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A WORLD MODEL FOR THE REFINERY AND PETROCHEMICAL INDUSTRIES.

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Final report

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FINAL REPORT

INTRODUCTION : SCOPE OF THE PROJECT

This study on the issue of Industrial Cooperation between the European communities and the Arab world in the field of the refinery and petrochemical sectors was started in 1984 under the auspices of the Euro-Arab dialogue. For that purpose an econometric model was developed to be used as an instrument for scenario building. Such model is particularly interesting to obtain instantaneous revision of quantitative assessments in a world with highly volatile economic conditions such as the oil prices or the exchange rates of the main trade partners. Instead of providing a quantitative study which is out of date as soon as the environment changes, we present an instrument, a tool for the analysis of an ever changing industrial sector. We have constructed an exhaustive databank which can be updated and improved continuously within a completely consistent framework allowing all possible cross-checking and hypothesis testing. We have combined these data with economic laws and econometric measurements techniques into an operational tool for simulation. It is the purpose of this tool to be used as an auxiliary and complementary device together with the more specific and locally more precise expert judgement of the clients.

The model has been designed to assess global macroeconomic scenario's in interaction with the energy, refining and petrochemical industry. It assesses total energy requirements, evaluates the penetration of alternative energy resources, studies the role of crude oil and its supply/demand balance in the light of different price assumptions. The model treats the interaction between international trade and the oil product balance and the implications of capacity and capacity structure development for refining and petrochemical industry based on company projects (gross investments and retirement). Economics of production are described in detail using eight aggregated refinery and petrochemistry linear programming (L.P.) models for eight zones which add up to the entire world. These L.P.-models describe the fully integrated refinery and petrochemistry. They allow the calculation of demanded crude slates. They describe gas and petrochemical feedstock availability and demand.

On the basis of this model and in the light of different scenario's one will be able to show the principal areas of complementarity that may exist taking into account different production and viability factors on both sides of the Euro-Arab dialogue.

The originality of the model is that it includes a set of interdependent dynamic models describing the petrochemical sector, the refining industry, the energy market and the macroeconomic environment at the world level including trade between eight world zones. It combines linear programming models with dynamic econometric models and solves them simultaneously.

The limitations of the model are a function of the limited resources used to build such a prototype model. It is limited by its level of aggregation reflected by the number of zones, the number of products and processes and the periodicity and time horizon for its resolution. Most of these limitations are fixed by the terms of references of the study and will not be justified here.

- According to our terms of reference, the world is divided into following zones :

Arabian Countries	(AR)
Europe	(EU)
United States and Canada	(US)
Japan	(JA)
Latin America	(LA)

Socialist Countries (SO)
Far East (FE)
Rest of Arabia and Africa (RE)

The data have been collected at a national level, but the model only uses and produces variables at the aggregate level of the zones. The composition of the zones is given in appendix 1.

- Products and product groups are identified according to the terms of reference as follows :

  4 energy products : oil, gas, coal, other primary.

  7 refined products : LPG (LP), gasoline (GA), naphtha (NA), jet fuel (JF), kerosene (KE), gas oil (GO) and heavy distillate (HD).

  34 petrochemical products : Ethylene (EY), Propylene (PR), Butadiene (BU), Benzene (BE), Toluene (TO), Orthoxylene (OX), Paraxylene (PX), Hydrogen (HY), Ammonias (AM), Methanol (ME), Ethanol (EA), Ethylbenzene (EB), Styrene (ST), Ethyleneoxyde (EO), Monoethylene glycol (MG), MTBE (methyltetrabuthether, MT), Ethylenedichloride (ED), Vinyl chloridemonome (VC), Cumene (CU), Phenol (PN), Cyclohexane (CH), Acrylonitrile (AN), Dimethylterepthalate (DT), Terephtalic acid (TA), Polyethylene low density (PL), Polyethylene high density (PH), Polypropylene (PP), Polyvinylchloride (PVC, PV), Polystyrene (PS), Melamine (ML), Polyester fibers (PE), Acrilic fibers (AF), Polyamide fibers (nylons 6/6.6, PF), Synthetic rubber (BR-SBR, SR)

A number of other products are introduced to complete the cost calculation in view of the technical characteristics of the represented process. Only the products listed are treated exhaustively, and have their supply, demand and price determined endogeneously in the model.

- Econometric inference is based on a databank covering the period 1970-1982. The points 1983 and 1984 are used as a starting point for projections into the future, covering the period 1985-1992, as specified by the terms of references for the study.

The issues to be studied and the sensitivity of the model are illustrated with alternative projections. Each of these projections can be compared to a reference so as to provide multipliers. They reflect the sensitivity of the variables of the model to the change to environmental or policy instrumental variables. The reliability of these multipliers allows us to construct scenario's for the future of the industry. Furthermore, it will be essential to incorporate the client's expert judgement about environmental and policy assumptions.

Since we do not want to create the illusion that a model is able to make deterministic forecast of the future, we produce projections without fixing one of them as a reference. They all have the same status and represent alternative sets of internally consistent values of the variables projected. The actual outcome will depend on the decisions made by the governments and companies which select one out of a considerable number of possible strategies in a risky and uncertain environment. The impact and the timing of strategic moves of individual agents is obviously not simulated explicitly by the model. Only the effects from interdependence are measured.
The actual outcome will also depend on the nature, the importance and the timing of exogeneous events, such as the evolution of the war between Irak and Iran, earth quakes, technological discoveries in the field of substitutes, etc. ... These events are not explicit in the model except under the form of residuals and using hypothetical quantification.
The use of the model is therefore best suited for reflection about the effects of possible changes which would be compa-

tible with the economic laws captured in the empirical relations of the model. All results are to be interpreted in a probabilistic way and reflect only orders of magnitude.

This report contains six chapters :

I. General features of the model

II. The databank

III. The macroeconomic and energy models

IV. Construction and utilization of the Linear Programming (L.P.) production model for the refining and petrochemical industry

V. The econometric relations of the Refinery and Petrochemical Industry model

VI. Simulations and scenario's

Conclusion of the study

References

Appendix 1	List and composition of the zones
Appendix 2	List of variables of the model.
Appendix 3	List of sources and identities of the variables.
Appendix 4	List of equations and identities of the simulation routines.
Appendix 5	The copyrighted softwares and their users guides. 5.1. Laboms 5.2. SAS 5.3. TSP.

I.2. GENERAL STRUCTURE

2.1. Two interdependent models

Structural interdependence between Europe and the Arab world is represented by two models : a macroeconomic model and an industry model. Each model comprises a data bank containing all initial conditions and a complete set of estimated equations, identities and exogeneous variables covering one of the domains of economic reality. It is identified for operational and organizational purposes. However, interdependence is measured both at the level of global aggregation - the international trade cycles, the interdependent interest rate movements, the international price transmission mechanisms, etc. - and at the level of the industry - where trade flows for each product market transmit impulses from demand or from supply. Therefore interdependence is represented within each of these models. But these models also interact with each other.
Interdependence at the macroeconomic level is also sensitive to the changes of the oil prices and interdependences at the industry level are also due to common reliance on the macroeconomic environment, growth, inflation, exchange rate, wage rates, interest rates, etc. ...

The two interdependent models are organized in a number of submodels and both are linked to each other through a number of variables.

