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PRODUCTION - DEMAND ADJUSTMENT IN NORWEGIAN MANUFACTURING: A QUARTERLY ERROR CORRECTION MODEL

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ABSTRACT

In this paper, we specify a general error correction equation for seasonally unadjusted data, with an arbitrary number of regressors. Special attention is paid to the specification of trend and seasonal filters, which have proved to be of importance when using seasonally unadjusted quarterly data. Within this framework, the adjustment of production to demand in a stock-building sector is analyzed. We have specified an output decision equation with three explanatory variables, capacity, demand, and stock imbalance. The model is estimated on Norwegian quarterly national accounts data by means of a non-linear least squares algorithm. Experiences from simulation exercises are also reported - illustrating the dynamic tracking as well as the dynamic behaviour of the model.

CONTENTS

1. INTRODUCTION

In empirical models of the behaviour of an economy in the short run, e.g. quarterly models, the treatment of the output decisions of the firms plays a crucial role. It is an empirical fact that in several sectors, notably in manufacturing, the time path of output from a sector over the business cycle often departs substantially from the time path of demand directed towards the sector. The counterpart to these deviations is variations in stock formation. In empirical work, such short run deviations are frequently analyzed by means of stock adjustment models of the standard textbook type, or simply generalizations of it (cf. e.g. Rowley and Trivedi (1975, ch. 2.2) and Feldstein and Auerbach (1976)).

In this paper, we take a different approach. Using the 'error correction' formulation as our point of departure (cf. Sargan (1964), and Hendry, Pagan, and Sargan (1984), pp. 1048-1049), we propose an econometric framework for analyzing the adjustment of production to demand on the basis of quarterly data from a stock-holding sector. The original error correction model, which is a one period adjustment model, has some deficiencies when applied to seasonally unadjusted quarterly data, and in this paper we use a generalized version of it.

The paper is organized as follows. First, we specify a general quarterly error correction (QEC) equation for seasonally unadjusted data, with an arbitrary number of regressors (section 2). It is an extension of the model in Biørn and Olsen (1986), with more specific attention to the trend and seasonal filters. Next, this general model formulation is accommodated to an output decision equation with three explanatory variables, capacity, demand, and stock imbalance (section 3). After a brief presentation of the data, which are aggregates for Norwegian manufacturing (section 4), and of the estimation procedure, which is a combined grid search, non-linear least squares procedure (section 5), the empirical results are reported. We focus on the one hand on the coefficient estimates, goodness of fit and dynamic tracking of alternative QEC eqations (section 6), and on the other hand on the dynamic behaviour of the model when exposed to sustained or temporary shift in its exogenous variables, i.e. capacity and demand (section 7). The final section gives concluding remarks (section 8).

2. A GENERAL QUARTERLY ERROR CORRECTION EQUATION FOR SEASONALLY UNADJUSTED DATA

2.1. The basic model

Consider first the case where economic theory postulates a linear static relationship to hold in the long run between the variables Y and $X_1,\ldots,X_K$,

$$(1) \qquad Y = \beta_0 + \sum_{i=1}^{K} \beta_i X_i \; .$$

The quarterly observations on these variables do not satisfy this static relationship, but we assume that their behaviour in the short run can be represented by a process correcting - according to 'servo-mechanistic' control principles - short run deviations from a 'steady state' path, given by (1). This mechanism will be formalized as an error correction (EC) process. Since the quarterly data are seasonally unadjusted, we use, rather than the one period version of the EC process (cf. Sargan (1964), Hendry and Richard (1983, pp. 130-131), and Hendry, Pagan, and Sargan (1984, pp. 1048-1049)), a generalization, denoted as a quarterly error (QEC) process and discussed, for the case with one X variable, in Biørn and Olsen (1986).

In the present paper, this QEC process is extended to an arbitrary number of X variables and specified in terms of seasonally adjusted values of the variables involved. The seasonal adjustment procedure is integrated in the model structure. The error correction equation is

$$(2) \qquad [1 - \varrho(L)]Y_t^S = \sum_{i=1}^{K} \alpha_i [1 - \varrho(L)]X_{it}^S$$

$$+ \gamma\varrho(L)[\beta_0 + \sum_{i=1}^{K} \beta_i X_{it}^S - Y_t^S] + \varepsilon_t \; ,$$

where γ is a constant between 0 and 1, $\varrho(L) = \varrho_1 L + \varrho_2 L^2 + \cdots$ is a polynomial in the lag operator L, ε is a zero mean, white noise disturbance, the subscript t is the time index, and the superscript S denotes a seasonally adjusted variable. The coefficients of $\varrho(L)$ are assumed to add to unity, i.e. $\varrho(1) = \varrho_1 + \varrho_2 + \cdots = 1$. This polynomial will be denoted as the <u>trend filter polynomial</u>, and we can accordingly interpret

(3) $$Y_t^* = \varrho(L)Y_t^S ,$$

and

(4) $$X_{it}^* = \varrho(L)X_{it}^S , \qquad i = 1,\dots,K ,$$

as trend values of Y_t and X_{it} and

(5) $$\Delta^* Y_t = Y_t^S - Y_t^* = [1 - \varrho(L)]Y_t^S ,$$

(6) $$\Delta^* X_{it} = X_{it}^S - X_{it}^* = [1 - \varrho(L)]X_{it}^S , \qquad i = 1,\dots,K ,$$

as detrended values of these variables. In the simple one period (quarter) EC model, we have $\varrho(L) = L$, i.e. $Y_t^* = Y_{t-1}^S$, $\Delta^* Y_t = \Delta Y_t^S = Y_t^S - Y_{t-1}^S$, etc. Extending the error correction to four periods (one year), we get $\varrho(L) = L^4$, i.e. $Y_t^* = Y_{t-4}^S$, $\Delta^* Y_t = \Delta_4 Y_t^S = Y_t^S - Y_{t-4}^S$, etc.

To show that (2) can be interpreted as an error correction equation, it is convenient, using (3) - (6), to rewrite it as

(7) $$\Delta^* Y_t = \sum_{i=1}^{K} \alpha_i \Delta^* X_{it} - \gamma\{Y_t^* - Y_t^{**}\} + \varepsilon_t ,$$

where Y_t^{**} is the steady state, or target value of Y in quarter t, defined by (1), i.e.

(8) $$Y_t^{**} = \beta_0 + \sum_{i=1}^{K} \beta_i X_{it}^* .$$

Eq. (7) says the following. For given trend values - i.e. for given values of Y_t^* and Y_t^{**} - a departure of X_i from its trend will induce a departure of Y from its trend by α_i units. If the trends do not satisfy the steady state path (8), there will be an error correction, so that if the trend Y exceeds its long run target ($Y_t^* > Y_t^{**}$), the difference will have a negative effect on the adjustment in Y. If the trend value of Y is below its target ($Y_t^* < Y_t^{**}$), the discrepancy will affect Y positively. The speed of adjustment is represented by γ. The trend departure of Y is the net result of two effects: the trend departure of the X's and the trend error correction.

The <u>seasonal filter</u>, $\mu(L) = \mu_0 + \mu_1 L + \mu_2 L^2 + \cdots$, is assumed to be the same for all variables, i.e.

(9) $Y_t^S = \mu(L)Y_t$,

(10) $X_{it}^S = \mu(L)X_{it}$, $i = 1,\ldots,K$,

where Y_t and X_{it} are the values of Y and X_i observed in period t. The filter is mean preserving, i.e. its coefficients add to unity, $\mu(1) = \mu_1 + \mu_2 + \cdots = 1$. Inserting (9) and (10) in (2), we get the QEC expressed in terms of the observed values.

$$(11) \quad \mu(L)[1 - \varrho(L)]Y_t = \sum_{i=1}^{K} \alpha_i \mu(L)[1 - \varrho(L)]X_{it} - \gamma\, \varrho(L)\mu(L)[Y_t - \sum_{i=1}^{K} \beta_i X_{it}] + \gamma\beta_0 + \varepsilon_t \, .$$

2.2. The trend and seasonal filters

In the empirical applications, the seasonal adjustment filter is specified as the one-sided unweighted four quarter moving average operator

$$(12) \quad \mu(L) = \frac{1}{4}(1 + L + L^2 + L^3) \, ,$$

i.e. all of its coefficients are a priori given. The trend polynomial is parametrized as

$$(13) \quad \varrho(L) = \varrho_1 L + \varrho_4 L^4 - \varrho_1\varrho_4 L^5 \, ,$$

where ϱ_1 and ϱ_4 are parameters between 0 and 1, at least one of them equal to 1. The latter restriction is needed to ensure $\varrho(1) = \varrho_1 + \varrho_4 - \varrho_1\varrho_4 = 1$, and implies that the detrending operation (5) - (6) contains a full differencing over either one or four quarters (or both). Stated equivalently: the trend operator defines either the value of the variable lagged one quarter plus a fraction ϱ_4 of the quarterly increase realized one year ago,

$$(13a) \quad \varrho(L) = L + \varrho_4 L^4(1 - L) \, ,$$

or the value lagged one year plus a fraction ϱ_1 of the annual increase realized one quarter ago,

(13b) $\varrho(L) = L^4 + \varrho_1 L(1 - L^4)$.

