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By/Av
FINN R. FØRSUND AND EILEV S. JANSEN

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PREFACE

Recent developments in empirical production analysis based on micro data include new tools like the frontier production function and the short-run macro production function. In this article it is shown how these concepts can be used as part of sectoral models in an interplay with models for the national economy.

The article is a revised version of a paper read to the conference "Skogsektorns utvecklingsproblem" at Umeå University, Umeå, 16-18 June 1982. The paper will also be included in a forthcoming conference volume, "Forest Sector Development. Issues and Analysis" (RR 1983:1), to be issued from the University of Umeå.

Central Bureau of Statistics, Oslo, 20 May 1983

Arne Øien

FORORD

Det har i noen år pågått et samarbeidsprosjekt mellom Sosialøkonomisk institutt og Statistisk Sentralbyrå, der målet har vært å utnytte data fra Industristatistikken til å tallfeste frontproduktfunksjoner og korttidsmakroproduktfunksjoner for utvalgte norske industrigrener. I denne artikkelen blir det vist hvordan disse produktfunksjonsbegrepene kan inngå i sektormodeller som kan nyttes i et samspill med modeller for den totale økonomien.

Artikkelen er en revidert versjon av et foredrag holdt på konferansen "Skogsektorns utvecklingsproblem" ved Umeå Universitet, Umeå, 16-18 juni 1982. Den vil også bli trykt i samlingen: "Forest Sector Development. Issues and Analysis" (RR 1983:1), som utgis av Umeå Universitet.

Statistisk Sentralbyrå, Oslo, 20. mai 1983

Arne Øien

THE INTERPLAY BETWEEN SECTORAL MODELS BASED ON MICRO DATA AND MODELS FOR THE NATIONAL ECONOMY[x)]

by

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1. Introduction

In a paper on large scale econometric models for national planning read at the symposium commemorating the twenty-fifth anniversary of the Econometric Institute at Erasmus University, Rotterdam, Leif Johansen (1982, p. 25) pointed out

> "that much of the modelling of the supply side will fail to come to grips with important problems because it relies too much on smooth, neo-classical formulations of production functions and derived concepts."

To increase the realism and explanatory power of econometric planning models he urged the adoption of the putty-clay approach. Regarding the data requirement for implementing such an approach he states:

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x) The authors wish to thank Olav Bjerkholt, Ådne Cappelen, Arne Jon Isachsen and Svein Longva for helpful comments.

> "It seems that much more of data from the micro level of the economy would be necessary for more reliable econometric implementations of the ideas of putty-clay technology" (Johansen (1982, p. 26)).

The annual Industrial Statistics from the Central Bureau of Statistics is the most important source of micro information on industrial economic activity in Norway. All firms with more than five employees in Norwegian industry are obliged to render each year very detailed information on production, employment, use of energy and other inputs. Several production studies have been based on this vast body of data. Griliches and Ringstad (1971) used data from the 1963 Census of Manufacturing Establishments to estimate CES production functions for broad industry sectors, and Ringstad (1971) gives a similar analysis based on time-series of cross-section data of this kind for the years 1959-1967. Recent developments include attempts to estimate frontier (micro) production functions via cost functions for the mechanical pulp industry (see Førsund and Jansen (1974), (1977)), and the construction of industry production functions of the Johansen (1972) type, e.g. for the Norwegian aluminium industry (Førsund and Jansen (1982)).

The purpose of this paper is to outline how sectoral models based on putty-clay production functions can interact with models for the national economy. The questions posed can be stated as two distinct problems:

Problem 1: How can past and present micro information, viz. as summarized in a sectoral model, be utilized within a dynamic macro model of the total economy?

Problem 2: How can the results of a macro model, in terms of time path for production aggregates, be translated into information about industrial structure within the framework of a production model for one sector based on micro units?

In the next section, the concepts of the industry production function and the frontier production function, respectively, are presented. The interplay between these concepts, which are tools for sectoral analysis, and a multi-sectoral, but otherwise unspecified, macro model is discussed in section 3. We consider first the short-run case where no new capacity is generated through investments, and then extend the analysis to include new capacity within a capital vintage model approach. The concluding section points to a number of problems which are likely to emerge if these procedures are implemented in the planning process.