The macroeconomic model contains four submodels :

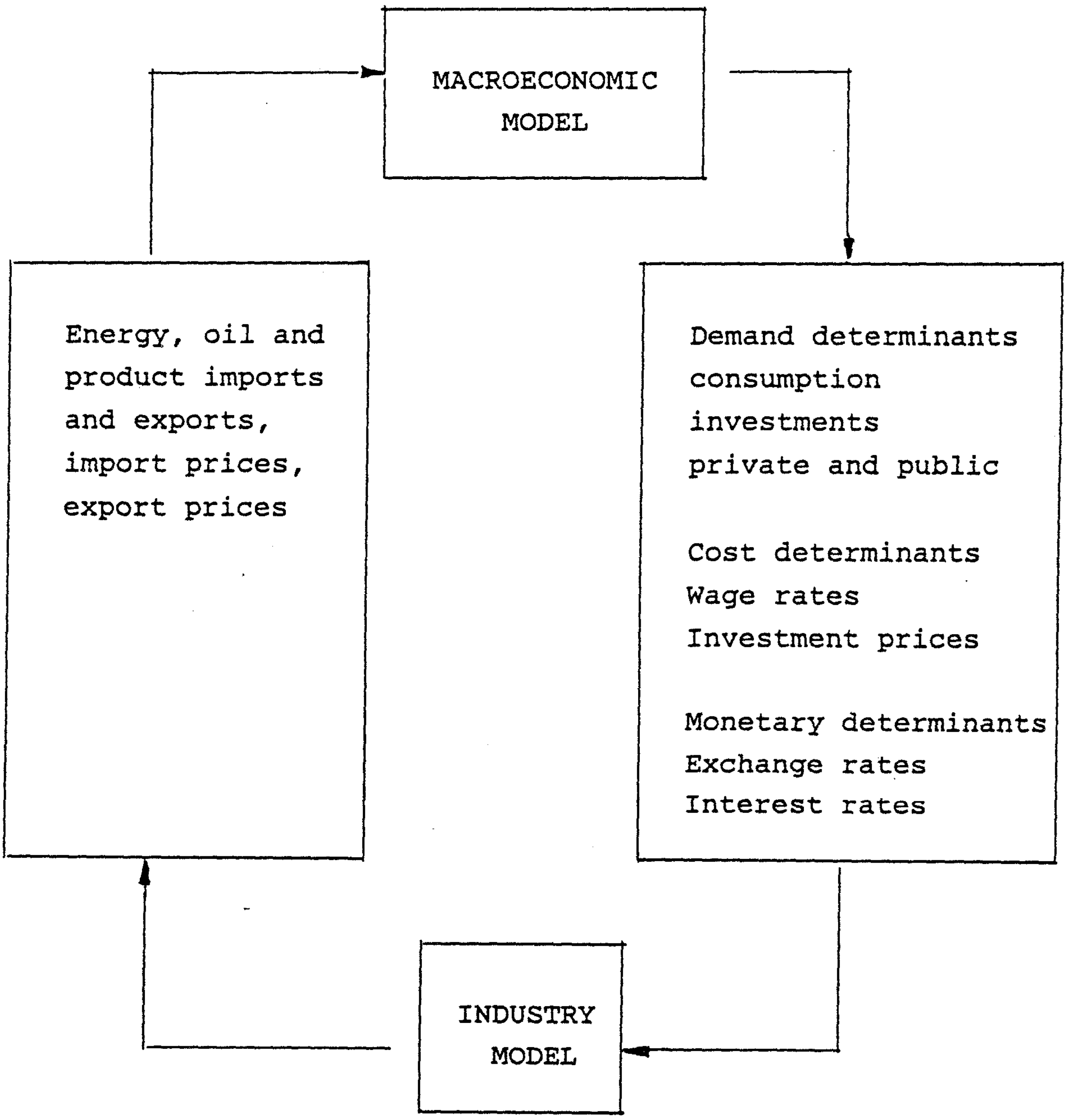
- the industrialized economies submodel describing Europe, the U.S. and Japan;
- the Arab zone macroeconomic submodel;
- the international trade submodel;
- the energy submodel.

The industry model also contains four submodels :

- the L.P. production submodel;
- the final consumption submodel;
- the submodel for the determination of prices;
- the international trade and transportation submodel.

Both models are linked through variables included in the following diagram :

FIGURE 1 : Diagram of macro-industry model linkage variables



2.2. <u>The four macroeconomic submodels</u>

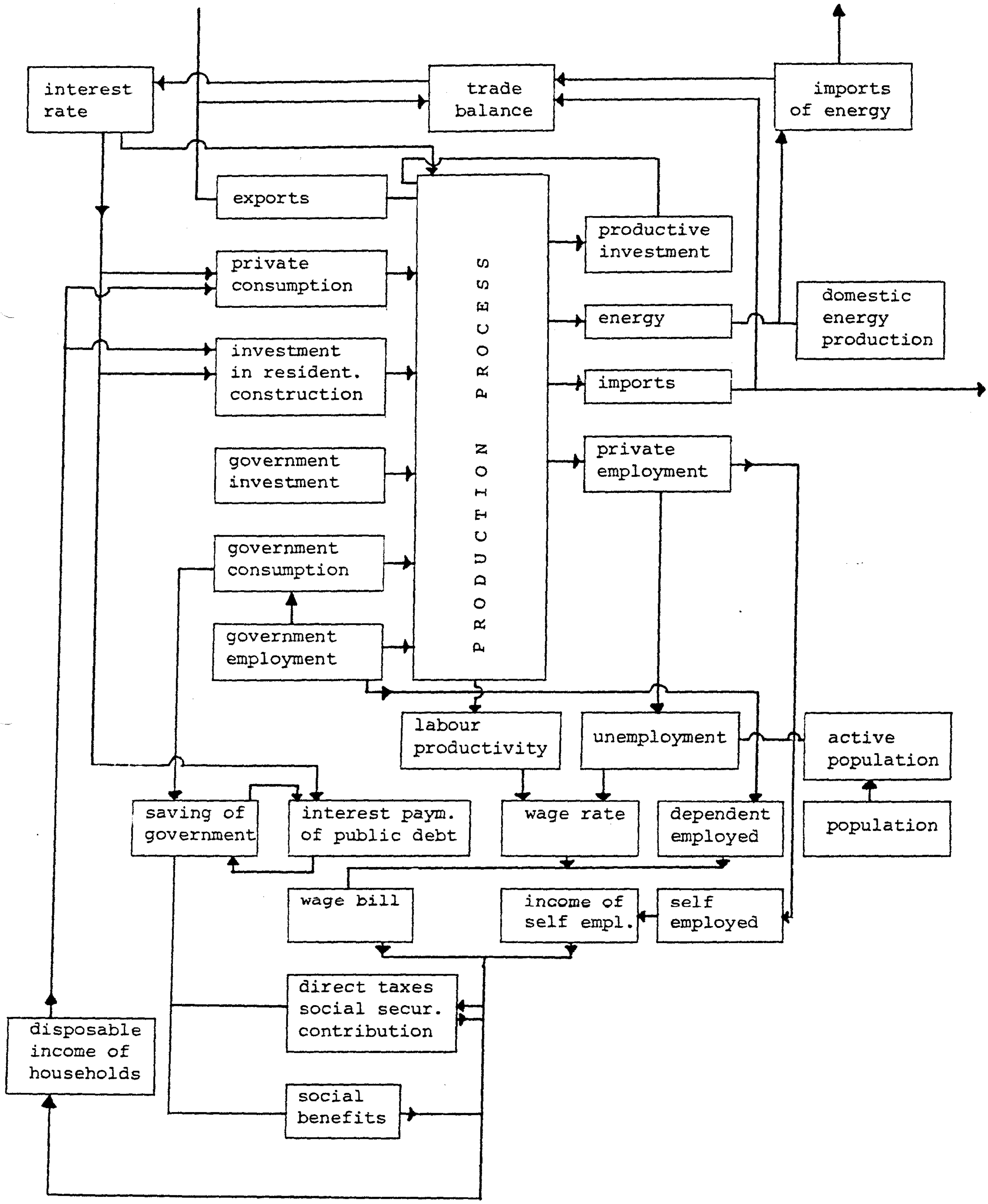
2.2.1. <u>The macroeconomic models for the advanced industrialized economies</u>

This submodel is treated on the basis of a modified COMET model.
COMET is an acronym for COmmon market MEdium Term model. The model itself, however, is not limited to the European Economic Community, but is in fact a model of the whole world. The version of COMET developed within the context of the Euro-Arab dialogue context is a condensed version of COMET since the original model comprises eleven European national economy models and two industrialized country models for the US and Japan while the present model comprises a unique condensed European zone model beside the US-Canada zone and Japan.
The detailed specification of the macroeconomic COMET model has been published in A.P. Barten, G. d'Alcantara and G. Carrin (1976), G. d'Alcantara and A. Italianer (1981), G. d'Alcantara and A.P. Barten (1984) and in a forthcoming book.

