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PREFACE

This report is a slightly revised version of a paper presented at the Seventh International Conference on Input-Output Techniques, Innsbruck 9-13 April 1979. The study is part of a project run by the Central Buerau of Statistics in cooperation with faculty members of the Institue of Economics at the University of Oslo. With the MSG-model as a starting point, the aim of the project is to construct a model which is tailored for energy analyses in addition to more traditional studies of long-term economic development.

This report gives a brief outline of the model, and surveys in more detail the modifications and the new elements of the MSG-model.

The complete equation system, estimation techiques and results, and model simulations will be presented in later reports.

Central Bureau of Statistics, Oslo, 21 December 1979

Petter Jakob Bjerve

FORORD

Denne rapporten er en noe revidert versjon av et notat til "The Seventh International Conference on Input-Output Techniques" som ble avholdt i Innsbruck 9.-13. april 1979. Med utgangspunkt i MSG-modellen har Statistisk Sentralbyrå, i samarbeid med forskere fra Sosialøkonomisk Institutt, arbeidet med å utforme et makroøkonomisk modellverktøy som er spesiellt innrettet mot energianalyser.

Denne rapporten gir en oversikt over hovedtrekk i modellen og redegjør i tillegg for modifikasjoner og nye elementer i MSG-modellen.

Det detaljerte ligningssystemet, estimering og modellberegninger vil bli presentert i egne rapporter.

Statistisk Sentralbyrå, Oslo, 21. desember 1979

Petter Jakob Bjerve

CONTENTS

INNHOLD

1. INTRODUCTION

The pattern of direct energy use in Norway is rather simple. Oil products are mainly used for transport and heating, while hydro electric power covers the rest of the energy demand from industries and households. This pattern has long traditions, both the industry innovations at the beginning of the century and the post war reconstruction programs initiated the expansion of heavy industries bases on hydro electric power. The government has a decisive influence on the development and operation of electricity production in Norway. However, the analytical tools provided for analysing energy economics on a macro level in Norway have so far been rather unsatisfactory. Existing macro economic models include only rough descriptions of energy in money terms, while sector models for energy supply have note taken careful account of the overall economic development.

The Central Bureau of Statistics is the main supplier of operational models for economic planning and analysis on a macro level in Norway. The Bureau is also responsible for the preparation of national accounts and energy accounts. One major task in the development of better tools for analysing energy development is to integrate energy flows, in physical as well as money terms, in operational macro-economic planning models. It is thereby possible to forge energy sector planning and overall macroeconomic analysis into the same framework.

The aim of the project presented below is to study the long term interaction between economic growth and energy production and use.[1)] The point of departure has been an existing multi-sectoral growth model, called MSG.[2)] The main features of the model are presented in chapter 2.

Compared with the MSG-model several parts have been modified or added to provide the MSG-E model described in this paper. The model has been restructured with a revised industry classification to include new elements in the modelling of energy flows and the generation and absorption of energy. The input-output part, based on national accounts, traces flows of energy and non-energy commodities measured in constant prices as inputs to industries and final demand. To identify the flows of energy in physical terms differential distribution costs and the occurrence of price discrimination has to be accounted for.

On the demand side for energy the production model for each industry has been developed to allow for substitution between various energy inputs and between energy and other inputs. For most industries the specification of the production structure is at present based on the neoclassical theory of production. However, the energy intensive industries will in later versions of the model be treated in more detail by elaborating sector models, partly based on engineering approaches and process analyses.

The household consumption model has been developed to include effects on energy demand of changes in stocks of consumer durables.

The energy supply model is at present only elaborated in any detail for the production of electricity. In the description of the supply of hydro electric power, the model benefits from calculations carried out by the Norwegian Water and Electricity Board. The results are used to estimate a cost function for the electricity producing sector. In addition the model specification requires information of resource use in the transportation or distribution of electricity from power stations to the various users.

A short discussion on the use of the model is included at the end of this paper.

The authors wish to thank Olav Bjerkholt for valuable comments and suggestions on our draft manuscript.

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1) In another project in the Central Bureau of Statistics the emphasize is on the short to medium term relationships between energy demand and economic development (see Hervik (1979)). This energy model translate the results from the national budgeting and planning model MODIS IV for energy flows in constant values into physical units in great detail. The model is used to provide short to medium term forecasts for energy consumption and to check the consistency between the overall economic, plan and the existing sector plans for energy supply. 2) See Johansen (1974). This model orginated as an empirical study of the growth potential of the Norwegian economy in Johansen (1960). It was later turned into an operational model, mainly for the use of the Ministry of Finance, and known as the MSG model. The last version was completed in 1975 (see Lorentsen and Skoglund (1976)). The model described in the present study is referred to as the MSG-E model.

2. A BRIEF OUTLINE OF THE MODEL

The operational model which serves as the point of departure (the MSG model) takes as exogenously given the growth in productive capacity for the economy as a whole, summarized by the growth in labour force, capital stock and the trends of technological progress. The main strength of the model is its ability to trace out the long term growth paths of the economy, especially the distribution of labour, capital and production over a disaggregated set of industries, the changes in the household consumption patterns, and the development in the corresponding equilibrium prices.

The major changes compared with the present MSG model are partly general improvements and partly determined by the energy orientation of the MSG-E model. These changes are discussed in detail in chapters 3, 4 and 5. A general presentation of the MSG-E model is given below emphasizing the main behavioral relationships.

A system of partly non-linear, simultaneous equations forms the core of the model. It is often a somewhat dubious task to explain the economic logic of a simultaneous system. One has to start somewhere and reason through, but inevitably one needs some loops back since the model has no head or tail. A simplified diagram of the structure of the model is depicted in figure 1.

For a guidance through figure 1 assume that all sectors produce at constant returns to scale, minimize costs and set prices equal to unit costs. Start in the upper left hand corner of the diagram and assume given wage rates, trends of technical change and returns on capital. The producers then have enough information to choose the cost minimizing technique in terms of input coefficitens and to determine prices that cover costs.

For given final demand the scale of production by industry is determined as in simple traditional input-output models. Industry demand for capital and labour services is also derived. Imports are calculated from import shares, differentiated by commodity and by purchasing sector. Actually, final demand is partly exogenous, such as exports and government expenditures and partly endogenous, such as private gross investments and household consumption.

Private gross investments are determined in a closed loop with the scale of production by industry. The scale of production by industry determines capital service and capital stock by industry and by kind of capital good. This again determines private gross investments by commodity.[1)]

For given prices the commodity composition of household consumption depend only upon total household consumption, which is determined in such a way that full capacity use in ensured. The total productive capacity for the economy as a whole is determined by the exogenous total labour force and total capital stock and the given production efficiency.

The above description may be regarded as the first iteration step in solving the equation system. Starting with arbitrarily chosen rates of return on capital and wage rates, the techniques chosen and the prices determined would generally not lead to an equilibrium solution. When producers optimize their use of labour and capital services for given remuneration to factors their total factor use will not equal given factor supply. Consistency may be achieved, however, by letting the index of overall returns on capital be endogenous[2)]. Gradually adjusting returns on capital imply changes in prices and input coefficitens. The final iteration will trace out a balanced picture of the economy with neither shortage nor surplus of commodities, labour and capital[3)].

The MSG-E model also includes submodels for capital depreciation, indirect taxes and changes in commodity stocks. Special options to "control" the model results for the deficit/surplus of the balance of trade (e.g. adjusting the import shares or the export estimated) are introduced. In some sectors, mainly primary industries, decreasing returns to scale are assumed. This impose another link between prices and quantities since unit costs in these sectors depend upon the scale of production. Som commodity prices are given outside the model, and the production levels and/or investments of some industies are exogenous.