When applied to a variable which follows a linear trend, i.e. $Z_t = A + Bt$, these two specifications of the trend filter give $\varrho(L)Z_t = A + B(t-1+\varrho_4)$, and $\varrho(L)Z_t = A + B(t-4+4\varrho_1)$, i.e. the filtered values will lag $1-\varrho_4$ and $4(1-\varrho_1)$ quarters behind the original values, respectively.

Written out, the composite detrending - seasonal filter polynomial and the composite trend - seasonal filter polynomial implied by (12) and (13) are, respectively,

$$(14) \quad \mu(L)[1 - \varrho(L)] = \frac{1}{4}(1 + L + L^2 + L^3)(1 - \varrho_1 L)(1 - \varrho_4 L^4)$$

$$= \frac{1}{4}[1 + (1 - \varrho_1)(L + L^2 + L^3) - (\varrho_1 + \varrho_4)L^4$$

$$- \varrho_4(1 - \varrho_1)(L^5 + L^6 + L^7) + \varrho_1\varrho_4 L^8] ,$$

$$(15) \quad \mu(L)\varrho(L) = \frac{1}{4}(1 + L + L^2 + L^3)(\varrho_1 L + \varrho_4 L^4 - \varrho_1\varrho_4 L^5)$$

$$= \frac{1}{4}[\varrho_1(L + L^2 + L^3) + (\varrho_1 + \varrho_4)L^4$$

$$+ \varrho_4(1 - \varrho_1)(L^5 + L^6 + L^7) - \varrho_1\varrho_4 L^8] .$$

In the general case, both filters will define autoregressive processes of order 8. If $\varrho_1 = 1$, terms of order 1,2,3,5,6, and 7 will vanish from $\mu(L)[1-\varrho(L)]$ and terms of order 5,6, and 7 will vanish from $\mu(L)\varrho(L)$. No term will vanish if $\varrho_4 = 1$ in the general case.

The wide variety of lag patterns inherent in this specification is illustrated by the following examples. If $\varrho_4 = 1$, $\varrho_1 = 0$, the composite polynomials are

$$\mu(L)[1 - \varrho(L)] = \frac{1}{4}(1 + L + L^2 + L^3)(1 - L^4)$$

$$= \frac{1}{4}[(1 - L^4) + (L - L^5) + (L^2 - L^6) + (L^3 - L^7)]$$

= average of annual increase over the last four quarters,

$$\mu(L)\varrho(L) = \frac{1}{4}(L^4 + L^5 + L^6 + L^7)$$

= annual average lagged four quarters,

$\varrho_1 = 1$, $\varrho_4 = 0$ implies

$$\mu(L)[1 - \varrho(L)] = \frac{1}{4}(1 + L + L^2 + L^3)(1 - L) = \frac{1}{4}(1 - L^4)$$

= average of quarterly increase over the last four quarters,

$$\mu(L)\varrho(L) = \frac{1}{4}(L + L^2 + L^3 + L^4)$$

= annual average lagged one quarter,

while $\varrho_1 = \varrho_4 = 1$ leads to

$$\mu(L)[1 - \varrho(L)] = \frac{1}{4}(1 + L + L^2 + L^3)(1 - L)(1 - L^4) = \frac{1}{4}(1 - L^4)^2$$

= one quarter of second annual difference,

$$\mu(L)\varrho(L) = \frac{1}{4}[L + L^2 + L^3 + L^4 + (L^4 - L^8)] .$$

= annual average lagged one quarter plus average of quarterly increase lagged four quarters.

2.3. Quarterly error correction versus cointegration

The relationship that exists between error correction models and cointegration has been discussed in recent literature (cf. Granger (1981), Granger and Weiss (1983), Hendry (1986), and Engle and Granger (1987)). It is known that the simple one period error correction model (i.e. $\varrho(L) = L$) for non-seasonal data (i.e. $\mu(L) = 1$) usually has a cointegration representation (Engle and Granger (1987, p. 259)). Will this also be the case for our more general model?

Assume that $Y_t, X_{1t}, \ldots, X_{Kt}$ are integrated of order 1, i.e. their first differences have a stationary invertible, ARMA representation (cf. Engle and Granger (1987, p. 252)). Then $Y_t^S, X_{1t}^S, \ldots, X_{Kt}^S$ and $Y_t^*, X_{1t}^*, \ldots, X_{Kt}^*$ will also be integrated of order 1, since they are constructed by application of the linear filter $\mu(L)\varrho(L)$. (Cf. Harvey (1981, p. 42).) Our QEC model, as formalized in (7)-(8), says that

$$-\gamma(\beta_0 + \sum_{i=1}^{K} \beta_i X_{it}^* - Y_t^*) = \sum_{i=1}^{K} \alpha_i \Delta^* X_{it} - \Delta^* Y_t + \varepsilon_t \; .$$

The right hand side of this expression will then be integrated of order 0 when ε is a zero mean, white noise disturbance. This follows from the fact that the detrending operator $1-\varrho(L)$ always contains the first order difference operator $1-L$. If $\varrho_1 = 1$, we have

$$1 - \varrho(L) = (1 - L)(1 - \varrho_4 L^4) \; ,$$

if $\varrho_4 = 1$, we have

$$1 - \varrho(L) = (1 - \varrho_1 L)(1 - L^4) = (1 - \varrho_1 L)(1 - L)(1 + L + L^2 + L^3) \; .$$

Since in both cases the first order difference operator is applied to the seasonally adjusted variables, $\Delta^* X_{it}$ and $\Delta^* Y_t$ will be integrated of order 0.

From this we can conclude that the seasonally adjusted variables, $Y_t^S, X_{1t}^S, \ldots, X_{Kt}^S$ will be cointegrated of order 1,0, according to the Engle-Granger terminology, under the assumptions made.

3. THE OUTPUT DECISION FUNCTION

3.1. Theoretical background

We now accommodate the general QEC framework to the specification of a short run output decision function for a stock-holding manufacturing sector. The variables assumed to motivate the sector's choice of production scale, Y, are its production capacity, $\bar{Y}$, its expected demand, $\bar{D}$, and the difference between its desired and actual stock of finished goods, $\bar{S} - S$. These three variables correspond to X_i in the general model in section 2.

The producers in manufacturing industries are often keeping considerable stocks of finished products - the manufacturing sector is sometimes referred to as the stock-holding sector. These stocks may act as a buffer between production and demand. Producers may in some periods meet demand by reducing stocks. In other periods, they may produce more than necessary to meet actual demand by increasing stocks (cf. e.g. Biørn (1985, section 2)).

How can a long run steady state path be represented with this interpretation of the variables ? A balanced expansion (or contraction) can be characterized by equality of production, capacity, and demand, i.e. $Y = \bar{Y} = D$, and equality of the actual and the desired stock, i.e. $S = \bar{S}$. Since it involves three equations, this expansion path can only be fully represented within a multi equation model, including the identity $Y = D + \Delta S$ and equations for supply and demand of the commodity in question. We shall not construct such a model, but 'condense' the long run expansion path into one equation containing capacity, demand, and stock imbalance as joint determinants of the production target. The equation for the production target is

$$(16) \qquad Y_t^{**} = \sum_{i=1}^{K} \beta_i X_{it}^{*} = a\, \bar{Y}_{t-1}^{*} + (1 - a)\, \bar{D}_t^{*} + b\, (\bar{S}_t^{*} - S_{t-1}^{*}) ,$$

where the asterisks indicate trend values, as in eq. (4), and a and b are constants between 0 and 1. It may be given the following rationalization. At the beginning of quarter t, there is an imbalance between the (trend values of the) production capacity and the desired stock, on the one hand, and the (trend values of the) demand and the actual stock, on the other, reflecting decision errors, costs of adjustment, erroneous expectations, etc. in previous quarters. Eq. (16) represents the firms' strategy to eliminate these discrepancies and can be formally derived by minimizing with respect to Y_t^{**} a cost function specified either as

$$A[Y_t^{**} - \overline{Y}_{t-1}^{*}]^2 + B[Y_t^{**} - \overline{D}_t^{*} - C(\overline{S}_t^{*} - S_{t-1}^{*})]^2$$

or as

$$A[Y_t^{**} - \overline{Y}_{t-1}^{*} - C(\overline{S}_t^{*} - S_{t-1}^{*})]^2 + B[Y_t^{**} - \overline{D}_t^{*}]^2 .$$

Here A, B, and C are positive constants, C being the share of a stock imbalance which the firm desires to eliminate in one quarter. This cost minimization gives eq. (16) with a = A/(A+B), b=(1-a)C in the first case and A/(A+B), b=aC in the second. Interesting special cases are a = b = 0 (i.e. target value of production equal to trend value of demand, regardless of capacity and stock imbalance), and a = 1, b = 0 (i.e. target value of production equal to trend value of production capacity, regardless of demand and stock imbalance). This interpretation of (16) implies that it does not represent a strict long-run relationship, but rather a medium-term target relation, the corresponding long run model being characterized by equality between production, capacity, and demand, and no stock imbalance.