For expository purposes one can distinguish in a national economy a domestic sector and a foreign sector, which is engaged in international trade. The way the model pictures international trade is the topic of a next subsection. Here, the main lines of reasoning underlying the domestic sectors of the model are presented.

From a macroeconomic point of view one can distinguish in a national economy a demand side and a supply side. Demand for output, final demand, takes the form of consumption by the households and government and of capital formation by production units. Exports can be seen as demand by the foreign sector. The demanded output has to be produced. Macroeconomic production is the transformation of primary inputs, namely energy, imported goods, labor and capital into final demand. Supply of primary inputs and final demands depend on relative prices. If supply and demand do not coincide spontaneously, an adjustment process will be set in motion to achieve equality adjustments, part of it works by way of quantity adjustments induced by appropriate price changes. Since (primary) income is the reward of the primary inputs or production factors this income changes as the amount and price of the input changes in the adjustment process. Primary income is redistributed among agents and takes the form of disposable income which codetermines demand. This feedback may speed up adjustment or delay it. In COMET the degree of utilization of capacity (DUC) plays a pivotal role as a measure of lack of adjustment of demand and supply on the one hand and as an impulse variable causing corrective movements on the other hand. Figure 2 below shows a flowchart of the advanced industrialized country macroeconomic submodels. Never forget that flowcharts cannot be exhaustive representations of the full structure of a model. They should be used and interpreted as an illustrative introduction to its complete algebraic representation !

FIGURE 2 : Flowchart of the advanced industrialized country macroeconomic models



2.2.2. The macroeconomic model for the Arab zone

The macroeconomic model for the Arab zone has been called SMAL. This stands for Sectoral Macroeconomic model for the Arab League countries. Twenty two countries have been included in the data constructed for this aggregate model. The sources and procedures used to build these data are extensively described in chapter III.2. Complete national accounts have been obtained including very much simplified government accounts. The activity of the zone was disaggregated into the oil (including refinery and petrochemistry) and non-oil sector. Value added, employment, average labor compensation per worker, gross investment in fixed assets, imports and exports can therefore be explained at the level of each of these sectors and aggregated so as to yield the macroeconomic totals. The unit of account used for this submodel is the Arabian Currency Unit (ACU), computed as the trade weighted currency basket of the Arabian League member countries.

The model determines demand, supply and prices for the two production sectors. Simplified intermediary inputs and deliveries are made consistent within a two sector input-output scheme. Value added result from final demand and intermediary deliveries minus intermediary inputs. Final demand components, private and public consumption, gross investment in fixed assets, 95% of which is imported, and exports are explained separately. Factor demands, labor employment, capital use and total consumption of energy result from the level of production and from exogeneous productivity increases.

Fixed investments result from the decided capital stock and therefore from an acceleration mechanism. The real wage rate is related to the non-oil sector productivity and the excess supply of labor ratio. Prices are determined on the basis of cost components and import contents while the degree of capacity utilization introduces cyclical deviations due to market pressure.

The international trade aggregates in the oil sector are treated differently for imports and exports. Exports on the one hand are explained from its three components : exports of crude oil, natural gas and solid fuels, exports of refined products and exports of petrochemicals. For imports on the other hand, the three classes are explained together. The imports in the non-oil sector are sensitive to the various components of final demand, taken into account their specific import contents. They are also sensitive to relative prices and to the degree of capacity utilization.

2.2.3. The international trade-submodel and the rest of the world trade feedbacks

The international trade component constitutes the core of COMET. It provides the international linkage of the models for economies of the eight world zones. Because of this component COMET is more than a set of zone models. It is a coherent set of such models enabling one to get a sharper picture of the international economic environment conditioning national possibilities on the one hand and of the international consequences of national economic policy on the other hand.

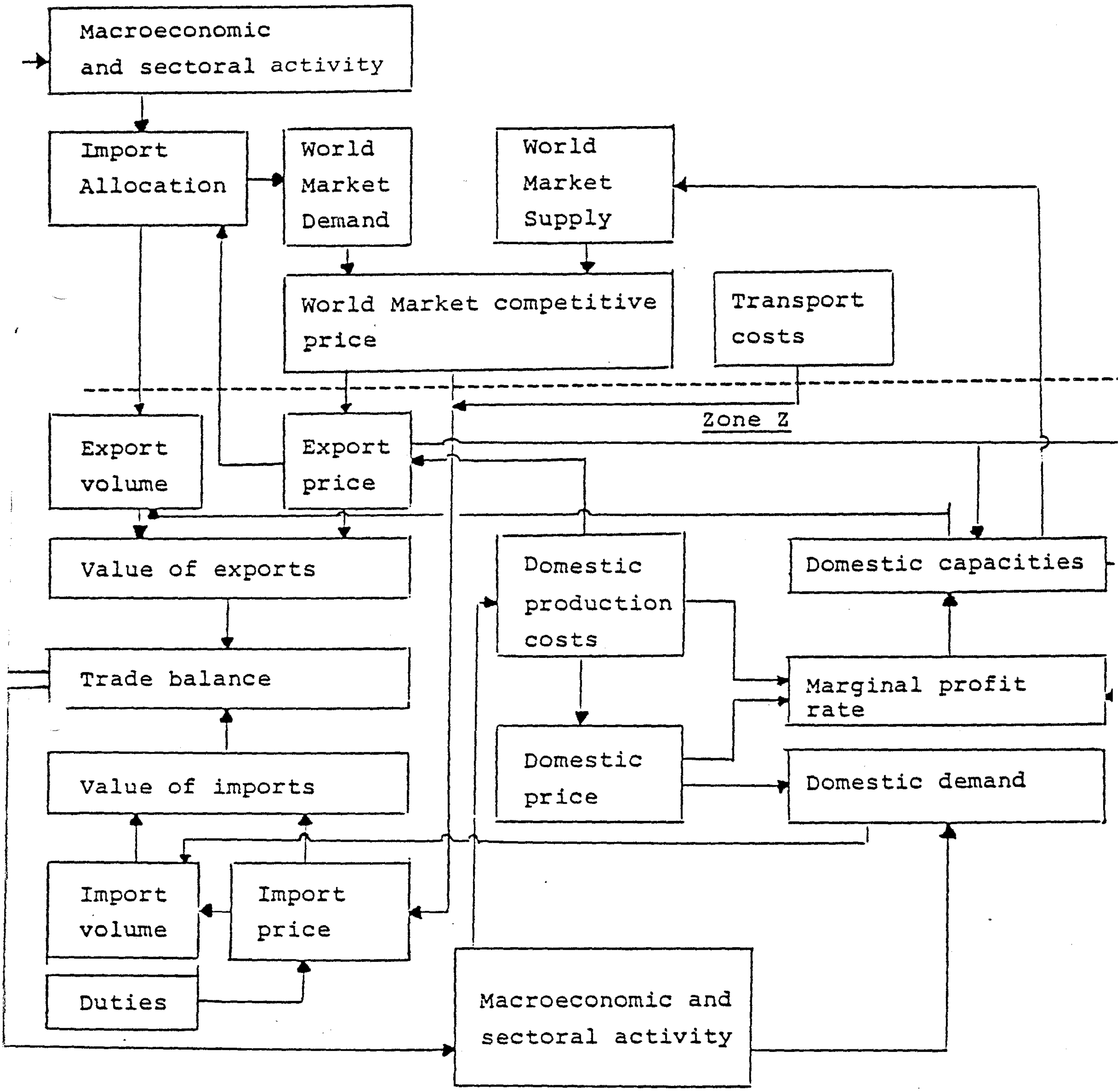
Our international trade model for each zone distinguishes 4 categories :

- trade in refinery and petrochemical products at the industry level, treated in another chapter;
- trade in services in volume and in prices at the import and at the export side but without identifying bilateral trade flows;
- trade in energy, explained in two ways : first per product (solids, natural gas, oil and other primary energy), with a simplified demand-supply balance for each zone and at the world level; second at the bilateral trade flow level. When bilateral trade flows are available, they are used to compute competitive export prices to determine export prices, together with cost determinants, and to compute import prices on the basis of weighted export prices.