2. Micro-based models for one sector.

2.1. The industry production function.

The concept of a short-run industry production function derived from micro observations was put forward by Leif Johansen, see Johansen (1972)[1]. He considers the case of an industrial sector consisting of production units (firms) which produce a reasonably homogeneous output. His key assumption - which makes industrial structure an interesting concept - is that substitution possibilities ex post are more restricted than ex ante for each firm.

The ex ante production function at the micro level can be thought of as a neo-classical production function with continous substitution possibilities. It is assumed to sum-

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1) For a further discussion of the concept of the short-run industry production function, see Førsund and Hjalmarsson (1980), (1983).

marize the relevant technological knowledge available at the moment of investment, and the choice of technique relates to this function. Once the choice is made, fixed factors - such as capital - determine the capacity of that particular production unit, now also characterized by fixed requirements of current inputs. Ex post, the production possibilities embodied in each unit is assumed to follow a limitational law, i.e.

(1) $0 \leq x \leq \bar{x}$

(2) $v_j = \frac{\bar{v}_j}{\bar{x}} x = \xi_j x \qquad j=1, \ldots., n.$

(1) states that current production (x) cannot exceed capacity ($\bar{x}$), and (2) expresses that current inputs are required in the same proportion to output as they would be at full capacity utilization ($\bar{v}_j/\bar{x}$). In practice, the input coefficients ξ_j are estimated by the observed coefficients.

The short-run industry production function

(3) $X = F(V_1, \ldots., V_n)$

is now defined by solving the classical problem of maximizing output for given levels of inputs:

(4) Max. $X = \sum_{i=1}^{N} x^i$, subject to

(5) $\sum_{i=1}^{N} \xi_j^i x^i \leq V_j \qquad j = 1, \ldots., n,$

(6) $x^i \leq \bar{x}^i \qquad i = 1, \ldots., N,$

(7) $x^i \geq 0 \qquad i = 1, \ldots., N,$

where X denotes output and V_1, ..., V_n current inputs for the industry as a whole and where i = 1, ..., N refers to plants with a capacity of $\bar{x}^i$.

The industry production function (3) is a technical relationship which is not dependent upon prices or economic behaviour. We may obtain a deeper insight into the nature of this function by formulating the dual problem of (4)-(7). Let the dual variables q_1, ..., q_n correspond to the restrictions on current inputs in (5) and r^1, ..., r^N correspond to the capacity limitations in (6). The full dual problem is then:

(8) Minimize $\sum_{j=1}^{n} q_j V_j + \sum_{i=1}^{N} r^i \bar{x}^i$ subject to

(9) $\sum_{j=1}^{n} q_j \xi_j^i + r^i > 1 \quad , \quad i = 1, ..., N.$

With regard to the capacity utilization of each unit the correspondence between the solutions of the primal and the dual problem yields

$$\sum_{j=1}^{n} q_j \xi_j^i > 1 \quad \Rightarrow \quad x^i = 0$$

(10) $$\sum_{j=1}^{n} q_j \xi_j^i = 1 \quad \Rightarrow \quad 0 < x^i < \bar{x}^i$$

$$\sum_{j=1}^{n} q_j \xi_j^i < 1 \quad \Rightarrow \quad x^i = \bar{x}^i$$

The variables $q_1, \ldots, q_n$ are shadow prices of the current inputs and express the marginal productivities in the industry production function. Whether a production unit is operated or not is, according to (10), decided by whether operation "costs" calculated at these shadow prices are less than unity or not. The units with non-negative quasi rents (r^i) are those which are utilized. This is illustrated in figure 1 for the case of two current inputs, where only the units on or below the zero quasi rent line are in operation.

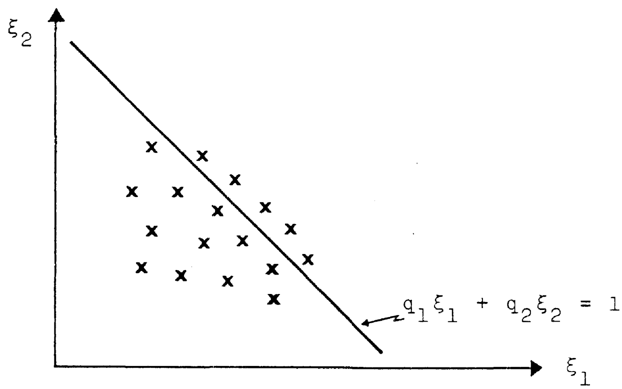

Figure 1. The zero quasi rent line in an input coefficient diagram. Observations are indicated by crosses.