3.2. The QEC version of the output decision function

The departures of the (seasonally adjusted) values of capacity, demand, and stock imbalance from their trends are assumed to induce a departure of Y from its trend equal to

$$(17) \qquad \sum_{i=1}^{K} \alpha_i \Delta^* X_{it} = \alpha\, \Delta^* \overline{Y}_{t-1} + (1-\alpha)\, \Delta^* \overline{D}_t + \beta\, \Delta^*(\overline{S}_t - S_{t-1}) ,$$

where

$$\Delta^* \overline{Y}_{t-1} = \overline{Y}_{t-1}^{S} - \overline{Y}_{t-1}^{*} = [1 - \varrho(L)]\overline{Y}_{t-1}^{S} = \mu(L)[1 - \varrho(L)]\overline{Y}_{t-1} ,$$

$$\Delta^* \overline{D}_t = \overline{D}_t^{S} - \overline{D}_t^{*} = [1 - \varrho(L)]\overline{D}_t^{S} = \mu(L)[1 - \varrho(L)]\overline{D}_t ,$$

$$\Delta^*(\overline{S}_t - S_{t-1}) = (\overline{S}_t^{S} - S_{t-1}^{S}) - (\overline{S}_t^{*} - S_{t-1}^{*}) = \mu(L)[1 - \varrho(L)](\overline{S}_t - S_{t-1}),$$

Inserting (16) and (17) in (7), we get the QEC output decision function

$$(18)\qquad \Delta^{*}Y_t = \alpha\,\Delta^{*}\overline{Y}_{t-1} + (1-\alpha)\,\Delta^{*}\overline{D}_t + \beta\,\Delta^{*}(\overline{S}_t - S_{t-1})$$
$$- \gamma\,[Y^{*}_t - a\,\overline{Y}^{*}_{t-1} - (1-a)\,\overline{D}^{*}_t - b\,(\overline{S}^{*}_t - S^{*}_{t-1})] + \varepsilon_t\ .$$

Inserting the trend and seasonal adjustment filters, (18) can be written in terms of the observed, seasonally unadjusted variables [cf. (11)] as

$$(19)\quad \mu(L)[1 - \varrho(L)]\ Y_t$$
$$= \sum_{i=1}^{K} \mu(L)[1 - \varrho(L)]\ [\alpha\,\overline{Y}_{t-1} + (1-\alpha)\,\overline{D}_t + \beta\,(\overline{S}_t - S_{t-1})]$$
$$- \gamma\,\varrho(L)\mu(L)[Y_t - a\,\overline{Y}_{t-1} - (1-a)\,\overline{D}_t - b\,(\overline{S}_t - S_{t-1})] + \varepsilon_t\ ,$$

or, when collecting terms as

$$(20)\qquad \mu(L)[1 - (1-\gamma)\varrho(L)]Y_t = \mu(L)\ [\alpha - \varrho(L)(\alpha - \gamma a)]\overline{Y}_{t-1}$$
$$+ \mu(L)[(1-\alpha) - \varrho(L)(1 - \alpha - \gamma(1-a))]\overline{D}_t$$
$$+ \mu(L)[\beta - \varrho(L)(\beta - \gamma b)](\overline{S}_t - S_{t-1}) + \varepsilon_t\ .$$

This version of the QEC output decision function will be analyzed empirically in the following sections of the paper.

4. DATA

Quarterly data on production (Y), production capacity ($\overline{Y}$), demand (D), and stocks of inventories (S) at constant prices in total manufacturing are used. The data are, with some exceptions to be explained below, taken from the (seasonally unadjusted) Norwegian quarterly national accounts and are an extension of the data base for the quarterly model KVARTS (see Biørn, Jensen and Reymert (1987)). The quantity series in the Norwegian national accounts change base year regularly, and the quarterly data used in the present investigation are all rebased to 1985 prices at a fairly disaggregate level of sector and commodity classification and are then aggregated to manufacturing totals.

The data on capacity, $\bar{Y}$, are constructed by using a modified version of the Wharton-method which is based on linear trends passing through the peaks of the seasonally adjusted production series.

Data on actual stocks of finished goods in this sector, S, is constructed from the quarterly quantity index of stocks, which is based on information on stocks in the major industry groups, exclusive of commodities in progress. This index is rebased to be consistent with the changes in stocks recorded in the national accounts. The data on stocks are available from 1972.1 only, which restricts the estimation period.

Since the Norwegian quarterly national accounts are based on the SNA commodity-sector approach, they include no information about the demand which is directed to each specific sector. The demand indicator, D, is constructed indirectly, by subtracting the increase in stocks from the production in the sector. Then, since each sector usually produces a multitude of commodities, we ignore on the one hand supplementary production taking place in the sector we are considering, and on the other hand supplementary production of its primary commodity in other sectors. The consequence of this simplification may not be too serious because the aggregate manufacturing sector covers most of the stockbuilding activities in the economy. In the presentation of the theoretical model in section 3, we assume that expected demand ($\bar{D}$) is the relevant variable influencing the production decisions. It is, however, unobservable, and instead of trying to model the expectation process in the empirical version of the model, we have used actual demand (cf. Biørn (1985, p. 31)). An interpretation of this formulation may be that the producers have rational expectations.

In the Norwegian national accounts (annual as well as quarterly), sources and uses are balanced for each <u>commodity</u>, while our focus is on the stockbuilding of the manufacturing <u>sector</u>, which, as mentioned above, produce several commodities. As shown in Biørn ((1985), section 2.5 and 4.1) this causes some complications because of the discrepancy between the change in stocks as recorded in the quantity index and as recorded in the national accounts. To have the balance equation $Y = D + \Delta S$ fulfilled we must allocate this discrepancy either to the demand or to the stock component. If we allocated it to demand, this discrepancy would influence the production activity. If not, it would simply be an adjustment in the stockbuilding component. As we find the production data in the national accounts most reliable and there is no information on how to distribute this disturbance term, we have allocated it entirely to the stockbuilding component.

Desired stocks ($\bar{S}$) is an unobservable variable as well. A reason why the firms want to hold stocks is to satisfy the expected demand in this and possibly also in future quarters. We have, as a simple approximation, assumed proportionality between expected demand and desired stocks. To eliminate expected demand we, unsuccessfully, tried different specifications of the anticipation process, and in the empirical version there is no distinction between expected and actual demand. Desired stocks is thus estimated by

(21) $\bar{S}_t = kD_t$

where k is a factor of proportionality. Proportionality between desired stocks and actual demand may be justified if the producers perfectly forecast the future demand when they make their decisions about production and stockbuilding today (rational expectations).

5. ESTIMATION PROCEDURE

The output decision function (20), with the trend and seasonal filters (12) and (13) as well as (21) inserted, is linear in (the current and lagged values of) Y, D, $\bar{Y}$, and S and non-linear in the eight parameters a, b, k, ϱ_1, ϱ_4, α, γ, and β. For given values of k, γ, ϱ_1, and ϱ_4 it is, however, linear (with no constant term) in a, b, α, and β. The equation is estimated by the non-linear least squares routine NLS in the TROLL system (see TROLL (1981)), by means of which we can perform an unconstrained minimization of the sum of squared residuals

$$\sum_{t=1}^{T} \varepsilon_t^2 = Q(a,b,\alpha,\beta,\gamma,k,\varrho_1,\varrho_4),$$

where T is the number of observations. If the disturbances are normally distributed, the estimates will be maximum likelihood estimates. The latter property holds strictly if the initial values of Y_t (i.e. those necessary to construct the initial lags) are regarded as fixed, or conditionally on these initial values. Otherwise, this iterative procedure will give approximate maximum likelihood estimates. (Confer Harvey (1981, pp. 121-122).)

NLS solves this minimization problem iteratively by means of a quasi-Newton algorithm (NL2SOL). There is no guarantee that this iterative process will converge to the global minimum of Q. In some cases, this was checked by repeating the computation, starting from a different set of initial values of the coefficients, but there was no indication that these values influenced the final result.

A simultaneous minimization of Q with respect to all the eight coefficients in the model proved, however, to be difficult. A combined grid-search-NLS procedure was therefore used. We set either ϱ_1 or ϱ_4 equal to 1 (cf. section 2.2) and specified a two-dimensional grid over the "free" ϱ-parameter and k. Then we obtained estimates of the remaining five coefficients conditionally by unconstrained NLS. The final solution is the coefficient set which minimizes Q. For ϱ_1 and ϱ_4 the search is done over the interval (0.0, 1.0), with a step length of 0.1. We had some a priori assumptions about the feasible interval for k and did the search for this parameter over the interval (0.2, 0.7), with a step length of 0.1.

6. EMPIRICAL APPLICATIONS

6.1. Coefficient estimates

Non-linear least squares estimates of (20), implemented by means of the above mentioned grid-search procedure are presented in Table 1. A comparison of the different specifications reveals interesting differences. Consider first the case where both ϱ_1 and ϱ_4 are set equal to 1, which implies a joint differencing over one and over four quarters (case A). This case gives evidence of a very high degree of adjustment of production to departures of capacity and stock imbalances from their trends, the short run adjustment coefficient of capacity, α, being 0.68, the complementary short run coefficient of demand, $(1-\alpha)$, is thus 0.32, and the short run adjustment coefficient of stocks exceeds unity (β=1.07). This overadjustment may be a consequence of the fact that we impose a four quarter difference on data which have already been seasonally adjusted by the moving average filter (12). If no stable seasonal components are left in the seasonally adjusted data, this may imply an overdifferencing which is "compensated" by the trend departure correction.