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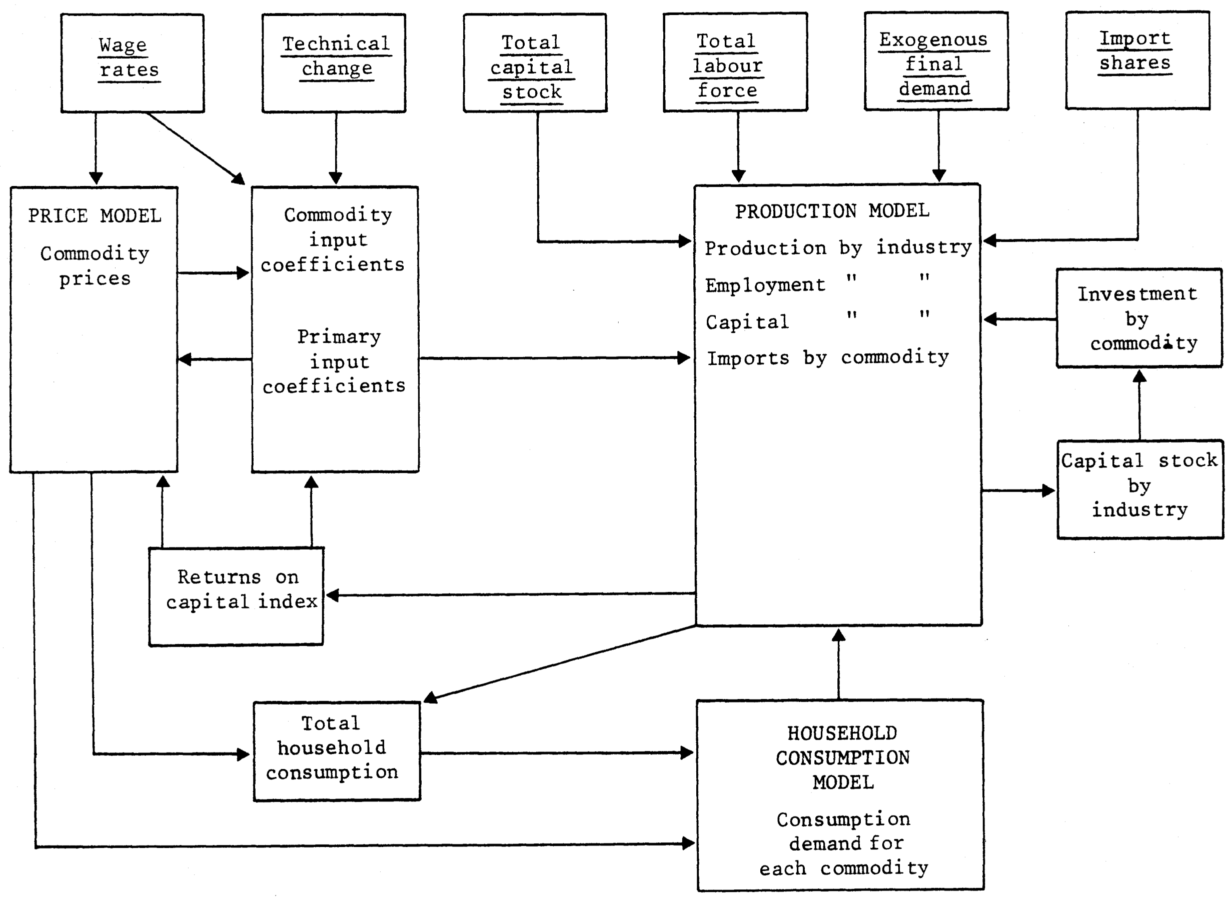
1) A submodel for depreciation is also included (not indicated in figure 1). 2) The rate of return on capital in sector j can be written $R_j = \rho_j R$ where ρ_j is the relative rate of return (exogenous structure coefficient) and R is an endogenous index of overall returns on capital, for simplicity normalized to one in the base year. 3) As formulated above, the crucial link between the price and quantity side of the model is the index of the overall level of returns on capital. This link could be broken by giving rates of returns exogenously, thus dividing the model into a price-model and a quantity model. One of the resource restrictions, preferably for capital, would then have to be relaxed and total capital stock endogenously determined. The model could then be characterized as a demand oriented model, whereas it now is better characterized as supply oriented. The equation system would remain unaltered. For medium term planning such a demand oriented version of the MSG-E model may be more appropriate.

Some of the special cases referred to above (decreasing returns to scale, exogenous prices, exogenous estimates for production and investment) apply to the energy producing sectors, and will be further discussed in chapter 4.

A complete representation of technological and behavioral relations within households and industries would exceed the limits of a manageable model. In MSG-E the interplay of sectors in a growth process is focused; behaviour and technology within sectors are given a rather simple representation. To supplement and check the results of the MSG-E model, detailed sector models will therefore be worked out.

It should be noted that several general weaknesses of the existing MSG model will be inherent in MSG-E. For instance, all exports are exogenous. Energy intensive industries are major export industries, which means that the assessments of exports directly influence the development of energy use. However, several ongoing projects are aiming at modifying and improving various parts of the model. Results from these projects will gradually be implemented in MSG-E.

FIGURE 1. Structure of MSG-E



3. BASIC CONCEPTS

The Norwegian national accounting system, which is in very close adherence to the new SNA (see the United Nations (1968)) forms the conceptual framework of the MSG-E model. The model includes an accounting system, i.e balance equations and definitional relations, which to a great extent are identical with the real flows of the national accounts. The financial flows are at present not included. A major part of the statistical data required for estimation, including base year values, is supplied by the national accounts.

3.1. Sectors, commodities and primary factors[1)]

The inter-industry transactions of the economy form a central component of the MSG-E model. In accordance with the accounting framework the inter-industry transactions are represented by a pair of rectangular commodity-by-industry matrices, one for input of commodities to industries and one for output of commodities from industries. The representation of commodity flows of the economy also includes output of commodities from import categories and input of commodities to final demand categories.

The commodity flows of the model may be described as flows between (functional) sectors. The sector concept is first of all used for the classification of establishments and similar economic units into production sectors (industries). The model has 32 production sectors, including five general government production sectors. Special attention is paid to the specification of major energy producing and energy consuming industries. The major energy producing industries include sectors for the production of electricity, the production of crude oil and natural gas, and the refining of crude oil. The major energy consuming industries (energy intensvie industries) include sectors for the production of pulp and paper, the production of metals, and the production of chemicals.

In addition to a classification of establishments, the sector concept is also applied to broad categories of goods and services classified by origin or use, i.e. one sector for imports, exports, household consumption, general government consumption, private investments, and general government investments, respectively.

In the model an important distinction is drawn between production sectors (industries) and commodities. The commodities of the model include all commodities of the Bruxelles nomenclature and in addition groups of services. The commodity classification is arrived at by adopting the "main producer" principle, i.e. letting all goods and services with the same industry (production sector) as the main producer form one commodity. The classifications of production sectors and commodities are thus closely related.

Strictly followed this procedure will give the same number of commodities as the number of industries, i.e. square commodity-by-industry matrices.[2)] However, in a couple of cases energy commodities have been separated from other commodities with the same main producer. Also commodities representing imports for which there is no domestic production (non-competitive imports) are included as separate commodities.

Altogether there are 40 commodities in the model. Five of these may be characterized as energy commodities, namely electricity, crude oil (incl. natural gas), coal, petrol and fuel oil. The production sector for refining of crude oil has both petrol and fuel oil as separate output commodities while coal is a separate output commodity in the production sector for mining.

In addition to commodities each production sector has input of primary factors, i.e. of labour and capital services. In the model there is just one category of labour input, while the model distinguishes between three main categories of capital goods in the specification of input of capital services ("buildings and constructions", "machinery" and "transportation equipement"[3)]).