This procedure enables us to derive supply and demand functions which correspond to the short-run industry production function. One interpretation of this function is that it prescribes the optimal way to organize the industry - i.e. the degree of capacity utilization of each unit - when varying the current output and factor prices, given that all units face the same prices. Conditional upon this interpretation, we obtain the supply of output if we substitute actual real prices[2] for the shadow prices in (10) and then sum the outputs in the production units which yield a non-negative quasi rent. The corresponding demand for inputs is obtained from (2).

In the case of a discrete distribution of the input coefficients (ξ_1, ..., ξ_n), which we have considered here, the implicit supply and demand functions in this approach will not be "well-behaved", i.e. they will not be unique analytical functions of the real prices. In Johansen (1972) it is shown that such functions follow if we can assume a continous capacity distribution, $f(\xi_1, \ldots, \xi_n)$, over a n-dimensional region in the (ξ_1, ..., ξ_n) space. If G denotes the set of points in this region where the quasi rent is non-negative, we can write the supply and demand functions in the following way:

(11) $$X = \int \ldots \int_G f(\xi_1, \ldots, \xi_n)\, d\xi_1 \ldots d\xi_n$$

(12) $$V_j = \int \ldots \int_G \xi_j f(\xi_1, \ldots, \xi_n)\, d\xi_1 \ldots d\xi_n \quad j = 1, \ldots, n.$$

2.2. The frontier production function

The theoretical requirement of the frontier production function for an industry is that it should show the most efficient way available of transforming inputs into outputs. This concept may be considered as a pessimistic estimate of the choice of technique function, i.e. the ex-ante production function as described in the previous section.

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2) I.e. prices of inputs relative to the output price.

Let us again consider an industrial sector with production units producing a homogeneous output. It is assumed that the industry frontier function is composed of the production units' functions - either observed or hypothetical production possibilities - that yield maximum output for a given set of inputs (see Førsund and Hjalmarsson (1974)). During the last decade such functions have been estimated from observed performances, normally assuming perfect substitutability between all inputs ex post as well as ex ante[3]. The standard approach is to fit an envelope function to all observations available in the space defined by inputs and output. This procedure is illustrated in figure 2 for the case of one input.

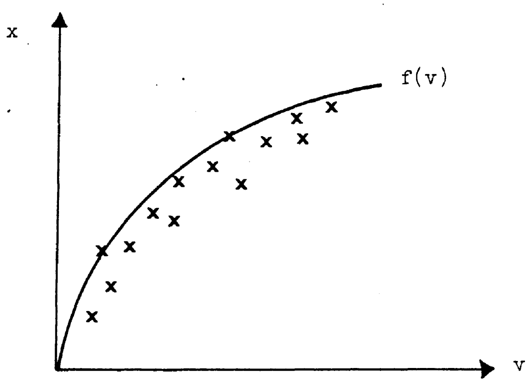

Figure 2. The frontier production function f(v). The case of one input. Observations are indicated by crosses.

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3) For a survey, see Førsund, Lovell and Schmidt (1980).

If we revert to our assumption of fixed input coefficients ex post, each unit provides only one observation for the estimation, and this sample point is a realisation of the ex ante production function at the time of investment. Under certain assumptions about technical change in the ex ante function for the industry, it is still possible to estimate the function. Note that this function contains capital as a variable factor.

3. The interaction between sectoral models and models for the national economy.

The macroeconomic model considered in this paper is a multi-sectoral model at a moderate level of disaggregation intended for medium-term projections of, say, four to ten years.[4)]

Let us, for sake of simplicity, look first at the short-run interaction between a macroeconomic model of this kind and a sectoral model. This means that we can disregard investments and their effect on productive capacity. Let us further assume that this sector produces a relatively homogeneous output (the volume of which is X) by means of two current inputs, labour (N) and energy (E), and that we have reliable data for these entities. In this situation, the interplay

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4) The model we have in mind is the Norwegian planning model MODAG (see Cappelen, Garaas and Longva (1981)) with 30 production sectors, which are identical to the sectors specified in the MSG model, see Bjerkholt (1982) and the original text by Johansen (1974).

between the macro model (M) and the sectoral information (S), represented by the data underlying the industry production function, is quite straightforward, as shown in figure 3.

