}	e_{ML}	e_{ME}
1970	-0.78	-0.62	-0.32	0.00	0.40	0.42	0.00	0.15	0.01
1975	-0.80	-0.76	-0.31	0.00	0.42	0.41	0.00	0.15	0.02
1980	-0.83	-0.79	-0.30	0.00	0.45	0.43	0.00	0.14	0.02
1985	-0.85	-0.78	-0.27	0.00	0.49	0.47	0.00	0.14	0.02
1990	-0.87	-0.75	-0.25	0.00	0.54	0.52	0.00	0.13	0.02

Table 4: Capacity Output Elasticities

Total Manufacturing

	e_{YL}	e_{YE}	e_{YM}	e_{YK}	e_{YT}
1970	-0.103	0.070	-0.438	1.543	-0.036
1975	-0.098	0.062	-0.444	1.320	-0.022
1980	-0.102	0.054	-0.438	1.367	-0.008
1985	-0.111	0.042	-0.442	1.476	0.009
1990	-0.110	0.033	-0.448	1.352	0.026

Traditional Manufacturing

	e_{YL}	e_{YE}	e_{YM}	e_{YK}	e_{YT}
1970	0.008	0.035	-0.602	1.207	-0.030
1975	-0.004	0.029	-0.585	1.237	-0.024
1980	-0.008	0.018	-0.570	1.322	-0.018
1985	-0.027	0.014	-0.551	1.556	-0.011
1990	-0.048	0.017	-0.533	1.481	-0.004

Hi-Technology Manufacturing

	e_{YL}	e_{YE}	e_{YM}	e_{YK}	e_{YT}
1970	-0.107	0.038	-0.369	0.996	-0.031
1975	-0.101	0.030	-0.375	1.035	-0.011
1980	-0.097	0.020	-0.387	0.840	0.010
1985	-0.092	0.012	-0.393	1.159	0.032
1990	-0.084	0.007	-0.388	1.017	0.052

APPENDIX II

DATA

The quarterly, seasonally adjusted, index of industrial output used in the calculation of the peak-to-peak measure was taken from the CSO Databank. The surveyed capacity utilisation measures are taken from the computerised Databank of the IBEC-ESRI Monthly Industrial Survey undertaken on behalf of the EU. The relevant mnemonics are described in Kearney(1991).

The data for the manufacturing sector employed in this study is taken from the Department of Finance/ESRI Databank. All variables are available annually over the 1970-1990 period. The mnemonics associated with the relevant variables are given in the Table below.

Variable	Total Manufacturing	HI-Technology	Traditional
Y	QGIMT	QGIMH	QGIMD
K	KIMT	KIMH	KIMD
L	LIMT	LIMH	LIMD
E	QEIMT	QEIMH	QEIMD
M	QRIMT	QRIMH	QRIMD
P_Y	PQGIMT	PQGIMH	PQGIMD
P_K	PKIMT	PKIMH	PKIMD
P_L	WIMT	WIMH	WIMD
P_E	PQEIMT	PQEIMH	PQEIMD
P_M	PQRIMT	PQRIMH	PQRIMD

The Total Manufacturing sector includes the Food Sector(NACE code 411-423) in addition to Hi-Tech and Traditional Manufacturing. The High-Technology Manufacturing Sector combines the Chemical, Metal and Engineering sectors(NACE code 25-26, 22, 31-37). The Traditional Manufacturing Sector incorporates the residual non-food and non Hi-Tech sectors(i.e. NACE codes 11, 21,23/24,424-429, 43, 44-45/46/47/14,48-49). The data has been derived from a variety of sources including the *Census of Industrial Production,* the *National Accounts* and the OECD. Output is measured on a gross rather than net basis as is appropriate under the KLEM framework adopted here. The capital stock for the manufacturing sector (and sub-sectors) has been estimated from Henry's(1989) data. Persons employed is taken as a measure of the labour input. A complete description of the data is given in **Bradley et al.(1990).**

Following Berndt and Hesse(1986), all price variables are re-based to equal 1 in 1970. The output and input quantity variables (apart from labour input which is measured as persons employed) are also re-based to 1970 using their respective price deflators. As a result, the variable cost shares are not invariant with respect to which base year is chosen. However, the output deflator (PQGIMT/H/D) is used to re-base the capital stock measure in order to ensure that the capital-output ratio is invariant with respect to the chosen base period.