Next consider the alternative with ϱ_1 equal 0 and ϱ_4 equal 1 (case B). The estimated error correction parameter, γ=0.94, indicates that output is adjusted towards its equilibrium value nearly instantaneously. This may be a consequence of the existence of a non-linear trend in the data which is not adequately eliminated by taking the four quarter differences. This may be indicating that in the present alternative the variables are not co-integrated of order 1, as assumed in ch. 2.3. The presence of this kind of specification error is supported by the very low value of the Durbin-Watson statistic and the Box-Ljung statistics indicating significant first, fourth, and eighth order autocorrelation. In fact, this is not surprising. The data are already seasonally adjusted and the four quarter differencing implies a redundant elimination of seasonalities, which may have serious consequences for the dynamic properties of the disturbance term.

Table 1. Production in manufacturing industries. Quarterly Error Correction model. Million 1985 kroner. Nonlinear Least Squares/Grid Search estimates[1)2)]. Estimation period: 1975.1-1985.4.

	A	B	C	D	E	F	G
ϱ_1	1	0	1	1	1	1	1
ϱ_4	1	1	0	0	0	0	0
k	0.4	0.4	0.3	0.5	0.4	0.4	0.4
a	-0.32	0.20	0.04	0.01	0.24	1	0
	(-0.94)	(1.91)	(0.07)	(0.04)	(0.90)		
α	0.68	0.44	0.49	0.46	0.49	0.50	0.46
	(4.62)	(3.19)	(3.41)	(3.08)	(3.46)	(2.90)	(3.21)
b	0.26	0.25	0.08	0.37	0.28	0	0
	(1.71)	(3.38)	(0.34)	(1.26)	(1.49)		
β	1.07	0.33	0.40	0.29	0.31	0.34	0.31
	(17.23)	(2.86)	(2.15)	(1.73)	(1.72)	(1.87)	(1.85)
γ	0.34	0.94	0.15	0.15	0.18	0.00	0.09
	(3.45)	(5.36)	(1.44)	(1.97)	(2.18)	(0.05)	(1.46)
R^2	0.9998	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999
DW	1.88	0.38	1.56	1.58	1.54	1.63	1.53
SER	597.4	675.7	375.6	374.1	374.8	387.6	378.1
B-L(1)[3)]	0.09	27.86	1.70	1.30	1.87	1.40	1.93
B-L(4)[3)]	8.16	43.70	4.84	3.60	5.18	4.67	4.50
B-L(8)[3)]	12.15	74.92	12.83	9.40	12.06	9.58	10.75

1) A - E: Estimation conditional on ϱ_1, ϱ_4, k.
F - G: Estimation conditional on ϱ_1, ϱ_4, k, a, b.

2) t-values in brackets.

3) B-L(i) is the Box-Ljung statistic for i'th order residual autocorrelation.

The estimation experiments indicate that the best results - both in terms of fit and plausibility of estimates - are obtained by setting ϱ_1 equal 1 and ϱ_4 equal 0, i.e. by performing a full quarterly but no annual differencing. The alternatives C, D and E are not very different with respect to statistical properties, but on a judgemental basis we prefer alternative E, where k = 0.4, by a slight margin. This implies that the desired stock is 40 per cent of the quarterly demand. In this alternative, producers seem likely to pay about the same attention to demand as to capacity when adjusting output. The estimate is α=0.49, i.e. 1-α=0.51. Thus in the short run, i.e. in one quarter, production adjusts to approximately half of the trend departure both in capacity and in demand. The short run adjustment coefficient for stocks, β=0.31, indicates that approximately one third of the trend departure is eliminated. Reasonably, in the short run, the producers must pay much attention to existing capacity because some time is needed either to reduce or expand the capacity. In other words, capacity constrains production in the short run. In the long run, however, producers give the two components different priority: a, indicating the effect of capacity on production is estimated to 0.24, i.e. (1-a) is 0.76, and b, the effect of the stock-imbalance, is 0.28 which indicates that the priority given to establish an output level keeping the stock at a level which is necessary to meet the expected demand, is somewhat lower in the long than in the short run. In all the above mentioned alternatives, the estimates satisfy α>a, whereas $\beta \gtreqless b$. The interpretation of the first inequality is that the effect of the capacity is more important in the short than in the long run, while more attention is paid to demand in the long than in the short run. This conclusion seems to be robust to the dynamic specification of the equation. In the short run, production may be restricted by capacity constraints. On the other hand, some time may pass before increased demand has fully influenced production, but in the long run, there is a tendency that the producers give priority to fill demand. It is then possible - via adjustments in other variables, e.g. investment - to adjust the capacity to the level which is necessary to satisfy this demand.

One might, somewhat roughly, interpret these findings as indicating that in the short run, production is restricted from the supply side and in the long run it is restricted from the demand side of the economy. The estimated error correction parameter is γ=0.18, i.e. only 18 per cent of the discrepancy between the actual production and its corresponding long run equilibrium will be eliminated in one quarter.

As mentioned above, desired stocks is an unobservable variable which is assumed to be proportional to actual demand. Because we had problems concerning estimating all the parameters simultaneously, we have used a grid-search to estimate k, the factor of proportionality. In alternative E, k was equal 0.4. To indicate the sensitivity of the results with respect to this choice, Table 1 also include corresponding results with k set equal 0.3 and 0.5 (alternatives C and D). The goodness of fit test statistics are virtually unaffected, but there are considerable changes in some of the estimates. Especially the long run coefficients a and b are changed. The short run effect, however, is virtually unchanged. When k is increased, and thus the level of desired stocks is increased relative to demand, the estimated short run effect of stock imbalances is increased, but the long run capacity effect is not much changed and is in no case significantly positive. Neither is the error correction parameter much affected.

In the last two alternatives (F and G), the long run parameters are restricted. From (16) it follows that if both a and b are set equal to 0, the target value of production towards which producers attempt to adjust, is equal to the trend value of expected demand, i.e. stock imbalances and the degree of capacity utilization plays no role to the long run decisions. The most important change when this restriction is imposed is that the error correction parameter, γ, is reduced from 0.18 to 0.09. Thus, when long run capacity effects are eliminated, the estimated adjustment to trend imbalances becomes slower than in the unrestricted case.

Finally, we have also tried to restrict a to be 1 and b to be 0 (case F). This implies that the target value of the output coincides with the trend value of the production capacity. The main change in the estimates is that the error correction effect disappears (γ=0). Altogether, there are indications that when the specification of the long run response is made more rigid, the estimated degree of error correction becomes slower.

Because of the numerical problems encountered when estimating all the parameters simultaneously - due, inter alia, to collinearity in the data - we have used the grid search procedure with preassigned values of k, ϱ_1, and ϱ_4 in the above estimation exercises (cf. section 5). To check the effect of this simplification, the model is reestimated, with ϱ_4 treated as a free parameter in alternative E. Its non-linear least squares estimate is -0.25, which is not significantly different from 0. The remaining coefficients were not substantially altered and the main conclusions concerning the short and long run adjustments are retained. From this we can conclude that $\varrho_4 = 0$ is no 'effective' restriction, given the available data. Correspondingly, we have reestimated the model in alternative B (and A) treating ϱ_1 as a free parameter. Its non-linear least squares estimate exceeds 1, conditionally on k and $\varrho_4 = 1$. Lastly, we have reestimated the model (in both alternative B and E) with k treated as a free parameter which gave a least-squares estimate of about 0.3-0.4.

It may be argued that the right hand variables of our regression model, i.e. capacity, demand and stocks of inventories, are not predetermined in relation to the output level but jointly determined with it within a larger unspecified simultaneous model. The use of NLS could thus cause the estimated coefficients to suffer from simultaneity bias. To check for this we have reestimated some of the model variants above by means of the Instrumental Variables technique. In the TROLL system, this estimation procedure is only available for linear models. Our model is linear in the parameters, conditional on the values of ϱ_1, ϱ_4, γ, and k. We set $\gamma=0.18$, which is the NLS estimate in alternative E. With this simplification, the estimates obtained by using instrumental variables were not very different from the NLS-estimates. Detailed results are reported in Table 2.

Table 2. Production in manufacturing industries. Quarterly Error Correction model. Million 1985 kroner[1]. Comparison of estimates based on instrumental variables (IV) and non-linear least squares estimates (NLS). Estimation period: 1975.1-1985.4.

	IV[2)3)]	IV[2)4)]	NLS[2)]
ϱ_1	1	1	1
ϱ_4	0	0	0
k	0.4	0.4	0.4
a	0.22 (0.86)	0.26 (0.75)	0.24 (0.90)
α	0.46 (2.70)	0.42 (2.36)	0.49 (3.46)
b	0.28 (1.53)	0.26 (1.40)	0.28 (1.49)
β	0.36 (2.05)	0.35 (1.98)	0.31 (1.72)
γ	0.18	0.18	0.18 (2.18)
R^2.	0.4245	0.4117	0.9999
DW	1.43	1.38	1.54
SER	378.5	385.5	374.8

1) t-values in brackets.
2) ϱ_1, ϱ_4, k, and γ are fixed parameters in the IV estimation. ϱ_1, ϱ_4, and k are fixed in the NLS estimation. (Cf. alternative E in Table 1).
3) 14 instruments. Lagged values of the variables in the model and of macro variables which are assumed to be influencing the activity, seasonal dummies and strictly exogenous variables.
4) The 11 first principal components of the variables in footnote 3, although with more lags, are used instruments.