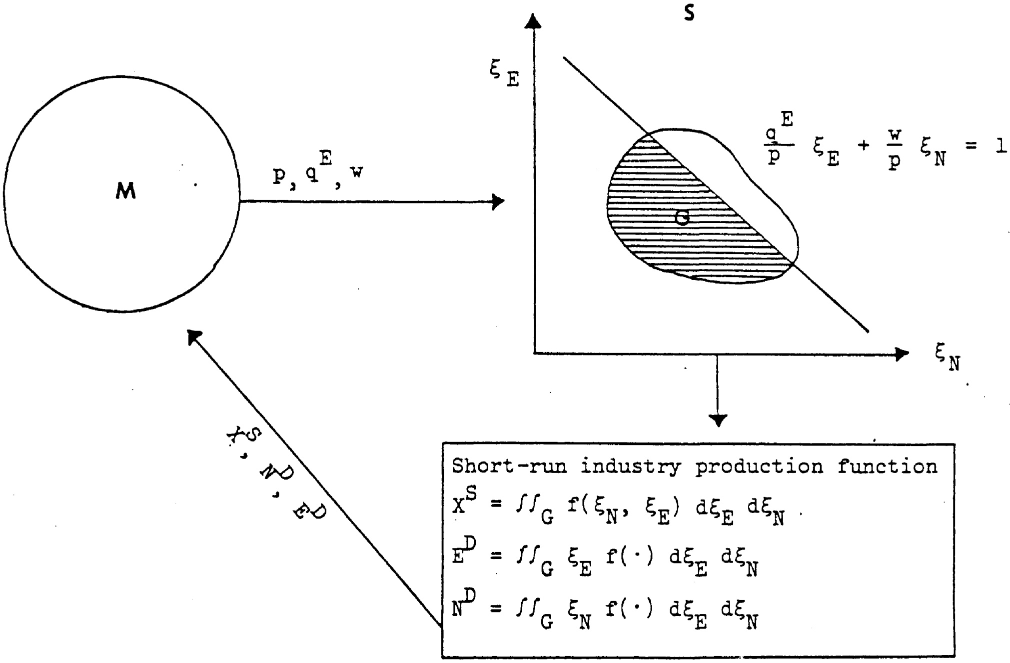

Figure 3. The interaction between the macroeconomic model M and the sectoral model based on the micro information S.

Suppose now that the sector price p and the factor prices of energy and labour, q^E and w, are determined in the macro model M. As explained in section 2 these prices define the line of zero quasi rent in the unit input diagram. With a given capacity distribution of the micro units in the sector - in figure 3 symbolized by a continuous capacity distribution function $f(\xi_N, \xi_E)$ defined over a region of positive capacity - we can derive the supply of output X^S and the demand for the current inputs E^D and N^D from the sector.

This, then, is one answer to problem 2 set out in the Introduction. If at least one of the price variables are endogenous in the macro model M, and the price solution of M is dependent on the sectoral quantum variables (X, E and N) - which are considered as predetermined variables in the macro model - the models can be solved iteratively until convergence with respect to the prices obtain. In this case we have also provided a simplistic answer to problem 1 for the short run.

In order to go beyond the short run and make medium term projections, we shall extend the analysis to include a model of investment demand for the sector. The investment demand can be captured by applying a capital vintage model to the sector as a whole. After the time of the last observation, we lose track of the individual establishment, and the capital vintage at the aggregated level is the only operational unit available for analysis[5].

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5) The use of the Industrial Statistics as a data source implies that the situation is quite different for the period of observation: All direct information refers to the establishment, and information for capital vintages is available only indirectly, as annual investments.