The international price system of COMET is built in such a way that all import and export prices are interdependent. In addition to competitive countries, they depend on and are determined by internal cost conditions in the advanced industrialized countries; these links are conditioned by exchange rate adjustments. Note that this interdependence is not instantaneous. Because of the model dynamics, it may take several years before a single price shock is propagated through the system. Note also that it is relatively easy to introduce such exogeneous shocks, which could result from oligopolistic pricesetting behavior.

Figure 3 gives a general idea of the international trade interactions in the model.

FIGURE 3 : International trade interactions



2.2.4. The energy submodel

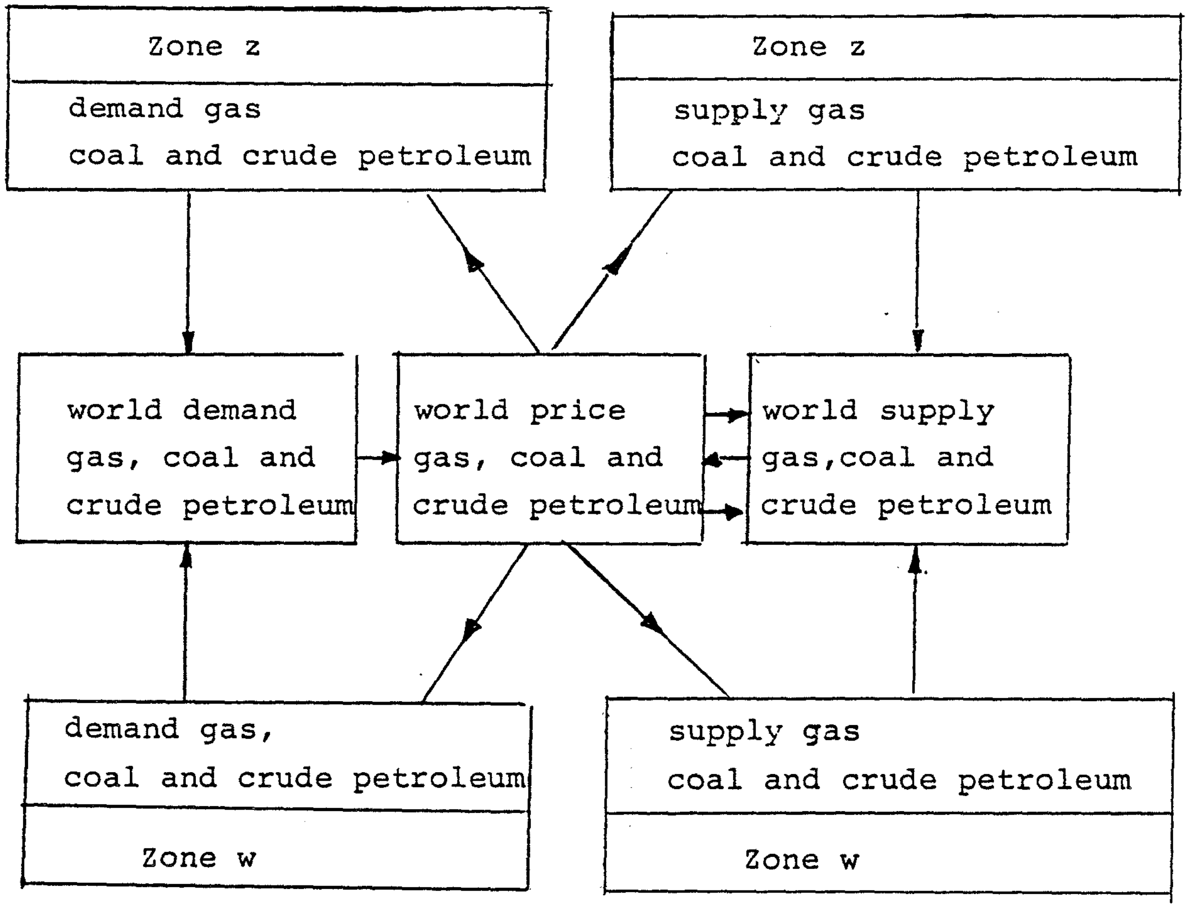
The energy model is conceived as a simplified linkage model between the macroeconomic models and the sectorial industry models. It is needed to generate energy prices which are determined as the result of an aggregated world market mechanism. Aggregate world demand and world supply for crude petroleum, coal, gas and primary electricity are used to determine long term equilibrium prices for energy under the exogeneous assumption of the oil price. These prices, consistent with the macroeconomic and international trade scenario's, are used as starting point for the pricing of feedstocks. They also enter as one of the cost components of all price indices at the macroeconomic level. Furthermore the energy production and trade generate macrofeedbacks on value added and trade balance.
The energy model is mainly seen as the interface between the macroeconomic levels and the refinery and petrochemical industry levels. It concentrates on the price of the feedstocks used in both industries namely crude, naphtha, LPG and gas-oil. These prices are determined at a world level. The products are being considered as sufficiently homogeneous and transportable to use unique reference prices as starting points. These prices have to be consistent with macroeconomic scenario's and result from demand and supply relationships for each of the eight zones, aggregated at the world scale.

The demand side of the market is modeled for each zone separately. There are two types of demands : final consumption demand and intermediate industry demand within the refining and petrochemical industries. All what is not classified in the latter will be considered to belong to the former. The demand for crude is considered to be totally absorbed by refineries and therefore results from demands for final refined products according to a material balance with given technological coefficients. The demand for energy products takes into account inter-energetic substitutions among the products identified by the model, LPG (excluding for petrochemical use), gasoline, kerosene, jet fuel, gas oil (excluding for petrochemical use), heavy distillate, coal, gas (natural) and primary electricity. Note that kerosene and jet fuel are always taken together in trade statistics so that their identification in consumption and production, demand and supply, is superfluous. These product demands are treated with a demand systems approach, i.e. a simultaneous determination of these demands taking into account allocation constraints.

At the supply side the energy model concentrates on the production of primary energy sources at the world level : crude petroleum, coal, natural gas and primary electricity. Supply of other energy products are given as the result of the industry models. Supply of crude, coal and natural gas is provisionally exogeneous but experiments are made with a function of profitability. Supply of primary electricity at the world level is held exogeneous and could also be made elastic to demand. This energy presently represents only 3 or 4 percent of the total energy resources but its importance increases in the industrialized countries.

The energy prices result from price setting practice and market clearing pressure. These prices are modelled as a dynamic process adjusting to the exogeneous crude oil price and submitted to effects from the specific product market discrepancies. The ratio of demand over supply exerts positive short run feedbacks on the prices. Figure 4 shows the worldmarket interaction of the energy submodel.