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1) A more comprehensive discussion of these concepts is given in Bjerkholt and Longva (1979).
2) This does not mean that there is a one-to-one correspondence between commodities and industry outputs. At the chosen level of aggregation there will still be significant non-zero off-diagonal elements in the commodity-by-industry output matrix, i.e. mulitple output in industries. 3) In addition capital in shipping and capital in crude oil production form separate categories.

3.2. Activities and the basic quantity equations

The rather disaggregated representation of the commodity-by-sector flows makes it possible to focus upon the interplay of sectors in a growth process. This interplay is believed to be of crucial importance for the study of links between economic growth and energy use. It is also possible to give the energy commodities and the energy producing and consuming sectors a proper representation.

In addition to the intra sectorial substitution, substitution possibilities within each sector is included in the model. In the submodels for producers' and consumers' behaviour we therefore explicitly assume the existence of production possibility functions for the production sectors and a utility function for the household consumption sector.

However, the rather disaggregated representation of the commodity-by-sector flows makes it hardly possible, nor essential for the quality of the model results, to introduce substitution possibilities between all inputs and outputs of each sector. To simplify we have therefore partitioned the set of detailed commodity and primary input flows of each sector into mutually exclusive and exhaustive subsets and a priori imposed the restriction that the production or utility function is separable in these subsets.[1)2)] Each subset defines an aggregate of input and output commodities or of primary inputs and the substitution possibilites are introduced only between these aggregates. Within each aggregate we assume fixed proportions, i.e. the aggregator functions are simple Leontief functions. In the following these fixed coefficient aggregates are called activities. The actual specification of activities in the producer and consumer submodels will be further discussed in chapters 4 and 5.

Formally, the subdivision of sectors into activities is also extended to the import and final demand sectors others than household consumption. For imports and exports there are one activity for each commodity flow, while general government consumption activities represent types of government services. The private and general government investment activities correspond to categories of capital goods.

In the model we distinguish between commodity activities, i.e. an aggregate of commodity flows in fixed proportions, and primary activities, i.e. an aggregate of primary inputs in fixed proportions. The commodity flows between commodity activities include all generation and absorption of commodities in the economy except changes in commodity stocks. The commodity balances can thus be written as:

$$X_i = \sum_j X_{ij}^{+} - \sum_j X_{ij}^{-} \qquad i=1,\ldots,n_X \qquad (3.1)$$

where X_{ij}^{+} is output of commodity i from commodity activity j,

X_{ij}^{-} is input of commodity i to commodity activity j, and

X_i is net increases in stocks of commodity i.

n_X is the number of commodities.

We also introduce the concept commodity activity level as net output of commodities from activity j, i.e.

$$A_j = \sum_i X_{ij}^{+} - \sum_i X_{ij}^{-} \qquad j=1,\ldots,n_A \qquad (3.2)$$

1) Sufficient conditions and implications for a production function having this property are discussed by Berndt and Christensen (1973). 2) Subsets for primary inputs and commodity outputs are of course only relevant for the production sectors.

where A_j is net output of commodities from commodity activity j (activity level for activity j).[1)]
n_A is the number of commodity activities.

The commodity balance equation, including the fixed activity coefficients for commodities (the basic commodity equation), is then given by

$$\Lambda_X A = X \qquad (3.3)$$

where $\Lambda_X = \{\lambda_{ij}\}$ is a commodity-by-activity coefficient matrix in which

element $\lambda_{ij} = \dfrac{X^+_{ij} - X^-_{ij}}{A_j} = \dfrac{X_{ij}}{A_j}$

(positive or negative) gives net output of commodity i per unit of commodity activity j,

$A = \{A_j\}$ is a vector of commodity activity levels, and

$X = \{X_i\}$ is a vector of increases in commodity stocks

Equation (3.3) follows directly from mainpulations of (3.1) by inserting the expression for λ_{ij}. The elements of Λ_X are estimated from base year data.

As mentioned above the model also includes activities for primary inputs (labour and capital). These primary activities are of course only relevant in the production sectors. The balance equations for primary inputs can be written as

$$Y_i = \sum_j Y^-_{ij} \qquad i=1,\ldots,n_Y \qquad (3.4)$$

where Y^-_{ij} is primary input i to activity j, and

Y_i is total supply of primary input i.

n_Y is the number of categories of primary inputs.

As for commodity activities the primary activity levels are defined as

$$B_j = \sum_i Y^-_{ij} \qquad j=1,\ldots,n_B \qquad (3.5)$$

where B_j is total input to primary activity j (activity level for activity j)

n_B is the number of primary activities.

The balancing equation for primary inputs, including the fixed activity coeffients for primary inputs (the basic primary equation) is then given by

$$\Lambda_Y B = Y \qquad (3.6)$$

where $\Lambda_Y = \{\lambda_{ij}\}$ is a primary input-by-activity coefficient matrix in which element λ_{ij} gives input of primary input i per unit of activity level j,

1) Import and final demand (including household consumption) activities have of course only output and only input of commodities, respectively. As will be discussed in section 4 the production sectors have normally separate activities for input and output of commodities. This means that, with a few minor exceptions, no activity has both inputs and outputs, i.e. for each activity either

$\sum_i X^+_{ij}$ or $\sum_i X^-_{ij}$ in (3.2) is zero.

$B = \{B_j\}$ is a vector of primary activities, and

$Y = \{Y_i\}$ is a vector of total supplies of primary inputs.

As for commodities the activity coefficients for primary inputs are estimated from base year data.

3.3. Value concepts

The value concepts adopted in the model are essential both because of the prominent role played by the interindustry transactions and because of the modeling of the price dependent substitution within sectors.

In general the elements of the commodity activity coefficient matrix are estimated from the national accounts for the base year of the model. This means that quantities of commodity flows are measured in unit prices of the base year, i.e. constand unit values. The principal concept for evaluating commodity flows in the model is (approximate) basic values.[1] The basic value concept is preferred to producers' value or purchasers' value because the trade margins (including transport charges) and commodity tax rates may vary between receiving sectors of the same commodity and thus may cause a discrepancy between total supply and total demand in constant unit values.[2]

The commodity activity levels are defined above as the constant unit value of net commodity output of each activity. In the MSG-E model the activities are not, however, evaluated in basic values but in market values, computed as producers' value of commodity outputs less purchasers' value of commodity inputs.[3] The reason for this is first of all that the substitution possibilities within each sector is specified between activities, not between commodities. Market prices are the relevant price concept in modeling the producers' and consumers' behaviour.

With commodity flows measured in constant basic values and commodity activities in constant market values the basic commodity price equation, which is the dual of (3.3)[4], can be written as

$$\Lambda_X' P_X = P_A - T_A \tag{3.7}$$

where P_X is a vector of commodity price indices in basic unit values,

P_A is a vector of price indices of activity levels in market unit values, and

T_A is a vector of commodity taxes, net, in current value per unit of activity level.[5]

The basic primary price equation, which is the dual of (3.6), can be written as

$$\Lambda_Y' P_Y = P_B \tag{3.8}$$

where P_Y is a vector of price indices of primary input by category, and

P_B is a vector of price indices of primary activity levels.

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1) The Norwegian national accouting system includes a set of value notions, as recommended in A system of National Accounts (United Nations 1968)). 2) Note that apart from trade margins and commodity taxes there may be genuine price differentiation in the base year. This bias in the base year weights may be a source of error in the model computations. As will be discussed later price differentiation will be explicitly corrected for in the case of elctricity. 3) Equation (3.2) must therefore be extended also to include indirect taxes. 4) Note that when a production function is separable in some aggregate inputs, the cost function will be sparable in the corresponding price indices. 5) Trade margins are treated as an ordinary commodity.