The capital vintage approach is consistent with the assumptions underlying the construction of an industry production function, made in section 2[6]. These assert that the industry production can be described by a putty-clay technology, and that a frontier (ex ante) production function for the industry exists and is known to the investors in the sector. Again simplifying, we shall assume that the investors behave as if they have certain expectations about future output prices as well as about future prices in the factor markets, including the price of capital, q_K. The discounted profit function Π for the sector can then be established, in which the discount rate can be interpreted as a required rate of return of capital, z. We assume that the investors maximize Π and it can be shown that, under certain regularity conditions, this maximum is obtained when the present value of the marginal productivity of capital (MPK) - derived from the ex-ante function - equals the price of capital. It is conceivable that investment demand calculated in this way, $\Delta K^D{}_{calc}$, may take on unrealistically high values. In practice, however, it is likely that one will constrain investment demand to be less than an upper limit $\overline{\Delta K}$ determined by such institutional conditions as, for instance, credit availability. The sector demand for capital can then be written

$$(13) \qquad \Delta K^D = \begin{cases} 0 & MPK\big|_{\Delta K=0} < q_K \\ \text{Min}\ (\overline{\Delta K},\ \Delta K^D{}_{calc}) & MPK\big|_{\Delta K=0} > q_K \end{cases}$$

We shall assume that ΔK_t (realized investments in period t) manifests itself as new production capacity at time t+1 and we let $f^+(\xi_N, \xi_E)$ represent the corresponding capacity distribution function. The links between the investment model for the sector, the macro model M and the sectoral information contained in S, are illustrated in figure 4.

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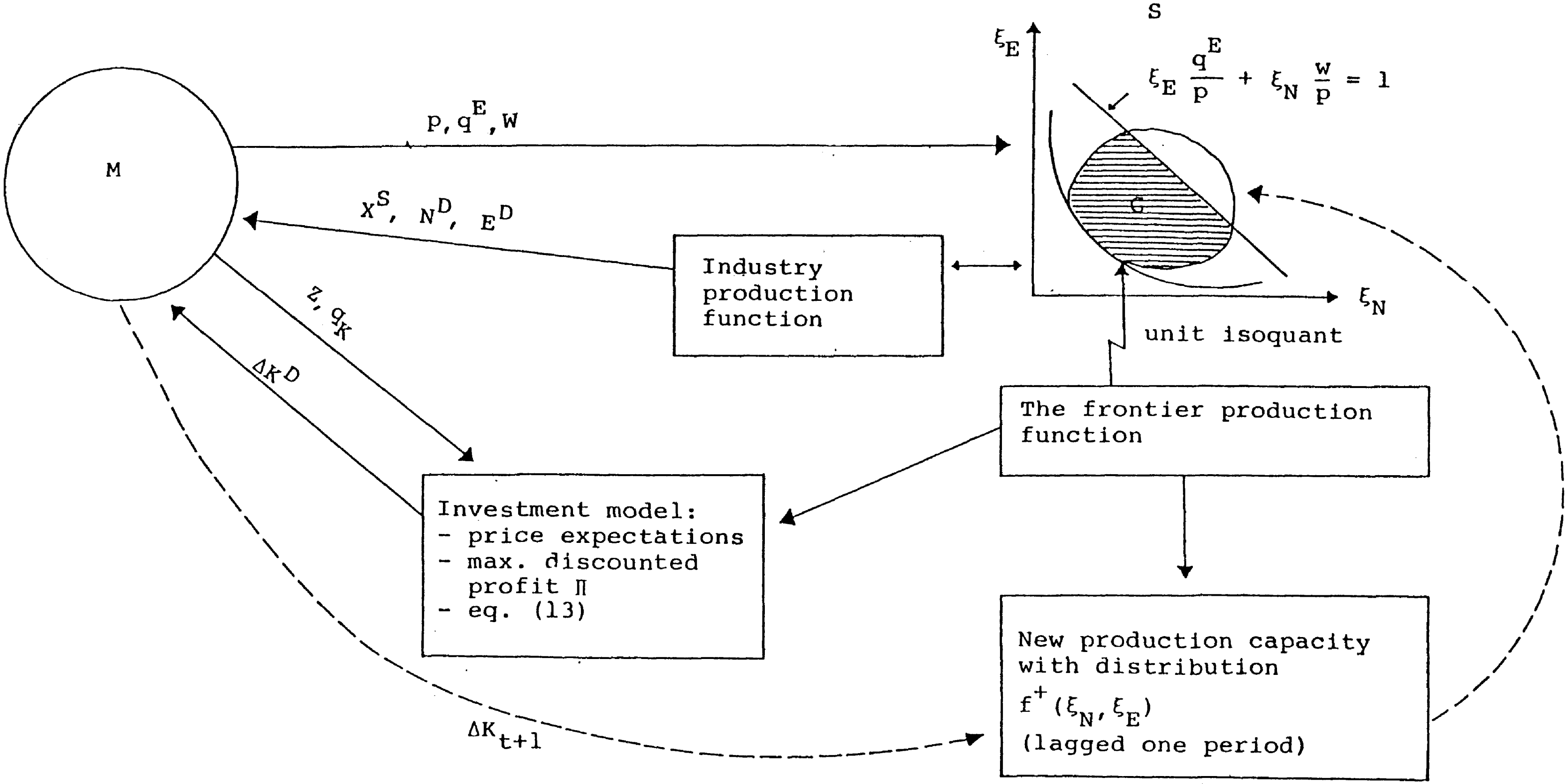
6) See Førsund (1981) for a further discussion of the capital vintage approach.