FIGURE 4 : World market interaction of the energy submodel



The trade model for energy is not a full productwise bilateral trade flow model as in the case of refinery and petrochemical products. One should note that the intra-zone imports are considered as belonging to the consumption of that zone and that the intra-zone export trade price is used as reasonable proxies for production prices for each zone.
In each zone the total import demand for energy products is allocated over the various exporting partner zones, taking into account the necessary constraints.
Total energy demand is allocated over various energy products. The demands for the specific energy forms will not be allocated individually over the export partners but rather aggregated to world demand and then allocated to exporters on the world market. Bilateral trade of aggregate energy is only used as weights in price equations.

2.3. The industry submodels

2.3.1. The representative aggregates

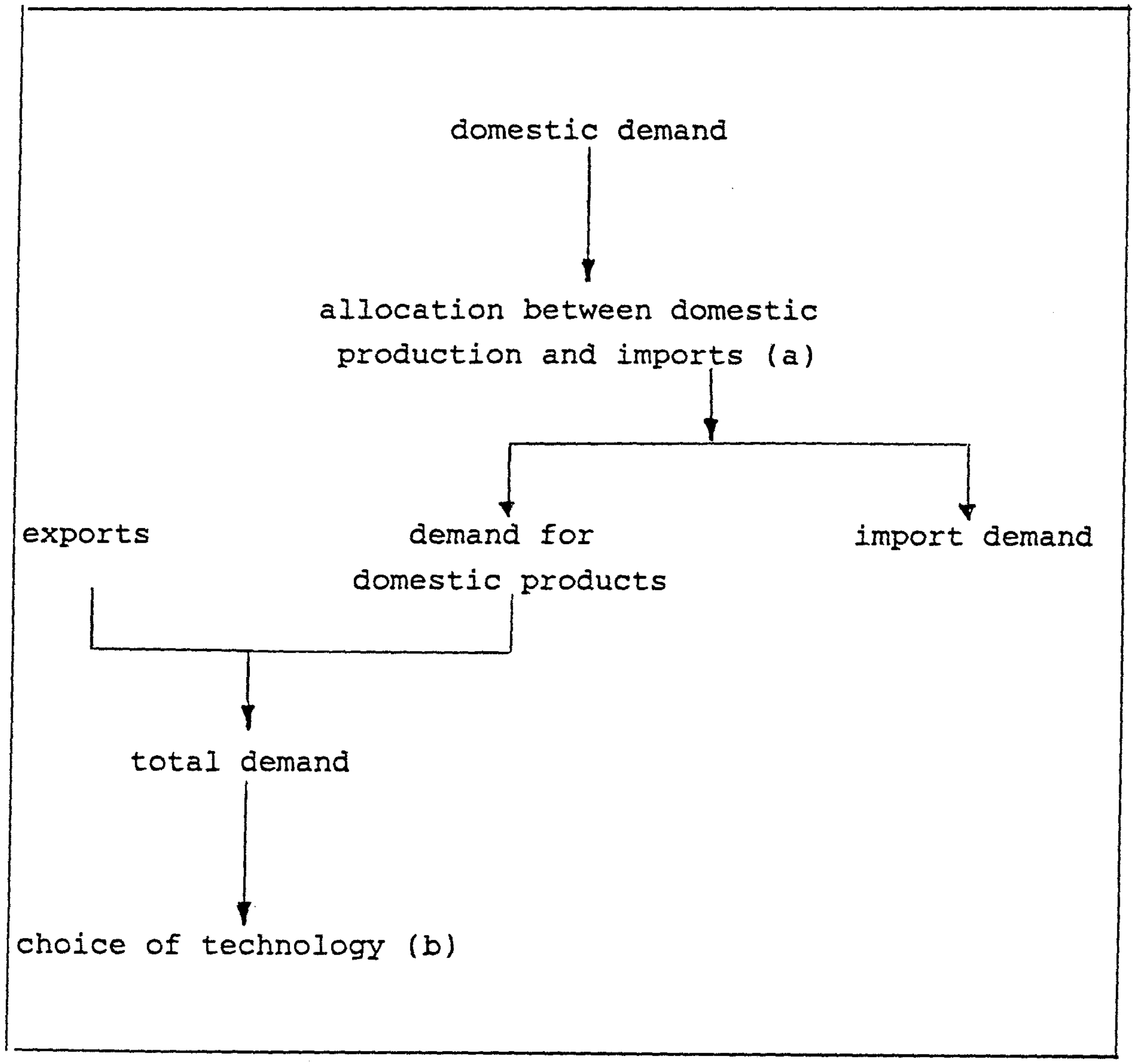
In the eight zones of the model production capacities, production and consumption for each product will be considered as aggregates. All individual consumers or producers will be replaced by one aggregate representative consumer or producer for each zone. The production capacities are aggregated per production process and the combination of all aggregates is considered as an abstract aggregate refinery or petrochemical plant. The model applies economic reasoning to the aggregate consumers or producers as if they were individual consumers and producers. This useful simplification should not leave uninterpreted problems such as for example the geographical dispersion of economic agents in a zone. Even when we assume that a commodity could be purchased all over a zone at the same domestic price, there can be a considerable variation in the import price of that commodity since the extensiveness of a zone implies that different transportation costs have to be paid when one imports the goods from the outside. In this way, variations in the relative prices show up; hence, economic agents within one zone do not necessarily make the same allocation decisions. Aggregating the solutions of the individual allocation routines may yield results which are different from those one would obtain by solving the aggregate model.

The ideal way of dealing with this fact would be the construction of different allocation models on a disaggregated level. However, restricted data availability, increasing degree of complexity and computational costs prevent us from doing so. Therefore it was useful to introduce some simplifying assumptions and to combine the deterministic L.P. procedure on the representative aggregates with probabilistic econometric relationships.

2.3.2. The allocation cycle

Economists are used to treat the economic allocation problem with econometric relationships. Since this model is a combination of contributions from economists and from engineers, it may be useful to show the allocation cycle in terms of a multi-step optimization process. Several steps of this optimization process are represented by econometric relations which have the property to smooth out the corner solutions of the L.P. model and to fit aggregate behavior better because of the dispersion of the variables observable at the micro-economic level.
In concentrating on the short term, we consider the different petrochemical and refinery markets as being demand - induced in the sense that at each stage of the production line, the level of supply is given and demand is expected to adjust to it. Schematically, this type of market behavior could be represented as in the following figure 5.

FIGURE 5 : Decomposition of market decisions



The steps (a) and (b) are not necessarily independent. One can think for instance of a producer who faces the choice of importing intermediate products or producing them himself; in this case, decisions (a) and (b) will be made simultaneously. Our stagewise representation is only for the sake of conceptual clarity.

If we consider the level of demand for petrochemical or refined end products in a given year as being determined in a first stage, demanders in each zone have to decide whether to purchase these products domestically or to import them from other zones. Naturally, an efficient allocation of domestic demand over these two possible sources following optimizing behavior will depend on the relative price of each product, e.g. domestic price versus import price. This stage is solved by the import equation.

The result of this stage consists of a demand level for domestic products, and an import demand. The latter will be channeled into international trade to which we will come back later. The former outcome - the level of demand for domestic products - is a datum the producers of the considered zone will have to take into account when determining their levels of production. Before we describe the producers behavior, it should be noted that the assumption of vertical integration is made. Therefore, the representative plants in the model are able to produce end products, as well as basics and intermediates.

In the second stage the production allocation problem is now divided into two steps. In the first step, producers will be understood to maximize their profits, given prices of outputs and production factors, and given capacities. However, the producers maximization problem is conceived as a restricted one, since the amount of end products which consumers want to purchase domestically is already determined. Therefore, producers cannot choose freely the level of local sales; what is left to their decision is the level of export supply, the amount of basic and intermediate products they wish to import and the choice of process technologies they want to use among the available capacities.