3.4. Energy flows in physical and money terms

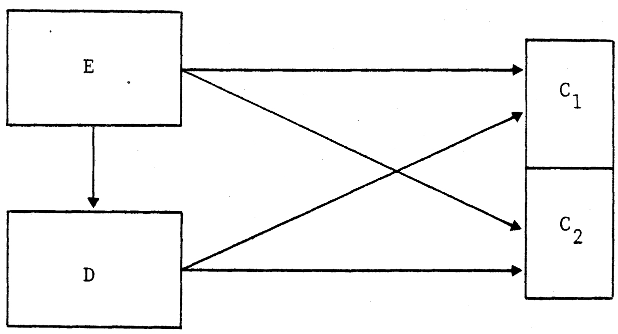
The model outlined in this report is designed to be used as a planning tool for the capacity of the electricity sector. It is therefore particularly important that the supply and demand of electricity in constant value terms in the model can be correctly "translated" into physical units, i.e. kWh. In later version of the model such on integration of electricity in physical as well as in money terms will be extened to other energy flows as well.

As discussed in the preceding section constant basic values are assumed to be the proper volume measures for the commodity flows. However, due to market differentiated distribution costs and significant genuine price discrimination constant basic value is not directly suitable as a volume measure of electricity.

The production sector for electricity in the national accounts comprises both the production part, i.e. the electric power stations, and the distribution part, which encompasses transmission lines, transformators and distribution network. Thus, while the basic values for most other commodities are corrected for differences in the amount of trade services including transport charges, this is not the case for electricity. Distribution costs vary considerably between different uses. Electricity intensive industries receive power directly from the transmission system at a very high voltage. Both the capital costs and the physical power losses are therefore relatively low. Electricity consumed by private households will, on the other hand, be carried over longer distances and through all stages of the distribution network; labour and capital costs and power losses are thus much higher. Furthermore, as will be discussed in section 4.3, the production structures in the two parts of the electricity supply sector are rather different. The resource use in the supply sector is therefore dependent on the composition of electricity demand and an aggregate specification of the electricity supply sector is not satisfactory.

In order to construct an overall volume measure for electricity it is therefore necessary to undertake a further separation of the basic values of the national accounts. In the model electricity supply is divided into two commodities, electricity and distribution services. As will be discussed in section 4.3 separate production functions are introduced for these two commodities. This specification is described in a simplified way in figure 2.

FIGURE 2.



As illustrated in this figure electricity ("E") - corrected for real distribution costs - in the energy model will be delivered to the electricity consuming sectors C_1 and C_2.[1)] Furthermore electricity distribution services ("D") are delivered to the same users. For each receiving sector electricity and distribution services are included in the same input commodity activity, i.e. fixed but purchaser differentiated proportions between electricity and distribution services are assumed.

1) Total physical power losses is considered as a significant input in the production of distribution services (see section 4.3). This is illustrated by a flow of electricity from E to D in the figure.

An additional problem in bridging the gap between value measures and physical flows of electricity is connected with the underlying price discrimination in the electricity market. The differences in market prices reflect only partly differences in the actual marginal unit costs. The most obvious deviations exist between (i) deliveries to the energy intensive industries and (ii) deliveries to households, the service sector and other industry sectors. Due to existing favourable long term contracts the prices paid by the first of theses groups are relatively low compared with the charges of other users when real cost are taken into consideration. As a consequence the quantity of electricity - in physical units - corresponding to the constant unit value terms will depend on what market these refer to even if basic values are corrected for different distribution costs. In order to establish a constant value measure for electricity which is proportional to kWh in all markets price discrimination will also have to be deducted from the basic values. The resulting unit value defines the volume notion for electricity - it may preliminary be called "constant standard value". The price discrimination in the electricity market is introduced explicitly in the energy model as an artificial "tax" or "subsidy" with differentiated rates. Total net price discrimination is conventionally normalized to zero in the base year.

Due to the rather detailed treatment of electricity demand and supply in the model the time series data from the national accounts have to be supplemented with information from other data sources. Electricity supply is represented by one single sector in the national accounts. The model structure outlined above thus requires a further separation of value flows in the national accounts. For every electricity using sector we need information to determine how much of the difference between the actual purchasers' price and a "standard price" (proportional with kWh) is accounted for by real costs of distribution and price discrimination, respectively.

Because of the assumption of fixed coefficients between the different value components of electricity for each receiving activity, base year data will be sufficient.[1)] The necessary information to estimate this breakdown empirically is provided by electricity and industrial statistics supplemented by technical data from engineering studies.

4. PRODUCTION

Several recent studies of energy demand indicate considerable substitution possibilities within aggregated sectors, both between different energy commodities and between energy and other aggregated inputs.[2)] In MSG-E such substitution possibilities are introduced as an integrated part of the model.

The formal specification of the production structure is similar for most of the 27 industry production sectors of the model. The neoclassical theory of production, formalized by Generalized Leontief cost functions, and Hicks neutral technical change, are probably sufficient as an approximation for the description of producer behaviour in summary form in a long-term model. However, for the energy producing sectors and for some of the main energy intensive sectors this approach has several limitations. The neoclassical approach will therefore for these sectors be supplemented by separate process oriented sector models. For the electricity supply sector such a sector model is from the outset partly integrated in the main model (see section 4.3).

4.1. General model

A primary objective of the models for producer behaviour is to derive demand functions for each commodity and primary input into each industry and supply functions for each output commodity. To simplify we have, as discussed in section 3.2, imposed a two-tier structure on inputs and outputs of each sector. The substitution possibilities are introduced only between aggregates of commodity and primary inputs within each sector, i.e. between activities.

1) However, time series will be necessary to estimate production functions on the supply side.
2) For a survey of such studies, see Blaalid and Olsen (1978).

On the input side the individual commodities and primary inputs are aggregated into five input activities, namely one for real capital (three types of capital), one for labour (only one type), one for materials (all non-energy commodities), one for electricity (two commodities, see section 3.4) and one for other energy inputs (two energy commodities), for short called fuels. On the output side the individual commodities supplied by a sector are, with three exceptions discussed later in this section, aggregated into one output activity.

The model for producer behaviour is defined in terms of these input and output activities. Since there are fixed proportions between the flows (commodities or primary inputs) composing each activity the commodity supply and demand and primary input demand are easily derived once the activity levels are determined.

As shown among others by Diewert (1971) the neoclassical theory of production can be represented in two ways; either by postulating production functions and necessary conditions for producer equilibrium or, alternatively, by directly specifying the cost functions of the model. Under certain assumptions the two procedures will give an equivalent description of the production structure. The introduction of cost functions is convenient also by the fact that input demand functions (following Shephard (1953)) can be derived simply as partial derivatives of the cost functions with regard to the corresponding input prices. Furthermore, this specification can facilitate the solution of large equation systems. Such considerations form the background for our choice of postulating cost functions in the energy model.

Below a brief outline of the relations between the specified activities and the corresponding price indices is given. On the demand side of the producer behaviour model we can for an arbitrary sector write

$$A_i = Z_i A_X \qquad i = \begin{cases} M & \text{Materials} \\ E & \text{Electricity} \\ F & \text{Fuels} \end{cases} \tag{4.1}$$

$$B_i = Z_i A_X \qquad i = \begin{cases} L & \text{Labour} \\ K & \text{Capital} \end{cases} \tag{4.2}$$

where A_i are commodity activity levels for aggregated commodity inputs

B_i are primary activity levels for aggregated primary inputs.