Figure 4. The interaction between the macroeconomic model M and the sectoral models based on the micro information S. The case with new capacity added through investments.



The sector investment model is connected to the sectoral information S through the frontier production function, which enters the investors' profit funtion Π. Moreover, it is plausible to assume that the investors' price expectations are determined by changes in the current prices p, q^E, and w as well as by past changes in these prices [7].

We assume that the price of capital q_K and the required rate of return z are determined in the macro model M. If z and q_K are endogenous variables in M and their solutions are dependent on ΔK^D, we shall have to solve the investment model for the sector and the macro model iteratively.

It is, however, conceivable that investment demand from the sector does not influence the solutions of the price variables in M to any significant extent. In that case, the investment model enters the model system, outlined in figure 4, as a recursive block, which for each period can be solved <u>after</u> we have found the iterative market solutions (prices and quantities) for the sector's output and current inputs.

Under these conditions, the short-run answers stated above to problems 1 and 2 of the introduction, are not dramatically changed by the presence of a model of investment which generates new capacity in the sector.

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7) This assumption is discussed further in section 4 below.

4 Some further considerations

In this concluding section we shall comment briefly on some problems which are likely to emerge if the procedures described in section 3 are to be implemented. We shall not dig deeper into the various ways in which the macro model M can be formulated, but shall take a closer look at some of the building blocks used in modelling at the sectoral level.

The first problem is one of aggregation: The industry production approach requires that the sector produce a reasonably homogeneous output which is measureable in technical units. One obvious limitation to the applicability of our analysis is that only a few branches of industry satisfy these assumptions. The best we can hope for is that for some industries, the sector specified in the macro model consists of several branches, each one of which may fulfil the requirements. For example, the pulp and paper industry may be divided into three relatively homogeneous branches: mechanical pulp, sulphate & sulphite pulp, and paper.

If the following assumptions holds, the interactive scheme of the previous section may still apply:

- The changes in prices are proportional within the aggregated sector (pulp and paper, say).

- The initial price levels are known for all branches.

We can then use the macro model to determine the common rate of change in the prices, while the sectoral analysis is carried out at the disaggregated branch level. The quantum variables to be used in the macro model are then determined by simple aggregation to the appropriate sector level.

A quite different problem is posed by the question of whether to choose a continuous or a discrete representation of the capacity distribution for the sector production. For industries with a small number of firms - like the aluminium industry in Norway - the best alternative is probably to utilize the primary input coefficient observations on the discrete form. If the number of firms in the sector is large, considerable gains may be made by using a continuous capacity distribution function as a means of data reduction to represent the observations. Even with only two current inputs, however, it is extremely difficult to find functional forms for this distribution function which are both simple enough to be estimated empirically and sophisticated enough to yield a realistic description of the underlying observations[8)]. We also require, moreover, that the capacity distribution function should be integrable in order to obtain the sector's supply of output and demand for inputs via eqs. (11) and (12)[9)].