The first stage and the first production allocation problem being run, all information to solve the third stage, the import allocation problem - leading to international trade at the industry level - becomes available. On the one hand, the first stage provides us with the import demand for end products; on the other hand, import demand for basics and intermediates, together with export supplies of these three categories, are given by the production allocation for each zone. Import demands are aggregated demand, i.e. without taking their origin into account. These demands have to be allocated over the export supplies of the various foreign zones. In order to do so in an efficient way, importers are minimizing bilateral transaction costs, respecting the export supply capacities and import requirements of the eight zones. In principle this problem is similar to the one of a linear programming transportation problem, but in this model it is represented by econometric relationships. The outcome of this minimization problem is a set of optimal bilateral trade flows, for each product. Considering the flows leaving from a particular zone, one can calculate the aggregate exports of that zone. These aggregate exports calculated in the first production allocation step need not to be equal to the export supplies. In fact, the former can be interpreted as optimal supplies while the latter are the effective export supplies satisfying the world import demand.

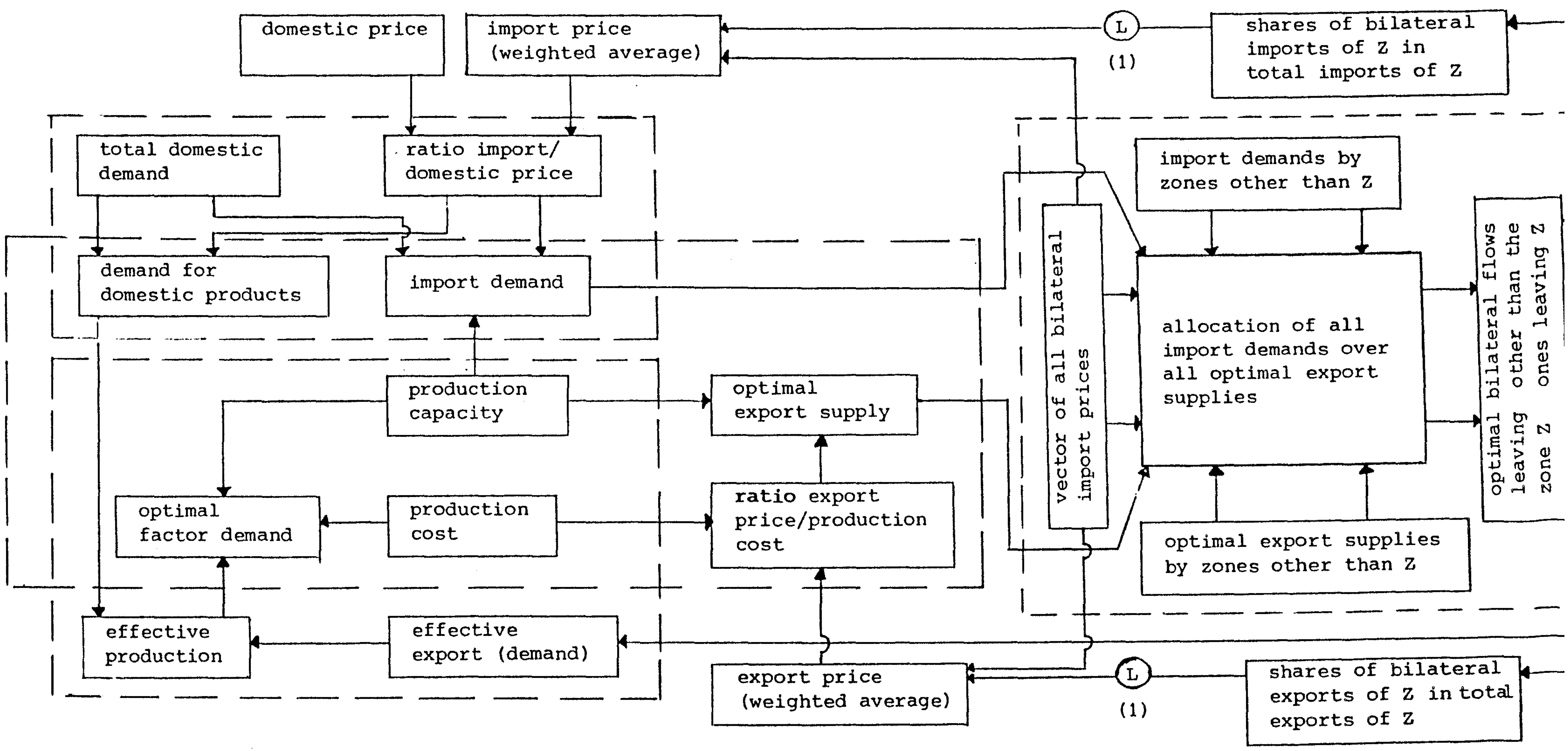
The second step of the production allocation model is now nothing more than a choice of technology. Knowing not only the level of local sales, but also the effective imports and exports, producers will have to make an efficient choice of production process utilization given the factor prices and the plant capacities, so as to minimize their costs. The outcome of this cost minimization consists of optimal factor demands, including optimal demand for refinery products which is part of the total demand for these products in a zone.

If one would specify all these optimization problems as L.P. programs and work out all simultaneous interactions including the L.P. implied price determination, one would have a model with high risk of non-convergence, high costs of operation and great difficulty of intellectual managability. Therefore it was a major task to increase the recursivity of the model by introducing dynamic mechanisms like formulate the choices using observed lagged prices, use informations like levels of marginal costs and capacity utilization, which become available at the end of the allocation cycle, to adjust current prices only partially, or introduce econometric relationships there where they can replace numerical optimization procedures.

The models discussed above, and their interactions are schematically represented (for a given year) in figure 6.

FIGURE 6 : Flowchart of the allocation cycle

ZONE Z



(1) For reasons mentionned in the text, all prices are treated as given within one year. Therefore, shares of the previous year are used as weights in the calculation of the import/export price which is a weighted average of the bilateral import prices hence the lag operation (L).

As a result of the complete cycle, which is reproduced in an iterative way by the simulation program, the determinants of the demand for petrochemicals and refined products are quantity impulses, taking into account price effects, transmitted starting from the macroeconomic activity, to final use energy and petrochemical products, then to the intermediary demand for petrochemicals, then to the demand for refined products and then to the demand for crude oil or other feedstocks. At each stage the demand is allocated over domestic and foreign demand. Effective domestic production and imports are obtained according to a demand allocation mechanisms which takes into account the relative domestic market or transfer prices and import prices. The allocation of demand of intermediary products in the refining and petrochemical sectors result from the complex interactions described by the production economics submodel. The complete technological structure of the sector will thereby be used as its results from the optimization of technological and production choices.