6.2. Tests of dynamic specification

To test the stability and the dynamic tracking of the model we have performed some statistical tests. Specifically, we have tested for the presence of autoregressive residuals. In addition to the traditional Durbin-Watson statistic, the Box-Ljung statistic (cf. Ljung and Box (1978)) and the goodness of fit F-test (cf. Kiviet (1986)) for higher order autocorrelation is used. The latter is preferable if, as is the case for some of the models, lagged endogenous variables occur as regressors. Then the standard Durbin-Watson and the Box-Ljung tests are biased. Since seasonally unadjusted quarterly data are used, fourth order autocorrelation, may be of importance. The different tests give quite similar qualitative conclusions. There is, in this respect, a remarkable difference between the case where $\varrho_1 = 0$, $\varrho_4 = 1$ and the case where $\varrho_1 = 1$, $\varrho_4 = 0$. In the latter case, there is no indication of significant fourth order autocorrelation, which indicates that the stable seasonalities are removed (compare alternatives B and C in Table 1). According to the Box-Ljung statistic, there are neither any first order residual autocorrelation. When no first order differencing is performed, i.e. when $\varrho_1 = 0$, there are, however, strong indications of first order autocorrelation from all the tests we have used. Thus there is obviously a non-linear trend in the data which is not removed by the specified model. When ϱ_4 is set to 1, there is significant fourth order autocorrelation, indicating overdifferencing. As discussed above this may be indicating that the variables are cointegrated of order higher than 1. The results from the Kiviet test are not presented, but corresponded to the tests referred above.

7. SIMULATION RESULTS

To test the dynamic behaviour of the different specifications of the QEC equation (20) we have performed some simulation experiments. Both the within sample tracking performance and the dynamic behaviour of the model when a permanent shift in one of the exogenous variables occurs, are investigated. The stability of the model is investigated by giving each of its exogenous variables a temporary shock.

These simulations are based on a two equation model, including the output decision function and the identity connecting production, demand and stockbuilding, i.e. $Y = D + \Delta S$. In this identity, the discrepancy between stockbuilding as measured in the national accounts and stockbuilding as measured by the quantity index for stocks (cf. chapter 4), is also taken into account. As it is not evident how to model this discrepancy, we have, for simplicity used the series calculated from the historical data. For genuine forecasting purposes this procedure would not be feasible, but we may, for instance, use a simple time series model (AR or ARMA) to predict the value of the discrepancy. We have used the two equations for joint simulation of production and stockbuilding, while taking demand as exogenous. More realistic simulation experiments could, of course, have been performed if we had endogenized the demand by specifying a demand function.

The ex post simulations are carried out for the estimation period 1975.1-1985.4 with the exogenous variables set equal to the values observed and the simulated values substituted for the lagged endogenous variables. In the starting period, the observed values of the lagged variables are used. Treating the endogenous variables in this way, simulation errors in one period are allowed to influence the forecasting performance in future periods because of the autoregressive structure of the model. The choice of the starting period may affect the forecasting performance since the effect of the initial disturbance will affect all the subsequent values of the endogenous variables. The within sample tracking performance of the different alternative specifications in Table 1 as measured by the Relative Root Mean Square Error (RRMSE) do not seem to be very different. For the seasonally adjusted production, RRMSE is about 1.4-1.5 per cent in the main alternative (E). For the seasonally unadjusted production variable, the RRMSE is 6.1 per cent, i.e. about four times as large as when measured in terms of the seasonally adjusted data. This illustrated that the smoothing of the data implied by the seasonal adjustment procedure tends to improve the tracking properties of the model to a considerable degree. The specification involving a full four quarter differencing (alternative B) has a different dynamic behaviour. In some periods it fits the historical seasonally adjusted series quite well, in others the simulated and historical data deviate considerably, probably as a consequence of over-differencing.

The simulation results are presented in Tables 3 and 4. Some of the results are also presented graphically in Figures 1-6.

The seasonally adjusted, exogenous variables are, one by one, given shifts to investigate the process of adjustment towards the new equilibrium. The effect of a permanent shift in demand by 10 billion N.kr. in 1978.1 is presented in Table 3, columns 1-4. As proportionality between demand and desired stockbuilding is assumed, the increased demand induces an increase in the desired stockbuilding which reinforces the expansion towards the new equilibrium. The long run effects are quite similar in the different models. The new equilibrium level of the production seems to have been reached by 1981.1, i.e. in about 3 years, and most of the effect is exhausted within 6-7 quarters. There is a tendency that the models with b set equal to 0 (alternatives G and F in Table 1), i.e. those in which the producers in the long run are assumed to take no account of stock imbalances when they decide how much to produce, attain the new production level with a smoother adjustment path than when the stock imbalances, which is

Table 3. Effect on production of an increase in demand by approximately 10 000 million 1985 kroner.

	Sustained shift from 1978.1				Temporary shift in 1978.1			
	i	ii	iii	iv	i	ii	iii	iv
1978.1	1 671	1 591	1 575	1 738	1 671	1 591	1 575	1 738
2	3 673	3 488	3 550	3 726	2 016	1 910	1 989	2 003
3	5 875	5 587	5 773	5 884	2 216	2 114	2 239	2 173
4	8 195	7 820	8 148	8 154	2 337	2 249	2 392	2 286
1979.1	8 916	8 550	9 039	9 238	726	735	897	1 092
2	9 349	9 032	9 581	9 910	436	486	547	677
3	9 609	9 352	9 904	10 324	262	321	325	417
4	9 765	9 563	10 088	10 577	157	213	185	255
1980.1	9 859	9 702	10 185	10 280	94	141	99	-298
2	9 916	9 795	10 231	10 157	57	93	45	-124
3	9 949	9 856	10 344	10 121	34	61	13	-37
4	9 969	9 896	10 240	10 125	20	41	-5	4
1981.1	9 981	9 923	10 225	10 119	12	27	-15	-6
2	9 989	9 940	10 205	10 098	7	18	-20	-21
3	9 993	9 952	10 184	10 078	4	12	-21	20
4	9 996	9 960	10 163	10 064	3	8	-21	-15
1982.1	9 997	9 965	10 143	10 054	2	5	-20	-10
2	9 998	9 968	10 125	10 046	1	3	-18	-8
3	9 999	9 974	10 109	10 038	1	2	-17	-7
4	9 999	9 972	10 094	10 032	0	1	-15	-6

i : $\varrho_1=1$, $\varrho_4=0$, a=0, b=0 (Alternative G).
ii : $\varrho_1=1$, $\varrho_4=0$, a=1, b=0 (Alternative F).
iii: $\varrho_1=1$, $\varrho_4=0$, a,b free (Alternative E).
iv : $\varrho_1=0$, $\varrho_4=1$, a,b free (Alternative B).

Table 4. Effect on production of an increase in capacity by approximately 10 000 million 1985 kroner.

	Sustained shift from 1978.1				Temporary shift in 1978.1			
	i	ii	iii	iv	i	ii	iii	iv
1978.1	0	0	0	0	0	0	0	0
2	1 140	1 247	1 237	1 091	1 140	1 247	1 237	1 091
3	1 825	2 073	1 971	1 824	690	832	739	737
4	2 236	2 621	2 387	2 314	414	553	420	495
1979.1	2 483	2 986	2 607	2 644	249	368	221	332
2	1 491	1 983	1 469	1 225	-999	-1 011	-1 146	-1 430
3	896	1 320	763	352	-600	-668	-711	-879
4	538	881	332	-181	-360	-442	-434	-536
1980.1	323	591	76	-502	-216	-292	-258	-324
2	194	399	-70	-177	-130	-193	-147	328
3	116	273	-147	-57	-78	-128	-78	121
4	70	189	-183	-37	-47	-84	-36	21
1981.1	42	133	-194	-59	-28	-56	-11	-22
2	25	96	-190	-67	-17	-37	4	-8
3	15	72	-178	-54	-10	-24	12	13
4	9	56	-163	-40	-6	-16	16	14
1982.1	5	46	-146	-32	-4	-11	17	9
2	3	39	-129	-27	-2	-7	17	5
3	2	34	-114	-24	-1	-5	16	4
4	1	31	-99	-20	-1	-3	15	4

i : $\varrho_1=1$, $\varrho_4=0$, a=0, b=0 (Alternative G).
ii : $\varrho_1=1$, $\varrho_4=0$, a=1, b=0 (Alternative F).
iii: $\varrho_1=1$, $\varrho_4=0$, a,b free (Alternative E).
iv : $\varrho_1=0$, $\varrho_4=1$, a,b free (Alternative B).

influenced by the expanded demand, is one of the factors motivating production. When b is a free parameter (alternatives B and E), i.e. when trend departure in stocks is one of the motivating factors, the producers are, in the initial stages, likely to overadjust. This is due to expansionary effects of increased stock imbalances. When production is too low compared to demand, the stocks are too low compared to the desired level. This gives a contribution to increased production beyond what corresponds to the actual increased demand.