A_X is the output activity level (assuming only one output activity in each sector), and

Z_i are input-output coefficients for the various input activities

The Z-coefficients are endogenously determined by assuming the existence of a set of "well-behaved" homogeneous production functions of degree one and that factor demand is determined in such a way that least cost production pattern is undertaken, i.e. cost minimization. The input-output coefficients for activities in the sector can then be written as a function of input prices and tecnhical change, i.e. as

$$Z_i = f_i\,(P_M, P_E, P_F, P_G, P_K, \varepsilon), \tag{4.3}$$

where P_M, P_E, P_F and P_L, P_K are price indices for commodity and primary input activities, respectively[1],

and ε represents technical change.

When the production function is linear homogeneous profit maximization fails to determine a unique supply curve for sector output. On the supply side of the producer behaviour model we instead assume that in each industry the output will be priced such that the price covers average costs, i.e. zero excess profit.

We can then write

$$P_X = c \tag{4.4}$$

1) As discussed above in section 3.3 all activity prices are market prices.

where c is total unit costs, and

P_X is the price of the output activity.

Total unit costs can be written as

$$c = Z_M P_M + Z_E P_E + Z_F P_F + Z_L P_L + Z_K P_K + T_S \tag{4.5}$$

where T_S represents net indirect taxes per unit of total output.[1)]

For given input prices the output price is thus independent of the output level and the producer supply what is demanded without any changes in prices, i.e. the supply curve is infinitely elastic.

4.2. Econometric specification

The principal features of the production structure outlined above correspond to the model of producer behaviour in the energy model for the American economy developed by Hudson and Jorgenson (1974). In their model the cost functions are represented by translog price possibility frontiers. In our energy model for the Norwegian economy we have chosen another functional representation. The startpoint of this project was the MSG model where the production structure is based on fixed coefficients or Leontief technology for input of commodities and a Cobb-Douglas technology for labour and capital inputs. A generalized representation of this rather rigid structure is provided by the Generalized Leontief (GL) cost function, first introduced by Diewert (1971).

In estimating these cost functions an additional a priori hupothesis of separability is introduced by assuming that the two specified energy activities can only be substituted against other inputs via an aggregate for total energy input. This description is consistent with most recent studies of energy demand (Hudson and Jorgenson (1974), Berndt and Wood (1975) and Fuss (1977)). Thus, on the most aggregated input level only four inputs are specified in the production functions; labour (L), capital (K), materials (M) and total energy (U). While the aggregator functions for the first three of these inputs are described simply by fixed coefficient activities, a more flexible functional form is chosen for the energy activity aggregate to allow for substitution between electricity (E) and fuels (F).

When a production function is separable in som aggregated inputs, the cost function will be separable in the corresponding price indices. The dual to the energy activity aggregate can thus be thought of as an aggregate price index for energy. Furthermore, if the energy activity aggregate is linearly homogeneous in its components the price index in market equilibrium will equal average energy costs. This opens for a two-stage optimization procedure: first optimize the mix of activities within the energy aggregate and then optimize the level of the four aggregated inputs.[2)3)]

Assuming that the production function of an arbitrary sector is homogeneous of degree one, the GL cost functions can be set out as

$$C = h(t)A_X \sum_i \sum_j \beta_{ij}(P_i P_j)^{\frac{1}{2}} \qquad i,j = L,K,U,M \tag{4.16}$$

where the P's are price indices for the four aggregated inputs and A_X is the output activity level as defined in section 3.2. The term h(t) represents an assumption of Hicks neutral technical change.

1) T_S will also include refunded commodity taxes on commodity inputs, most notable the value added tax. 2) Homotheticity is a sufficient condition for the validity of the two-stage procedure. The further restriction of linear homogenity is required to ensure that the product of the aggregate price and quantity indices equals total energy cost. 3) Since the activities themselves are commodity and primary input aggregates the cost minimization can actually be viewed as a three-stage procedure. However, because of the assumption of simple Leontief technology the "optimization" in the first stage degenerates to provide that there are no waste of resources.

Differentiating the cost function with respect to the input price, P_i, gives the demand function for the corresponding input aggregate. Dividing by the output activity level the input-output coefficient is derived as

$$Z_i = h(t)\ \Sigma_j \beta_{ij} P_i^{-\frac{1}{2}} P_j^{\frac{1}{2}} \qquad i,j=L,K,U,M \qquad (4.7)$$

It is seen from equation (4.7) that if all the off-diagonal elements of the matrix $[\beta_{ij}]$ are zero, the production model reduces to ordinary fixed-coefficient Leontief technology. Thus, with the specification (4.6) it is possible to test for the existence of substitution among aggregated inputs.

By imposing the restriciton that the coefficient matrix is symmetric, $\beta_{ij} = \beta_{ji}$ (i,j=L,K,U,M), there are ten coefficients to be estimated for each sector. With respect to the parameters the input demand functions are linear relations, and can thus be easily estimated by simultaneous regression methods.

The energy submodel is also represented by Generalized Leontief cost functions, i.e. by

$$P_U = \sum_{ij}\sum b_{ij}(P_i P_j)^{\frac{1}{2}} \qquad i,j,=E,F \qquad (4.8)$$

It is assumed that the energy cost functions are linearly homogeneous in the activity aggregate for total energy inputs. This secures the consistency of the two stage optimization procedure and makes the optimal energy mix independent of the volume of "energy" used.

Equivalent to the derivation of the equations (4.7), the demand for the energy activities relative to total energy input is derived as functions of the corresponding activity prices by differentiating the system (4.8) [1]. The estimation of the three parameters (the coefficient matrix $[b_{ij}]$ is again assumed to be symmetric) of the sub-model can not be performed directly on the base of the input demand functions, because total energy input is not observable. However, the cost shares of the two energy activities can easily be derived as

$$\alpha_i = P_i^{\frac{1}{2}} \frac{\Sigma_j b_{ij} P_j^{\frac{1}{2}}}{\Sigma_i \Sigma_j b_{ij}(P_i P_j)^{\frac{1}{2}}}, \qquad i,j=E,F \qquad (4.9)$$

These share functions are estimated by non-linear estimation methods. It is seen from the equation (4.9) that both actual and predicted shares sum identically to one. The standard solution to this problem is to delete one equation from the system. Furthermore it is clear from (4.9) that the matrix $[b_{ij}]$ is only determined up to an arbitrary normalization. The scaling of each coefficient is conventionally determined by deciding that the price index of total energy equals one in the base year. This is equivalent to imposing the restriction

$$b_{EE} + 2b_{EF} + b_{FF} = 1 \qquad (4.10)$$

on the estimating relation.

The estimation of cost functions for the endogenous production sectors is based on national accounting figures for the five aggregated inputs; labour, capital, materials, electricity and fuels and for price indices of the same inputs.[2] The sectors in the model are aggregates of the sector classification in the national accounts, and consequently the observations will provide a combined time series cross-section data set.

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1) Multiplying these energy coefficients by the input coefficient Z_U in (4.7) gives the specification of the input coefficients for the two energy activities, postulated in general form by relation (4.4).
2) The price index for labour input is defined as wage costs per manhour while the concept user costs of capital is applied for the capital input price index. Assuming constant returns to scale the user cost of capital can be determined in such a way that total costs equal total value. However, the calculated return on capital will probably be highly influenced by short term fluctuations in the variables. A major reason for such fluctuations is variations in the utilization rate of capital. As the MSG-E model is constructed to study long-term developments with the economy running at full capacity, the final estimation of the production structure will use data corrected for time varying capacity utilization.

4.3. Energy production

The most important energy producing sectors in the Norwegian economy are the electrivity supply sector and the sector for extraction and refining of crude oil. Naturally these production sectors are separately represented in the MSG-E model. In addition to the energy outputs from these sectors coal is explicitely specified as an output commodity of the mining sector of the model. Some minor products which might have been characterized as energy goods are included in non-energy commodities of the model. As will be described below the electricity sector in MSG-E is analysed in a rather detailed way, while the production of the other energy commodities is given a rather simple treatment in the present version of the model.