2.3.3. The L.P. model

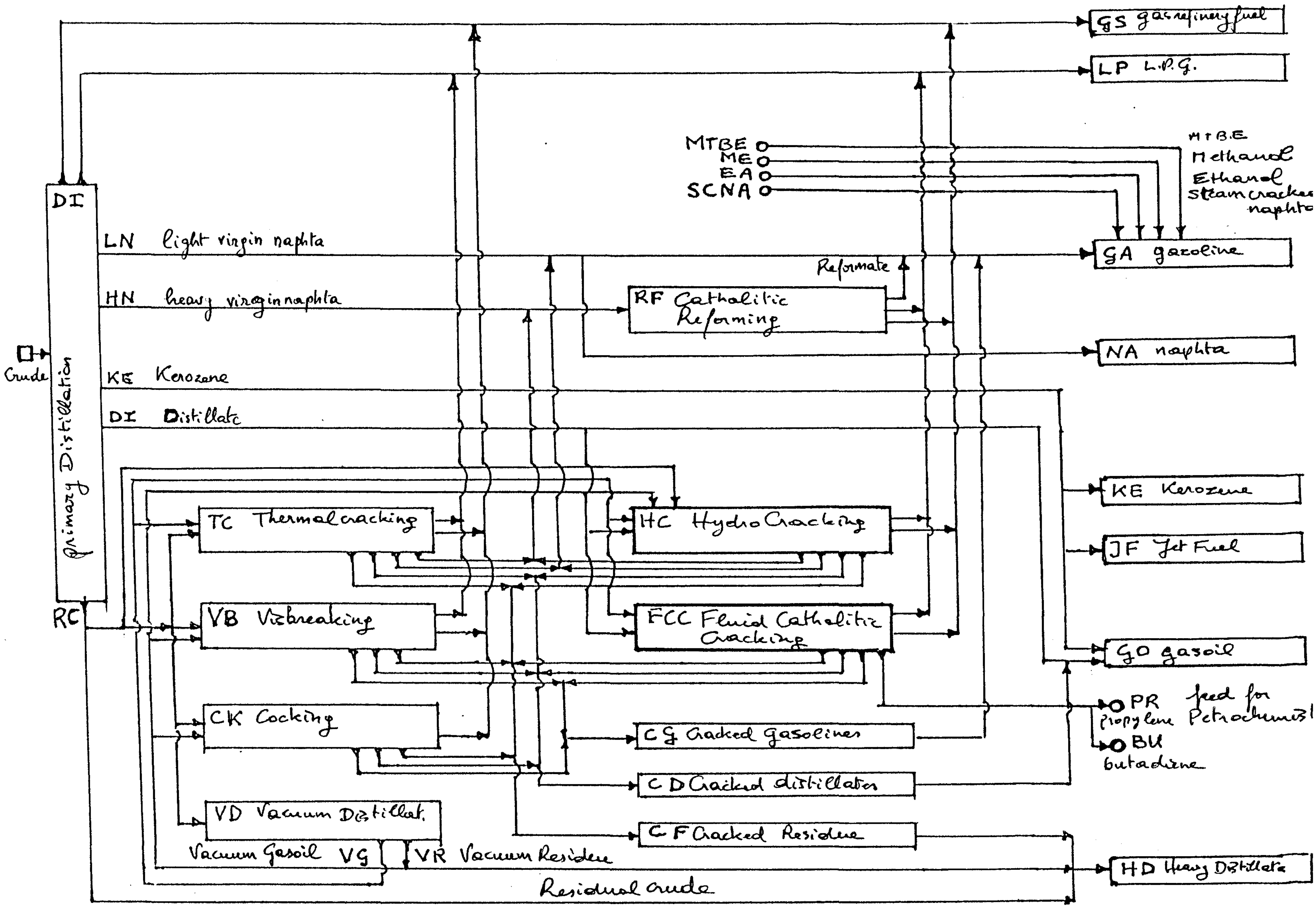
The use of an L.P. model as part of or within an econometric model is not a usual practice. It requires to be placed within the context of usual production model specifications. This model can be seen as an empirical implementation of a putty-clay or multi-input - multi-output production model. The term putty-clay implies that the choice of process technology is flexible at the time of installation and fixed when the plant is built. "Putty" refers to flexible technical coefficients ex ante and "clay" to fixed coefficients ex post. The putty-clay model explicitly describes the production process as adding new investment to capacity and scrapping old capacities. It is a vintage production model which determines the technology of each gross investment vintage as a function of expectations of capital, labor and other input prices in the long run. It determines the production capacity as a result of the installment of new capacity vin-

tages corresponding to gross investments and the scrapping behavior for old capacity vintages as a function of profitability at the extensive margin. As noted the specific restrictive assumptions of the putty-clay model are that the technological choice is open ex ante, but fixed ex post. Our model is even more general since it assumes a certain flexibility of average technological coefficients ex post as resulting from different process utilizations and severity conditions in function of the feedstock prices. "Clay" ex post therefore has to be replaced by "semi-putty". With respect to new gross investments, the choice of technologies is made among the existing more recent technologies. In theory they are a function of relative price expectations. In our model the technological coefficients of the individual processes however are given and fixed independently from prices. The selection of the process technologies in which one should invest, is done by the L.P.-program. In this way we should consider that our model is not fully "putty" ex ante. This would have implied that the technological coefficients of individual technologies would have been price sensitive, as resulting for example from research and development activities. This has not been included in this model. Only existing and known technologies can be choosen, like Linear Low Density Polyethylene, or new severities for older ones. Our model has to be qualified as a semi-putty-semi-putty production model. This type of approach is obviously much more relevant and realistic than the input-output model which can be seen as a clay-clay model, this means a fixed technology model. Our "marginal technical coefficients" which are defined as the inputs proportions per unit of output for a plant installed at a given date, result from a numerical L.P. program solution. They could have been derived from an ex ante joint output production function or cost function.
Our approach is closer to the engineering approach and differs from usual econometric models which usually determine technical coefficients by differentiating continuous cost functions. Our semi-putty-semi-putty production submodel is

the framework for the consistent derivation of production allocation, factor demand and production capacity for each product.

Figure 7 and 8 represent the flowcharts of the exact content of the L.P. models for refinery and petrochemistry respectively. The boxes represent processes. The straight lines with arrow represent the product flows and their direction. An incoming line represents feeds or inputs. An outgoing line represents exogeneous capacity or processes not represented by the model. Small circles represents modes which are connected with other producers or consumers in the model.