The change over time of a sector's production capacity is composed of two factors: creation of new capacity and scrapping of existing capacity. The scrapping criterion may be the quasi rent criterion, i.e. capacity with negative quasi rent according to the prices generated by the macro model is scrapped within each time period. With a view towards reality, this strict criterion may be relaxed to allow for a certain share of unprofitable operations, but if full employment is obtained at the macro level, it is logical to maintain the strict quasi rent criterion.

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8) Mathematical examples of capacity distribution functions are analyzed in Johansen (1972, chp. 5) and Muysken (1981). Confer also Levhari (1968) and Hildenbrand (1981).

9) Confer Bjøntegård (1981) and Seierstad (1981), (1982).

As regards creation of new capacity we encounter a problem due to the fact that the notion of individual production units disappear from the model at future points of time, whereas individual units, of course, do exist in the real world. If the formation of uniform price expectation based on the prices generated in the macro model is applied to the sectoral investment calculations, we end up realizing just one point on the ex ante function. In the case of a discrete distribution this means <u>one</u> artificial unit is created each time the sector increases its capacity, and for a continuous distribution the incremental capacity mass is concentrated at just one input coefficient point.

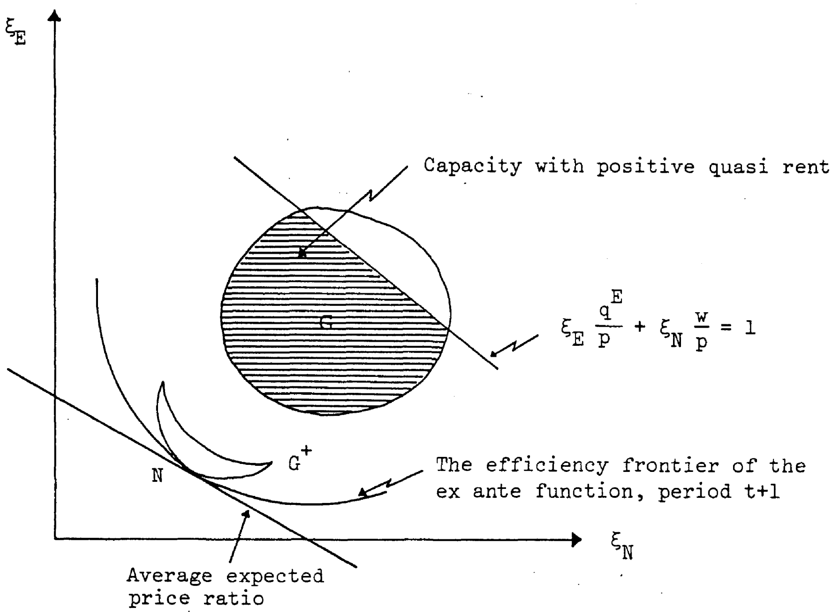

Figure 5. Creation of new capacity in the sectoral model.
G^+ = New capacity created when "stretching" the optimal choice of input coefficients.
N = Optimal point on the ex ante function for new investment for uniform price expectations and full information.

The more realistic situation, where investors may have different price expectations and new investments take place within existing plants, might be simulated by "stretching out" the investment point on the ex ante function. The degree of "stretching out" may be imposed directly or may be based on observed variation. The two alternatives are illustrated in figure 5 in the case of rapid technical change.

Technical change takes place through the movement of the ex ante function. Such changes may be predicted parametrically from estimations on observed data and/or based on engineering information. Our analysis of the Norwegian aluminium industry (Førsund and Jansen (1982)), for example, showed a typical movement towards a steady state structure of almost equal units in the sector. Further technical progress, especially as regards electricity unit consumption, can only be inferred from the use of engineering information.

In accordance with "the complete growth equation" found in Johansen (1972), disembodied technical change may also be introduced. This means that the region G in figure 5 of existing utilized capacity also moves over time.

Finally, in view of the problems and loose ends confronting the model builder of putty-clay production structures, it seems pertinent to again quote Johansen (1982, pp 25-26):

> "....this case is of course much easier to argue from a theoretical than from an econometric point of view, since the econometrics of putty-clay production is much more complicated than the econometrics of pure neoclassical production."

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