4.3.1. Production of electricity

In Norway the electricity supply system is predominantly a hydro-power system. Public authorities have a decisive influence on the planning and operation of the sector.

As mentioned in section 3.4 the electricity sector in the MSG-E model is subdivided in a production and a distribution part with separate production functions, one for the production of electricity and one for the production of electricity distribution services. The production part of a hydro power system has the following characteristic features:

i) Nearly all costs can be considered as fixed consisting of real capital outlays while operating costs (wages and material costs) are low. This as opposed to a production system dominated by thermal power plants, where variable costs are a major part of total costs.

ii) The planning problem in a hydroelectric power system has two main dimensions. As in a thermal power system it is necessary to provide sufficient plant capasity to meet peak load demand. But in addition, the hydroelectric system cannot be controlled except by water storage. The planning problem is therefore to provide, in addition to the necessary plant capacity, storage facilities that will be sufficient to meet total annual energy demand.[1)]

iii) A common feature of production based on extraction of natural resources is decreasing returns to scale. Thus, in formulating the production structure of a hydro power system it is essential to include the possibility of an increasing marginal cost function.

The production model for electricity is partly described by relationships on the micro level. In this paper only the derived macro relationships included in the MSG-E model will be indicated; for a complete presentation of the sector model, see Strøm (1979).

The enrgy dimension of the hydro power system is mainly related to the building of water reservoirs. A given water storage represents a certain volume of potential energy (kWh). Furthermore the load capacity (in kW) of the hydro power system will depend on the characteristics (heights and diametres) of the tunnels from the reservoirs to the power stations. The final transformation of water power to electricity requires the installation of turbins and generators in the hydro plants.

The demand for electricity varies during the day and during the year. Integrating the corresponding load curve gives the total annual electricity consumption. To simplyfy the MSG-E model we assume that the proportion between load capacity in the hydro power system and the annual production of electricity is exogenously given.[2)] Accordingly the planning problem in the hydro power system is reduced to one dimension, namely to determine annual electricity production.

From the sector model for the production of electricity the production structure to be specified in the MSG-E is derived as:

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1) A third dimension can be added to the planning problem in a hydroelectric power system because runoff to the reservoirs varies from period to period. For any given storage capacity there is therefore a certain risk that deficiences may occur. This uncertainty problem must be handled outside the MSG-E model in the actual planning of the supply system. 2) Let A_{XP} denote annual electricity production and Q the load capacity of the system. The relation $A_{XP} = t_B Q$ defines the user time, t_B, as the number of hours it will take for demand at peak load to meet the observed energy production. A sufficient condition for t_B to be constant is that the form of the load curve is unchanged over time. In the sector model t_B is an endogenous variable dermined by the tariff structure for electricity (peak-load pricing) and the composition of demand (households have shorter user time than energy intensive industries). MSG-E and the sector model must therefor be used interatively to reach a consistent solution.

$$A_{XP} = \alpha_{MP} A_{MP} \tag{4.11}$$

$$A_{XP} = \alpha_{LP} B_{LP} \tag{4.12}$$

$$A_{XP} = \alpha_{GP} B_{GP} \tag{4.13}$$

$$A_{XP} = f_P(B_{CP}) \tag{4.14}$$

where A_{XP} is the production of electricity,

A_{MP} is the input of materials,

B_{LP} is the input of labour

B_{GP} is the input of machineries (turbins and generators), and

B_{CP} is the input of constructions and buildings,

α_{GP}, α_{MP}, α_{LP} are parameters.

By (4.11) and (4.12) the minor inputs in the production process, labour and materiales, are simply assumed to be proportionate to the output level. (4.13) follows from an assumption of proportionality between the volume of machine installations and the load capacity of the hydro power system, and exogenously given proportion between the load capacity and energy production. A more flexible function is specified for input of constructions and buildings in (4.14). Decreasing returns to scale in electricity production is represented in the model by this relation.[1)]

The total costs of production are defined by

$$C_P = P_{CP}B_{CP} + P_{GP}B_{GP} + P_{LP}B_{LP} + P_{MP}A_{MP} \tag{4.15}$$

where P_{CP} and P_{GP} denote indices of user costs of capital.[2)]

P_{LP} is a price index of labour input and P_{MP} is a price index for materials. Assuming cost-minimization and specifying (4.14) as a constant elasticity function, the cost function can be derived as

$$C = \left[\frac{P_{LP}}{\alpha_{LP}} + \frac{P_{MP}}{\alpha_{MP}} + \frac{P_{GP}}{\alpha_{GP}} \right] A_{XP} + \frac{P_{CP}}{\alpha_{CP}} A_{XP}^{\gamma} \tag{4.16}$$

where α_{CP} and γ are parameters.

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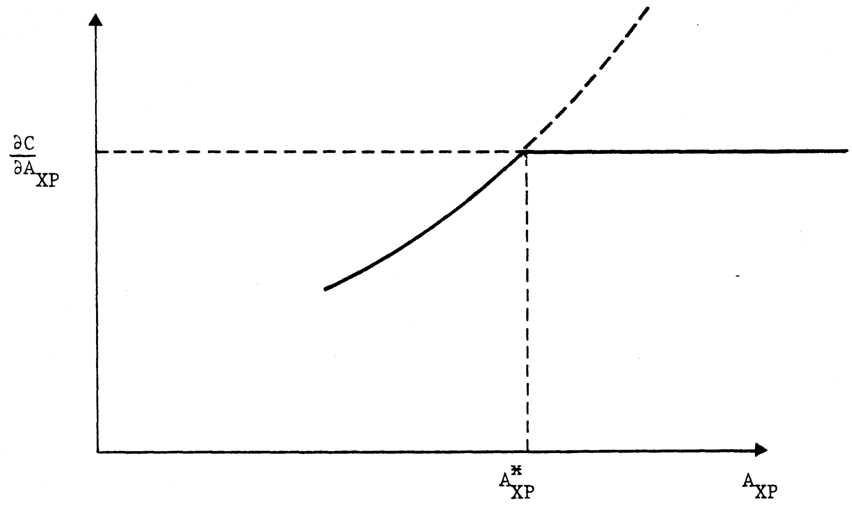
1) In the specification of the production structure (4.11)-(4.14) we have omitted the existence of technical change. In the operational model factor-augmenting technical change is included. 2) The user costs in the electricity sector are defined by the ralation $P_{kp} = \nu(R,t) \cdot P_{kI}$ (k=C,G) where ν is an annuity factor depending on a marginal rate of return (R) imposed on public investments and the economic life time of the projects (t), and P_{kI} (k=C,G) are price indices of the investment activities for the two categories of real capital. This way of calculating user cost of capital implies net profits in sectors with decreasing returns to scale.

The estimation of the cost structure (4.16) will be based on time series of calculated costs of present and potential water power projects. As a tool in the planning of the electricity sector the Norwegian Water and Electricity Board has developed methods to calculate and rank all konwn water power projects according to average costs at constant prices.[1)] Average cost in a "marginal plant" can be considered as an approximation to the long term marginal cost of the production system. The schedule of water power projects is therefore used to estimate the γ-coefficient in the marginal cost function specified as[2)]

$$\frac{\partial C}{\partial A_{XP}} = \left(\frac{P_{LP}}{\alpha_{LP}} + \frac{P_{MP}}{\alpha_{MP}} + \frac{P_{GP}}{\alpha_{GP}}\right) + \gamma \frac{P_{CP}}{\alpha_{CP}} A_{XP}^{\gamma-1} \tag{4.17}$$

The derived cost curve will have to be somewhat modified allowing for the fact that the Norwegian electricity supply system at a certain level of energy capacity will be supplemented by thermal power. In a supply system based for example on oil, gas or coal, a scale elasticity of one would be more appropriate; hence the marginal cost will be constant. The complete marginal cost function for the production of electricity is illustrated in figure 3.