Table 4, columns 1-4, gives the corresponding simulation results when the capacity (sesonally adjusted) is permanently increased by 10 billion N.kr. with the demand kept unchanged. In the long run, there is thus no incentive to increase the production. The effect of the shift is exhausted in about 3 years, i.e. the time lag is of the same order of magnitude as in the case with the demand stimulus. In the first quarters, production increases quite rapidly, initiated by the expanded capacity, and reaches its peak at about 1979.1, i.e. after approximately one year. Even if the peak is reached simultaneously in all the alternative specifications, the production effect varies, from approximately 2500 to 3000 mill. N.kr., i.e. by about 25 per cent of the capacity expansion. Then production is too high compared to demand, and this disequilibrium is stronger than the disequilibrium between production and capacity. This induces a reduction in production until it reaches its initial equilibrium, which is consistent with the actual demand. In the models where b is set equal to 0, i.e. with no production impulses from stock imbalances in the long run, there is a smooth adjustment towards the equilibrium level. When a and b are unrestricted, the production is contracted too strongly which is next compensated by an increase before the new equilibrium is attained. In periods when production is too high compared with demand, stockbuilding is also too high compared with desired stockbuilding, which consequently initiates negative production effects. The adjustment towards the equilibrium thus take the form of dampened oscillations. When a=1 (alternative F), i.e. when the producers try to adjust towards the trend in capacity only, production rises faster and later on, declines at a slower speed than in the other formulations.

To see how the model behaves when exposed to an exogenous shock we have performed similar simulations where respectively demand and capacity is increased <u>temporarily</u> by 10 billion N.kr. in 1978.1 and set back to its previous value in the next quarter. These results are given in Tables 3 and

4, columns 5 through 8. Such a demand shock might occur, for instance when a substantial increase in household taxes is announced or put into effect. In this model, the producers do not, however, realize that the shift is temporary. Also these exercises indicate that the long run properties of the models are quite similar and that the initial level of production is reattained about 1981.1. The demand shock induces a quite rapid increase in production, which attains its peak in 1978.4, which is about 2300-2400 million N.kr. above its initial level. Then there is a substantial drop during 1979, and during 1980 just minor adjustments occur. The only exception from this pattern is the model where $\varrho_1 = 0$ and $\varrho_4 = 1$ (alternative B). In this case, the decrease falls of during 1979, but is reinforced in 1980.1 and causes a too strong downward adjustment of the production which next initiates a compensating increase towards the equilibrium level. Compared with the unrestricted alternatives the adjustment is somewhat slower in the models where b=0 (G and F), in which the trend imbalance in stocks is not motivating production.

The temporary shift in capacity initiates an immediate and strong increase in production. Since it is not accompanied by a change in demand, a decline in production starts already in the following quarter. In 1979.2, i.e. one year after the original stimulus, there is a sudden and dramatic drop in production which is in this quarter 1000-1500 mill. N.kr. below its equilibrium level. This effect is probably a consequence of the large imbalance between capacity and demand five quarters earlier. This downward overshooting is somewhat slower when b=0, since in this case, there is no negative production impulses from the too high stocks which have accumulated. During the following quarters, there is consequently an increase in production towards the equilibrium level. An exception is, however, the alternative $\varrho_1 = 0$ and $\varrho_4 = 1$ (alternative B). Here the over-adjustment in 1979.2 is extraordinarily large because of the four quarter differencing and the following "catching up", which causes an upward over-compensation in the following quarters. Thus the production is approaching its new equilibrium through dampened oscillations.

Table 5. Effects of a sustained increase in demand by approximately 10 000 million 1985 kroner from 1978.1. Desired stocks kept fixed.

	Increased demand				Synchronized increase in demand and capacity			
	i	ii	iii	iv	i	ii	iii	iv
1978.1	772	711	947	1 056	772	711	947	1 056
2	1 586	2 569	2 467	2 588	3 867	5 061	3 705	3 680
3	3 073	4 641	4 355	4 439	6 724	8 787	6 326	6 263
4	4 966	6 857	6 478	6 503	9 439	12 100	8 865	8 818
1979.1	6 329	8 455	8 119	8 418	11 296	14 428	10 726	11 062
2	7 795	8 970	9 212	9 598	10 778	12 936	10 681	10 823
3	8 676	9 310	9 946	10 320	10 467	11 950	10 709	10 672
4	9 205	9 535	10 443	10 757	10 281	11 298	10 775	10 576
1980.1	9 523	9 684	10 468	10 416	10 168	10 867	10 544	9 913
2	9 713	9 783	10 458	10 319	10 101	10 582	10 389	10 142
3	9 828	9 848	10 430	10 336	10 061	10 393	10 283	10 278
4	9 897	9 891	10 393	10 396	10 036	10 268	10 210	10 359
1981.1	9 938	9 919	10 352	10 315	10 022	10 186	10 159	10 256
2	9 963	9 938	10 312	10 244	10 013	10 131	10 122	10 177
3	9 978	9 951	10 274	10 193	10 008	10 095	10 096	10 139
4	9 986	9 959	10 239	10 164	10 005	10 071	10 077	10 123
1982.1	9 992	9 964	10 208	10 141	10 003	10 056	10 062	10 109
2	9 995	9 968	10 180	10 119	10 002	10 045	10 051	10 092
3	9 997	9 970	10 155	10 099	10 001	10 038	10 042	10 075
4	9 998	9 972	10 134	10 082	10 000	10 034	10 035	10 062

i : $\varrho_1=1$, $\varrho_4=0$, a=0, b=0 (Alternative G).
ii : $\varrho_1=1$, $\varrho_4=0$, a=1, b=0 (Alternative F).
iii: $\varrho_1=1$, $\varrho_4=0$, a,b free (Alternative E).
iv : $\varrho_1=0$, $\varrho_4=1$, a,b free (Alternative B).

In the demand shift experiments reported so far, we have retained the assumption that the desired level of stocks changes in proportion to demand, i.e. that producers are assumed to revise instantaneously their desired stocks in accordance with the increased demand. Alternative simulations in which the desired level of the stocks is assumed to be unaffected by the demand shift have also been performed (see Table 5). This is a naive behaviour where the producers do not realize that increased demand should imply an increase in desired stocks. When b=0, i.e. no adjustment of output because of the departure from the long run trend in the desired stocks, the production rises smoothly towards its new equilibrium. The adjustment, however, seems to be slower than in the previous case. Even if there was no effect of stock imbalances in the long run, the increased stock imbalances induces short run production impulses. When there are no restrictions on a and b, i.e. when stock imbalances have an effect in the long run too, the simulation results seem a bit strange. In the first round, the rise in production is smaller than when stocks too were increased, because of the disappearance of this extra demand impulse. After a couple of years the rise in production is in fact stronger than in the alternative above. This is probably a consequence of the weak expansionary effects in the early phase of the recovery. Because of the slower adjustment of production, demand is met by reducing stocks. This causes an increase in the stock imbalances which gradually become so large that the production stimulus is stronger than in the original demand shift example.

Finally, we have performed an experiment in which a synchronized increase in demand and capacity by 10 billion 1985 kroner occurs in 1978.1. The desired stocks is in this alternative too kept unaltered. In all the four alternatives, the expansion imply an overadjustment of production. This effect is most pronounced when a=1, i.e. when producers adjust output only towards the long run trend in capacity. Discrepancies between the actual and trend demand also have expansionary effect on production. Altogether, this causes an overadjustment of production by more than 4 000 million N.kr. one year after the occurrence of the expansion. Then, however, the contractive effects dominate and production is adjusted quite fastly towards the new equilibrium. By the end of 1980 the production has attained about the same level in all the four alternatives.

8. CONCLUSION

In this paper, we have presented an extension of the quarterly error correction model with only one exogenous variable to a process including an arbitrary number of exogenous variables. This QEC framework is accommodated to the specification of an output decision function for a stock-holding manufacturing sector with three exogenous variables, capacity, demand, and stock imbalance. Simulation experiments indicate that this model have satisfactory dynamic properties.

An interesting extension of the work in this paper would be to build a multi-equation model endogenizing some of the right hand variables in the output decision function by imposing separate QEC processes in each equation. It is not obvious which dynamic properties such a model would have. A topic for further research is to investigate the choice of estimation technique for such simultaneous models as well as the simulation properties.

Figure 1. Effect on production of a sustained increase in demand by 10 000 million 1985 kroner. $\varrho_1=1$, $\varrho_4=0$, a, b free.

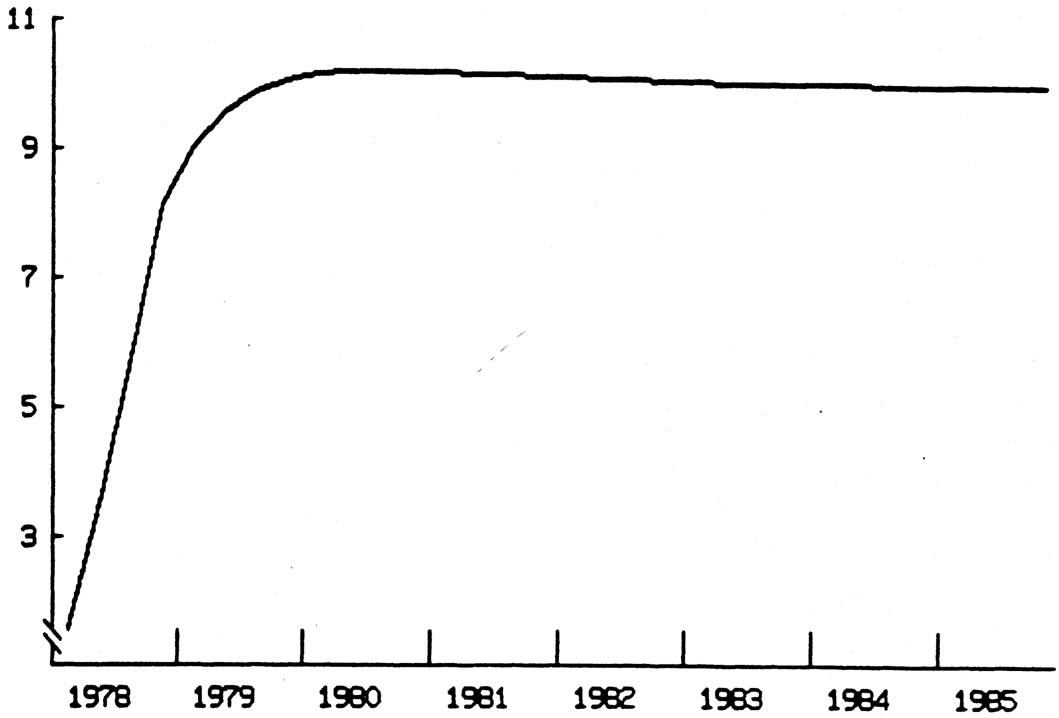


Figure 2. Effect on production of a sustained increase in capacity by 10 000 million 1985 kroner. $\varrho_1=1$, $\varrho_4=0$, a, b free.

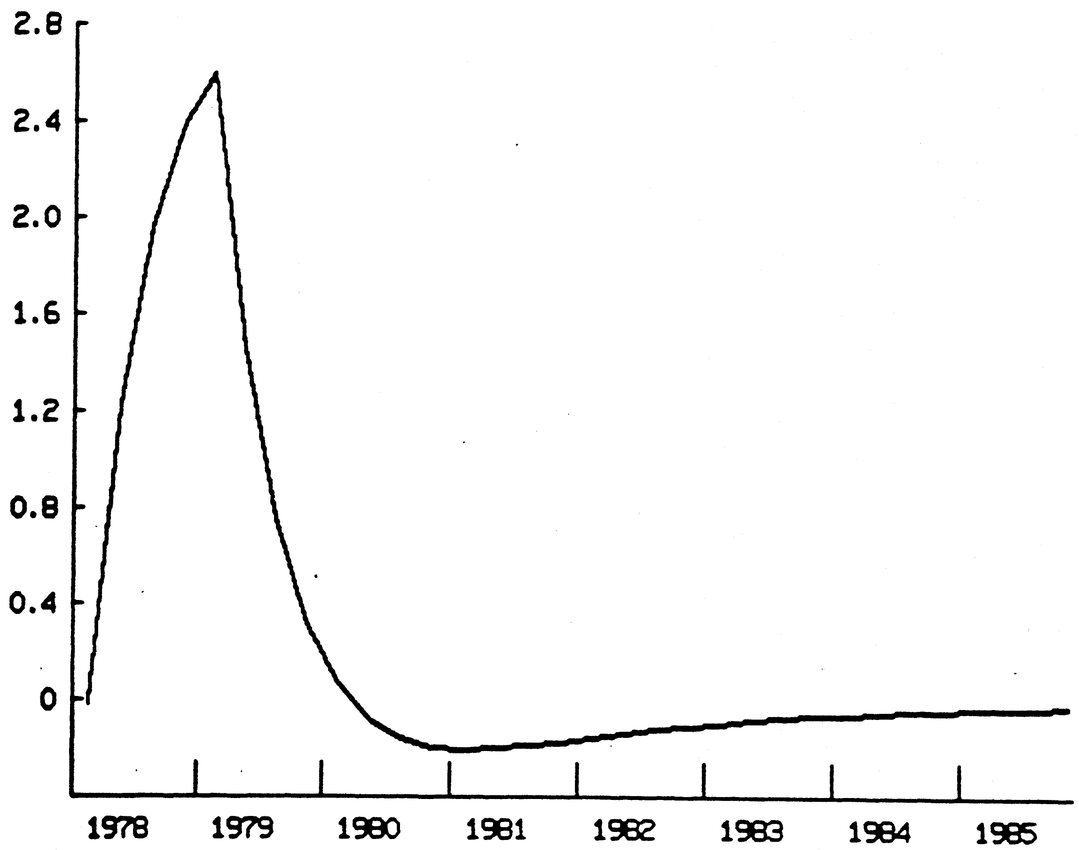


Figure 3. Effect on production of a temporary increase in demand in 1978.1 by 10 000 million 1985 kroner. $\varrho_1=1$, $\varrho_4=0$, a, b free.

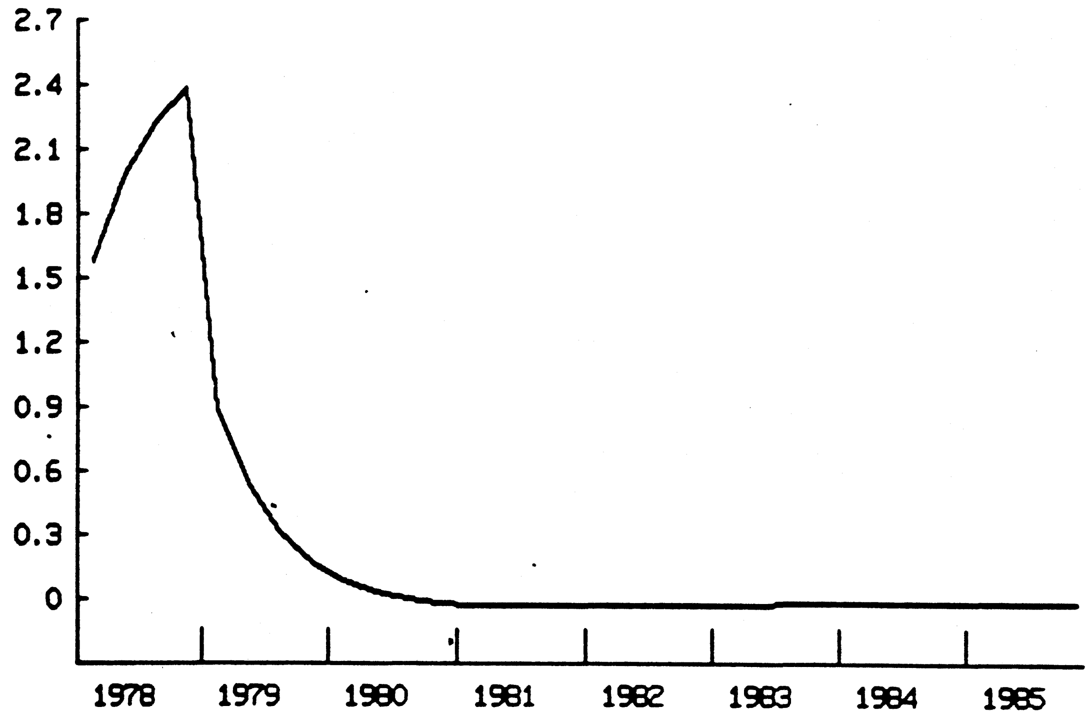


Figure 4. Effect on production of a temporary increase in capacity in 1978.1 by 10 000 million 1985 kroner. $\varrho_1=1$, $\varrho_4=0$, a, b free.

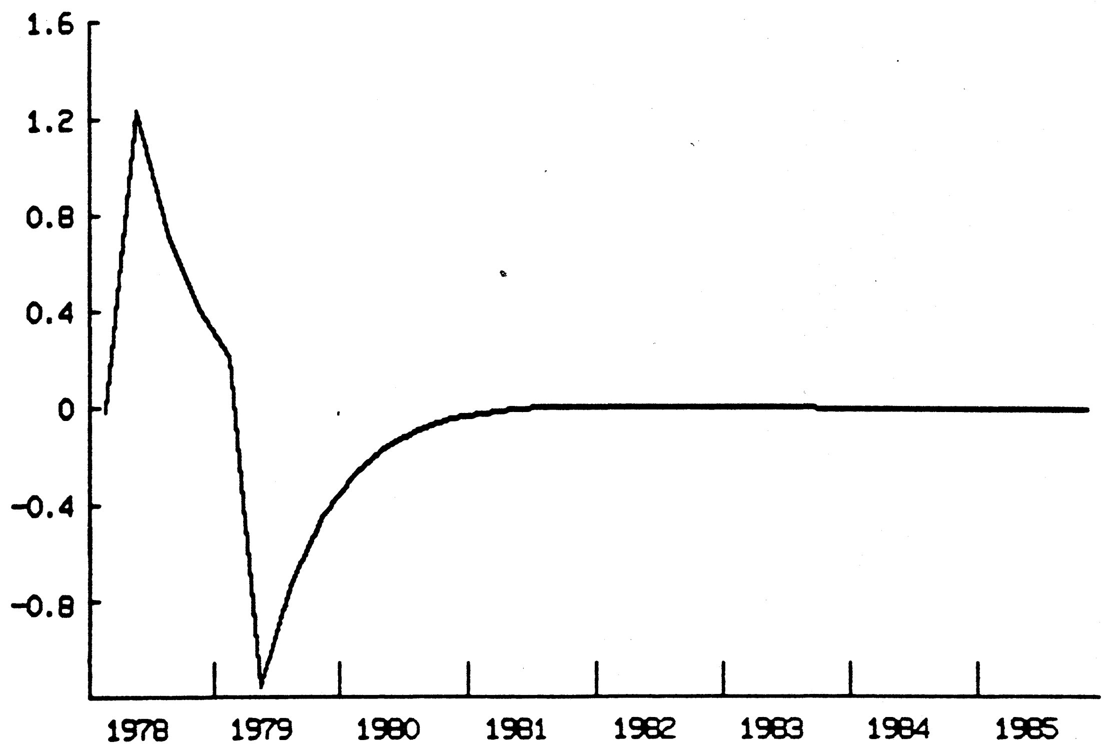


Figure 5. Effect on production of a sustained increase in demand by 10 000 million 1985 kroner. Desired stocks kept fixed. $\varrho_1=1$, $\varrho_4=0$, a, b free.