FIGURE 3.



At the production level A^*_{XP}, the costs of increasing the water power production just equal the marginal cost of introducing thermal power in the supply system. From that point the increasing marginal cost curve is therefore irrelevant.

As outlined in section 4.1 the relations to be specified in the MSG-E model are the relative demand function (4.1) and (4.2) for input activities. In the present case three of these relations are given directly by (4.11)-(4.13). The corresponding input coefficients (the Z's) equal the inverse of the α-parameters, hence the input coefficients of the electricity producing sector are independent of relative input prices.

The demand function for the input constructions and buildings is obtained as the derivate of (4.16) with respect to the price index P_{CP}. Due to the specification of (4.14) the corresponding input coefficient will depend on the output level A_{XP}, but not on relative prices. Thus, marginal costs will in general not be equal to average costs, and a pricing principle other than (4.4) is introduced. Using the model it is most convenient to let the electricity price be exogenously given. However, by iterative solutions the model can also be utlilized to trace out optimal investments paths for the electricity sector in the sence that the price of electricity in the long run should equal marginal costs.

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1) See Statens Energiråd (1969) and Fagerberg (1978). Of couse these cost calculations take into consideration only techniques that are available today. Thus, in the estimation of the cost structure (4.16) technical change should and will be neglected. 2) Note that all prices are kept constant in the estimation of γ.

4.3.2. Distribution of electricity

In the distribution part of the electricity supply sector total physical power losses are regarded as inputs in the production process in addition to the inputs of labour, real capital and materials.[1)]

As in the production part input of labour and materials are assumed to be proportionate to the output volume. Between the two production factors, capital and power losses we assume substitution, since engineering studies suggest that the power losses can be reduced considerably by reinforcement or rebuilding of some parts of the distribution network. There are some indications of increasing returns to scale in the production of distribution services. Some of the construction costs may be considered as fixed also in the long run; tne marginal costs following a future increase in electricity demand may accordingly be exceeded by average costs.[2)]

Based on the above considerations the production of distribution services is described by[3)]

$$A_{XD} = f_D(B_{KD}, A_{ED}) \tag{4.18}$$

$$A_{XD} = \alpha_{LD} B_{LD} \tag{4.19}$$

$$A_{XD} = \alpha_{MD} A_{MD} \tag{4.20}$$

where A_{XD} is total output of distribution services,

B_{KD} is the input of real capital in the distribution network

A_{ED} is the input of electricity (total power losees),

B_{LD} is labour input, and

A_{MD} is input of materials (commodities other than electricity)

Assuming the f_D-function to be homothetic with a constant elasticity of scale the cost function is derived as

$$C_D = A_{XD} \left[\frac{P_{LD}}{\alpha_{LD}} + \frac{P_{MD}}{\alpha_{MD}}\right] + A_{XD}^{u} h_D(P_{KD}, P_{ED}) \tag{4.21}$$

where P_{KD} is a price index for the user costs of capital,

P_{ED} is a price index for input of electricity (power losses),

P_{LD} is a price index for the input of labour,

P_{MD} is a price index for the input of materials, and

u is a parameter

---

1) The capital input in the distribution network is not directly related to the volume of energy deliveries; like the tunnels and machines in the production part it rather determines the capacity of the supply system. However, as in the production part, the planning problem can be reduced to one dimension by the assumption of proportionality between load capacity and the volumes of distribution services.
2) Increasing returns to scale in the production of distribution services must not be confounded with the effect on production caused by changes on the demand side of the model. The coefficients of the input activities for electricity, which include both electricity and distribution services as separate commodities, vary between the various receiving sectors. Changes in the composition of electricity demand may therefore change the relation between the production of distribution services and the total volume of kWh produced. 3) In the general description below we have omitted the specification of possible factor-augmenting technical changes.

The h-function is specified as a Generalized Leontief unit cost function.

The relations explicitly specified in the MSG-E model are again the input coefficients for the production factors. As in the production part the Z-coefficients for labour and materials are defined simply as the inverse values of the corresponding α-parameters. However, due to the general formulation of the f_D-function, the Z-coefficients for the capital and electricity inputs are functions of the output level of distribution services and the prices of the two inputs.

The estimation of the input demand functions is mainly based on data drawn from electricity statistics of Norway, which provide information of labour and material costs and physical power losses. Investments in the electricity sector are subdivided in production plants and distribution network respectively; the statistics thus provide information for the calculation of B_{KD}.

The parameters of the h_D-function are estimated by the same method as described in section 4.2 for the functions for energy activity aggregates.[1] The estimation of the scale parameter μ is, as for the production of electricity, based upon engineering studies.

4.3.3. Production of other energy commodities

In addition to electricity the energy commodities of the model include crude oil (including natural gas), petrol, fuel oil and coal. Compared with the detailed and specific representation of the production structure for electricity the production of other energy commodities are, in the present version of the model, treated in a rather simple way.

For the extraction of oil, which is an important and mainly export oriented off-shore industry, both total output, (i.e. the output activity) and the input activities for materials, energy, and labour services are exogenously given. In addition gross investments are also exogenous[2]. This means that both the production level and the input structure are determined outside the model. The price of crude oil is exogenously given which implies that return on capital in the extraction of crude oil is endogenous (determined as a residual).

The production sector for the refining of crude oil is the main producer of both fuel oil and petrol. We are assuming that the two commodities are produced non-jointly, i.e. with separate production functions. By adding an assumption of separability in inputs and outputs of the production sector as a whole it is implied that the two individual production functions are identical[3]. Two additive output activities, one for each output commodity, are therefore specified. The price indices of fuel oil and petrol are set equal and determined in the way indicated by equation (4.4), i.e. as equilibrium prices.

Even though coal at present is a minor domestic product, it is, due to possible future imports for the production of electricity, given a separate treatment. The domestic production is included as a separate non-joint output activity in the mining industry. Both production and price are exogenously given. For all sectors where production is determined exogenously, import is determined as the difference between production and domestic use plus exports.

5. HOUSEHOLD CONSUMPTION

As on the production side of the model a multi-tier structure is imposed on the inputs of the household consumption sector. The individual input commodities are aggreaged into 18 activities. Once the levels of these activities are determined, the demand for each commodity can be derived from the assumption of fixed proportions within each activity. The household demand system included in the core of the MSG-E model is an approximation to a more elaborate sector model for household consumption. The

1) The user cost of capital in the distribution network is calculated in the same way as for the cost structure of the production part, i.e. by applying the rate of interest imposed on public investments and by specifying a relevant depreciation formula. The relevant price for power losses is the long term marginal cost in the production of electricity. The costs of producing an additional kWh should be balanced against the costs of reducing the power losses with a kWh by reinforcement or rebuilding of the distribution network. 2) With constant rates of depreciation the gross investment estimates determine the development of the capital stock. 3) See Hall (1973).

amount of details in the sector model makes it too cumbersome to be formally integrated in the main equation system of MSG-E. The household consumption sector model is used to estimate parameters of the approximate demand system of the main model, and when needed the two models can be run in parallell updating each other. In the first section below we shall describe the main features of the approximate demand sytem of the main model, while a brief outline of the sector model for household consumption is given in section 5.2.

5.1. The demand system of the main model

In the main model, as well as in the sector model, two concepts of total expenditure are defined. V_C^N is the national accounting concept defined as the value of commodity purchases, including durable goods. Imputed costs (interest and depreciation) are used only for housing services[1]. The other concept of total household expenditure, V_C, is equal to V_C^N except that purchases of cars, V_{Ck}^N, are deducted and imputed costs of car services (interst and depreciation) V_{Ck}, are added, i.e.

$$V_C = V_C^N - V_{Ck}^N + V_{Ck} \qquad (5.1)$$

V_{Ck} is defined as the toal "user cost" of cars, i.e. by

$$V_{Ck} = \nu_C P_{Ck}^N A_{Ck} \qquad (5.2)$$

where

A_{Ck} is the value of the stock of cars at constant values.

P_{Ck}^N is the price index of purchasing a car, and

ν_C is an annuity factor[2] inserted to transform the price of purchasing a car into user costs.

Since household consumption is a flow concept V_C is theoretically the most appropriate concept to use in the consumption model. For instance, it is more reasonable to assume direct subsitution between use of private cars and use of public transportation than between purchases of cars and use of public transportation.

In terms of V_C the budget constraint is written

$$V_C = \Sigma_j P_{Cj} A_{Cj} \qquad (j=1,\ldots,18) \qquad (5.3)$$

where

A_{Cj} is the consumer activity j[3], and

P_{Cj} denotes the price index of consumer activity j[4].

The total household expenditure, V_C, is distributed between the 18 consumer activities according to the following system of demand funstions[5]:

$$A_{Ci} = \alpha_{Ci}(\Theta_C V_C)^{\xi_{Ci}} \prod_j P_{Cj}^{\kappa_{Cij}} \qquad (i,j=1,\ldots,18) \qquad (5.4)$$

---

1) Housing services is a separate commodity produced in a separate production sector both in the national accounts and in the MSG-E model. 2) See section 4.3. 3) All consumption activities are calculated in per capita terms. 4) In accordance with (5.2) the price index P_{Ck} in (5.3) is defined as νP_{Ck}^N. 5) In the equation sytem of the model the activity "medical care" is an exogenous item. Furthermore, "foreigners' consumption in Norway" is exogenously given and distributed between the various consumer activities by constant shares. These details are omitted in the formulation above.

where

α_{Ci}, ξ_{Ci}, κ_{Cij} are parameters, and

Θ_C is an endogenous variable necessary to ensure that the demand functions are consistent with the budget constraint at any point of time ("horizontal adjustment of Engel curves").

The relations (5.3-4) may be viewed as a local approximation to an arbitrary and more complicated system of demand equations. In particular, it may be used as an approximation to the more detailed sector model of household consumption described later in this chapter.

It should be noted that if the variable Θ_C in (5.4) is equal to one, as will be the case in the base year, the parameters ξ_{Ci} and κ_{Cij} can be interpreted as total expenditure and price elasticities respectively.1) Estimates of the parameters in the equation (5.4) are provided by the sector model as the price- and income elasticities in the base year. If these parameters are treated as constants over the simulation period, the approximate demand system will be strictly consistent with the sector model only at the point of departure. However, the sector model can be used - if deemed necessary - to update the elasticities at various points in the siumlation period by inserting prices and total expenditure from the main model.

As noted above A_{Ck} estimated by the demand system (5.4) is the volume of stock of cars. To provide the link between household consumption and production and imports it is necessary to calculate the purchases (gross investments) of cars by households.

Denoting the assumed rate of depreciation for cars, δ_{Ck}, the car purchases, A^N_{Ck}, follows from

$$A^N_{Ck} = (1+\delta_{Ck})A_{Ck} - A_{Ck}(-1) \qquad (5.5)$$

where $A_{Ck}(-1)$ is the stock of cars in the previous year.

5.2. The sector model for household consumption2)

The sector model is based on the "new" approach to consumer theory where households combine commodities in consumption technology functions to produce the consumption "goods" that enter the utility function. The system of demand functions is derived by specifying the indirect utility function of the quadratic expenditure system (see Pollak and Wales (1978)). The utility function of "the representative consumer" is assumed to be separable in the consumption goods (activities and activity aggregates). Assuming that the households are minimizing costs in "producing" these consumer goods the indirect utility function is separable in the corresponding price indices.

Households are divided into eight groups according to (i) four types of dwelling and heating equipment and (ii) whether the household owns a private car or not.3) While the utility functions for the various groups of households in the sector model are assumed to be the same, the technology relations differ between groups. With this specification it is possible to include effects on aggregate demand of changes in stocks of heating and transportation equipments. While most consumption production functions are simply activities (commodities in fixed proportions, see section 3.2), two of the consumption goods, "light and heating", and "transportation", are defined as activity aggregates being produced with more flexible technologies.

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1) General expressions for price- and income elasticities at any point of time is found by differentiating the demand system (5.3-4). 2) A detailed presentation of the sector model is given in Rødseth (1979). In addition to time series observations from the national accounts, observations for the variables in sector model are drawn from various cross-section studies, including the current consumer surveys and a survey of housing conditions from 1973. 3) The model includes relations describing the distribution of households between the different groups. In later versions of the main model these relations may be integrated in the consumer demand system to facilitate the updating of the parameters.

"Electricity" (A_{CE}) and "fuels" (A_{CF}) are defined as separate activities but are assumed to be demanded by households via the "produced" activity aggregate "light and heating" (A_{CU}.) In the same way the activity aggregate "transportation" (A_{CT}) is assumed to be "produced" in the households with inputs of the two specified activities "petrol and repairs" (A_{CR}) and "public transportation" (A_{CP}), i.e.

$$A_{CU} = F_U\ (A_{CE}, A_{CF}) \tag{5.6}$$

$$A_{CT} = F_T\ (A_{CR}, A_{CP}) \tag{5.7}$$

The technology functions, which are different for each of the eight groups of private housholds, are specified as linear homogeneous CES-functions. The price indices of the two activity aggregates, A_{CU} and A_{CT}, the dual unit cost functions of (5.6) and (5.7), are then easily derived.

6. USE OF THE MODEL

The aim of the project is to design and make operational a model suited for analysing alternative energy policies. Although energy commodities have many unique features, energy production and use should not be regarded as a target by itself, but rather be deduced from more primary targets of the economy. Even if we emphasize the description of energy supply and demand the rest of the economy is therefore given a relatively disaggregated description in MSG-E. The main advantage of using MSG-E is its ability to trace out coherent and consistent alternative paths of development. If the model fails to predict the development of the toal economy, it will also fail to predict supply and demand of energy, even if energy relations are correctly represented in the model.

Studying alternative energy policies requires that actual policy instruments could be translated to model parameters. For instance, indirect taxes on electricity by user are explicitly specified in the model, which easily allows for analyses of impacts of changed electricity prices via indirect taxation. With respect to energy analyses it is adjacent to point at three possible uses of MSG-E:

i) Sector planning of the electricity sector. In the production of hydro electric power the time lag between investments and new production capacity is 4-6 years. In the short run the principal problem is to regulate demand for a given capacity. The long run problem also includes determining the growth path for the optimal capacity and the break even point between long term marginal costs in production of hydro electric power and production of electricity based on oil or coal.[1)]

ii) Demand analyses, i.e. effects of changed demand patterns of industries and households. For example the model may be used to calculate the impacts of eliminating price discrimination on electricity, thereby squeezing industries based on low price energy input.[2)] Another example could be to calculate effects of energy conservation programs imposed on the consumers.

iii) Analyses of resource allocation. Alternative energy policies would mean different allocations of labour, capital and production between industries and regions. In the model, all production factors are assumed to be freely moveable. Since both labour and capital, particularly in energy intensive industries, could be regarded as local resources, any considerable reshuffeling of labour and capital should be checked for realism.

For analyses mentioned above the relevant scope of the model would be 4-20 years, long enough to allow for changes in economic structure and short enough to assume technology roughly predictable.

1) Partial investment analyses of the hydro power sector may be found in Olsen (1977) and Rødseth (1975).
2) An analysis of this kind based on the existing MSG-model is presented in Lorentsen, Strøm and Østby (1979).

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