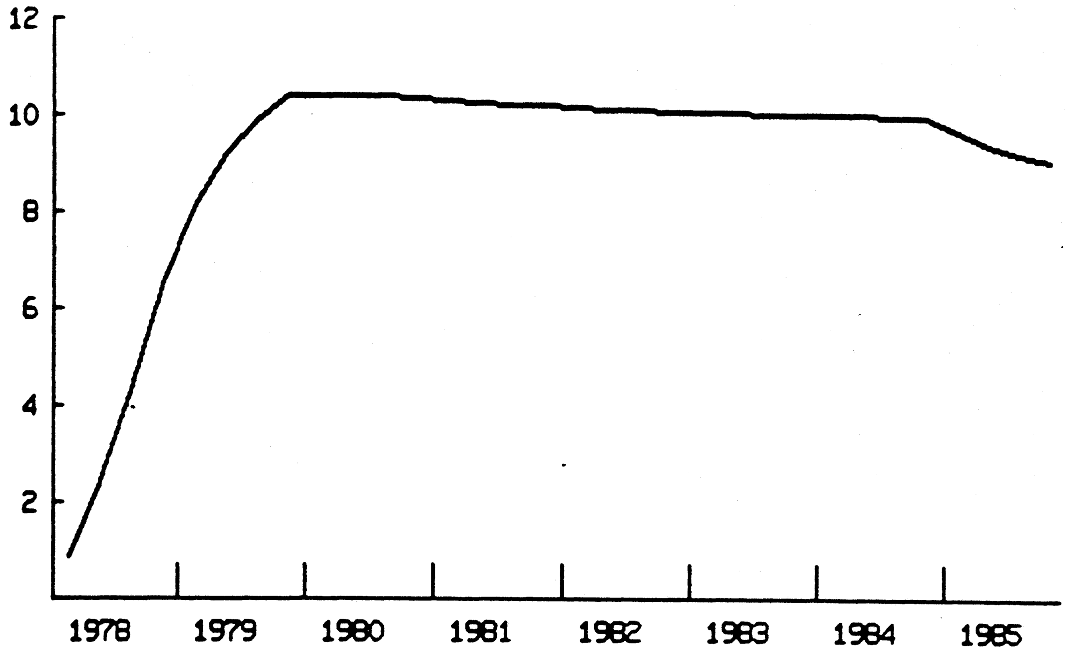
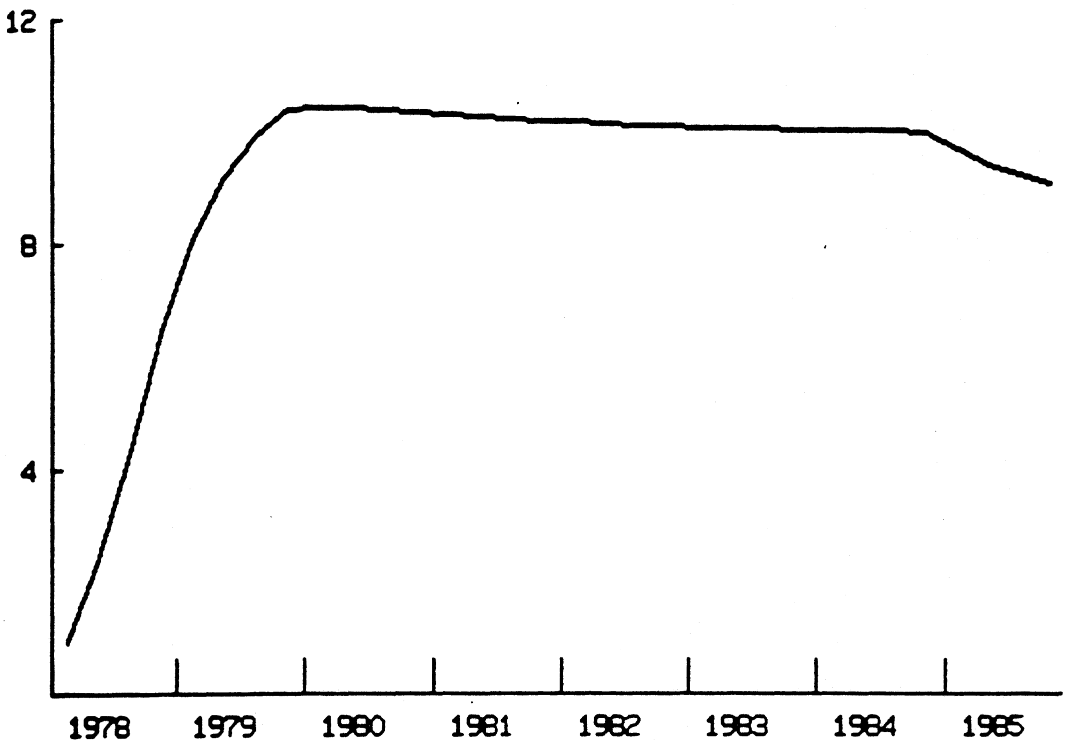


Figure 6. Effect on production of a synchronized increase in demand and capacity by 10 000 million 1985 kroner. Desired stocks kept fixed. $\varrho_1=1$, $\varrho_4=0$, a, b free.



REFERENCES

Biørn, E. (1985): Produksjonstilpasning og lageradferd i industri. En analyse av kvartalsdata. Reports from the Central Bureau of Statistics no. 85/25. (Oslo: Central Bureau of Statistics, 1985.)

Biørn, E., Jensen, M., and Reymert, M. (1987): KVARTS - A Quarterly Model of the Norwegian Economy. Economic Modelling, 4 (1987), 77-109.

Biørn, E. and Olsen, H. (1986): A Generalized Single Equation Error Correction Model and Its Application to Quarterly Data. Paper presented at the Sixth International Symposium on Forecasting, Paris, June 15-18, 1986. Discussion Paper No. 19, Central Bureau of Statistics, Oslo.

Engle, R.F. and Granger, C.W.J. (1987): Co-integration and Error Correction: Representation, Estimation and Testing. Econometrica, 55 (1987), 251-276.

Feldstein, M. and Auerbach, A. (1976): Inventory Behaviour in Durable-Goods Manufacturing. The Target-Adjustment Model. Brookings Papers on Economic Activity, 2 (1976), 351-396.

Granger, C.W.J. (1981): Some Properties of Time Series Data and Their Use in Econometric Model Specification. Journal of Econometrics, 16 (1981), 121-130.

Granger, C.W.J. and Weiss, A.A. (1983): Time Series Analysis and Error-Correcting Models. In Studies in Econometrics, Time Series, and Multivariate Statistics. (New York: Academic Press, 1983, pp. 255-278.)

Harvey, A.C. (1981): Time Series Models. (London: Philip Allan, 1981.)

Hendry, D.F. (1986): Econometric Modelling with Cointegrated Variables: An Overview. Oxford Bulletin on Economics and Statistics, 48 (1986), 201-228.

Hendry, D.F., Pagan, A., and Sargan, J.D. (1984): Dynamic Specification. In Handbook of Econometrics, vol. II, ed. by Z. Griliches and M.D. Intriligator, Ch. 18. (Amsterdam: North-Holland Publishing Company, 1984.)

Hendry, D.F. and Richard, J.-F. (1983): The Econometric Analysis of Economic Time Series. International Statistical Review, 51 (1983), 111-148.

Kiviet, J. (1986): On the Rigour of some Misspecification Tests for Modelling Dynamic Relationships. Review of Economic Studies, 53 (1986), 241-261.

Ljung, G.M. and Box, G.E.P. (1978): On a Measure of Lack of Fit in Time Series Models. Biometrika, 65 (1978), 297-303.

Rowley, J.C.R. and Trivedi, P.K. (1975): Econometrics of Investment. (London: John Wiley & Sons, 1975.)

Sargan, J.D. (1964): Wages and Prices in the United Kingdom: A Study in Econometric Methodology. In Econometric Analysis for National Economic Planning, ed. by P.E. Hart, G. Mills, and J.K. Whitaker (London: Butterworths, 1964.)

TROLL (1981): TROLL Program NLS (Nonlinear Least Squares). Technical Report No. 32. Massachusetts Institute of Technology, Center for Computation Research in Economic and Management Science, October 1981.

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