FIGURE 7 : Flowchart of the ref(ery L.P. model



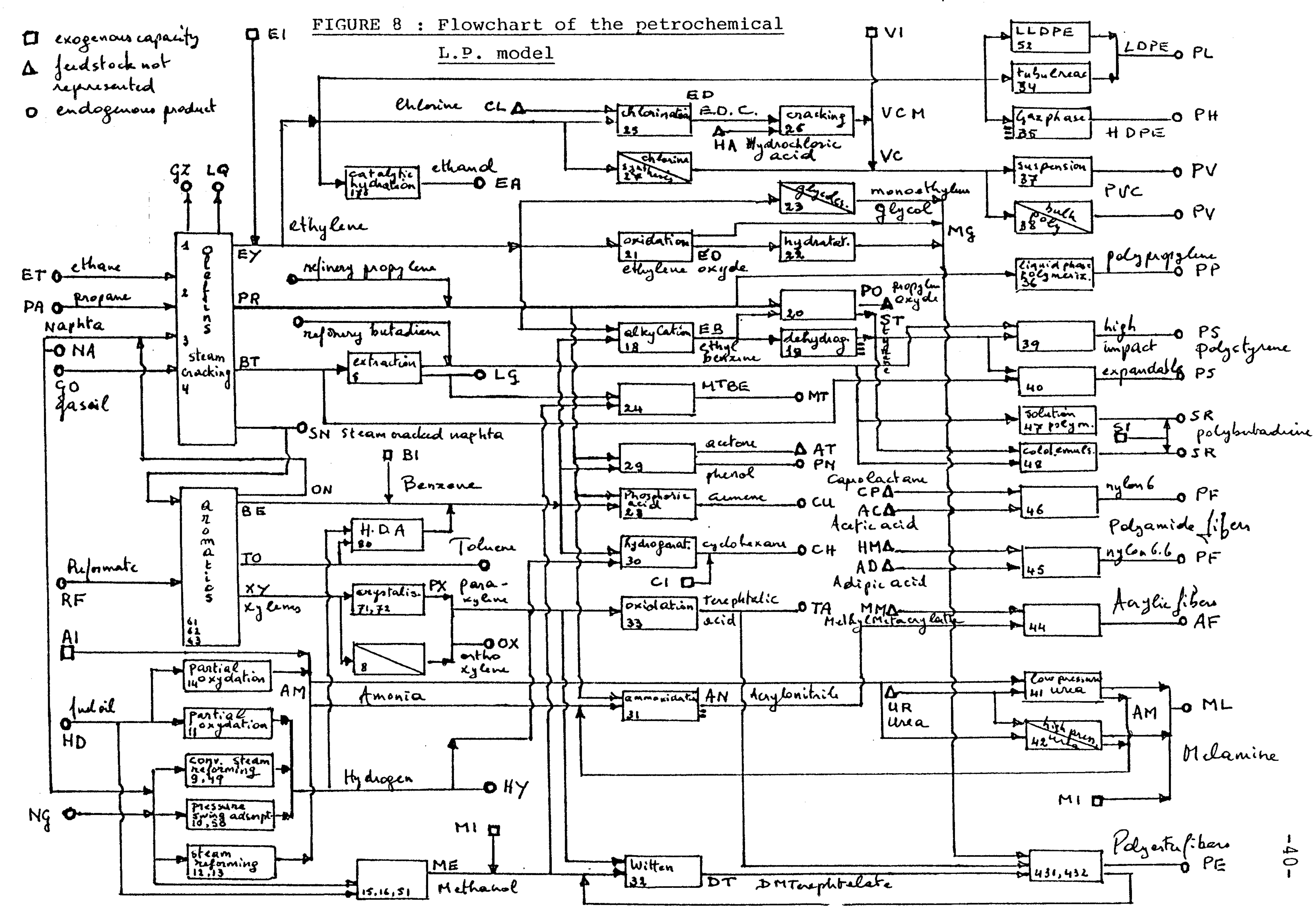


FIGURE 8 : Flowchart of the petrochemical L.P. model

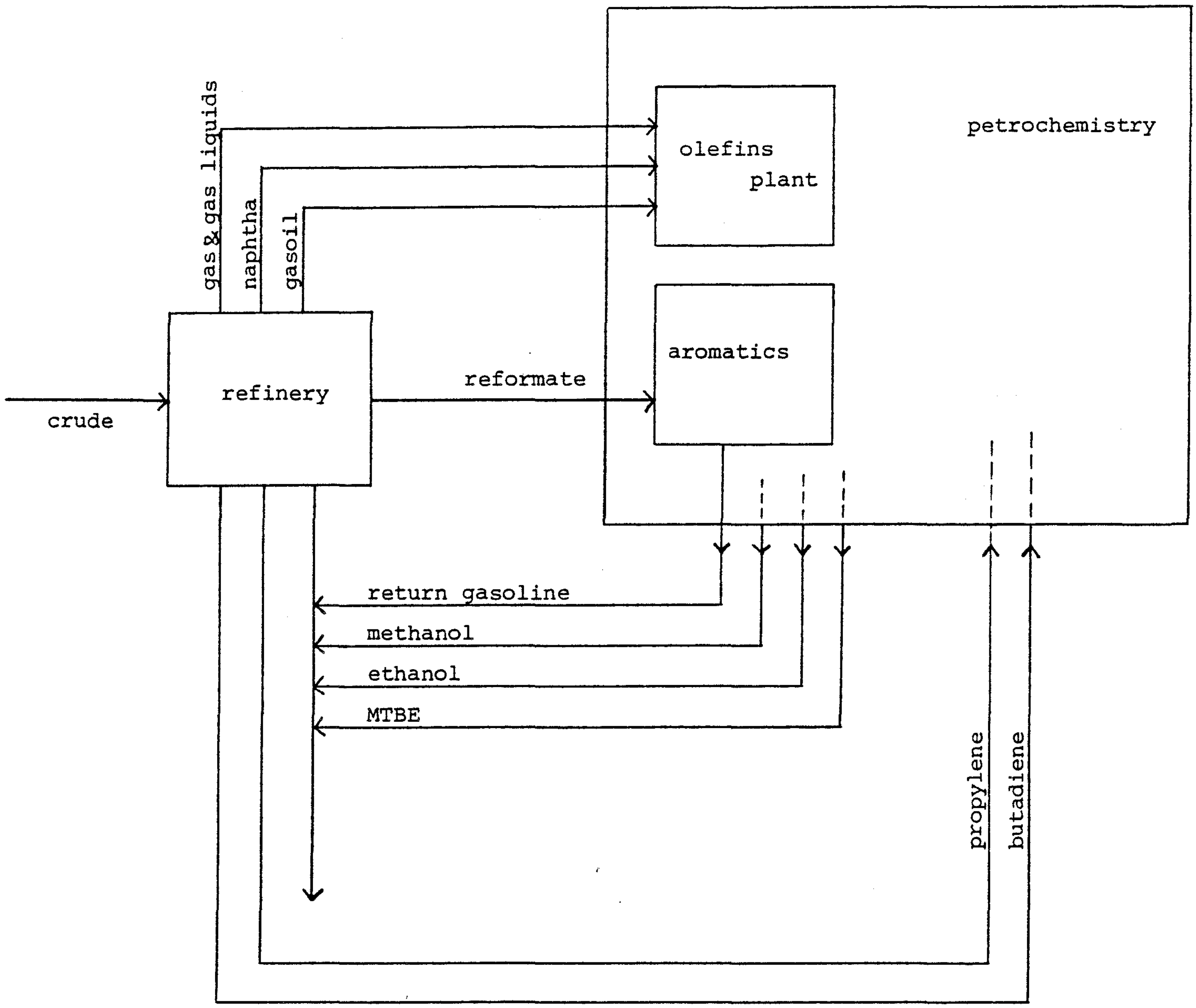
2.3.4. Integration of refinery and petrochemistry

In this model, the refinery and the petrochemical industries are treated as an integrated industry. They are represented together within a complete L.P. programming model allowing to describe the complete production economies.
The interdependence between the refinery model and the petrochemical model are :

- the refinery supplies part of the petrochemical feedstock,
  i.e.
  - gas and gas liquid;
  - naphtha;
  - gasoil;
  - reformate;
- the petrochemical plants supply blending components for the refinery,
  - return gasoline;
  - methanol;
  - ethanol;
  - MTBE;
- petrochemical intermediates can be produced ex refinery,
  - refinery propylene from catcracking effluent;
  - butadiene from dehydrogenation of butylenes.

This can be seen from figure 9 which follows.

FIGURE 9 : Interdependences between refinery and petrochemical industries



Due to the fact that there are these interrelationships between refinery streams and petrochemical streams, joint L.P. modelling handles these interrelationships.
When the petrochemical model is run, the marginal costs and not the market-prices for all feedstocks determine the requirements of refinery feedcomponents for petrochemistry. This is also applicable for propylene and butylene.
The production of return gasoline as a byproduct is automatically deducted from the gasoline market in the refinery model.
A more difficult problem is methanol and ethanol. These are basic petrochemicals and their market depends on the economic incentive to blend those in the gasolines especially with the trend to produce loadfree gasoline. To solve this problem, a detailed gasoline blending model would be necessary and this is not in the scope of this study.
A possible but rough approach would be to take a timewise increasing % of methanol, ethanol and MTBE in the gasolines, resulting in additional product demands for those products.

The total gasoline requirement in the refinery production is calculated as follows :

- the total market in each zone is known;
- on this market, a % is applied to calculate the quantities of methanol, ethanol, MTBE; these quantities are used in the petrochemical model;
- the petrochemical model calculates the quantity of return gasoline;
- gasoline produced by refinery = total market - methanol - ethanol - MTBE - return gasoline.

2.3.5. Consumption

Consumption of end products and final consumption in general, including consumption due to processes which are not represented by the model, is the final driving force for the level of activity of the whole industry. This consumption

is a relatively simple dynamic function of macroeconomic demand and a relative price.
Any element from expert knowledge which can improve the projection of short-term or medium-term development of this consumption conditional upon a general macroeconomic projection, can and has to be included through the residual structure of the consumption equations.
It is clear that the quality of the demand projections is crucial with respect to the issues of the Euro-Arab dialogue.

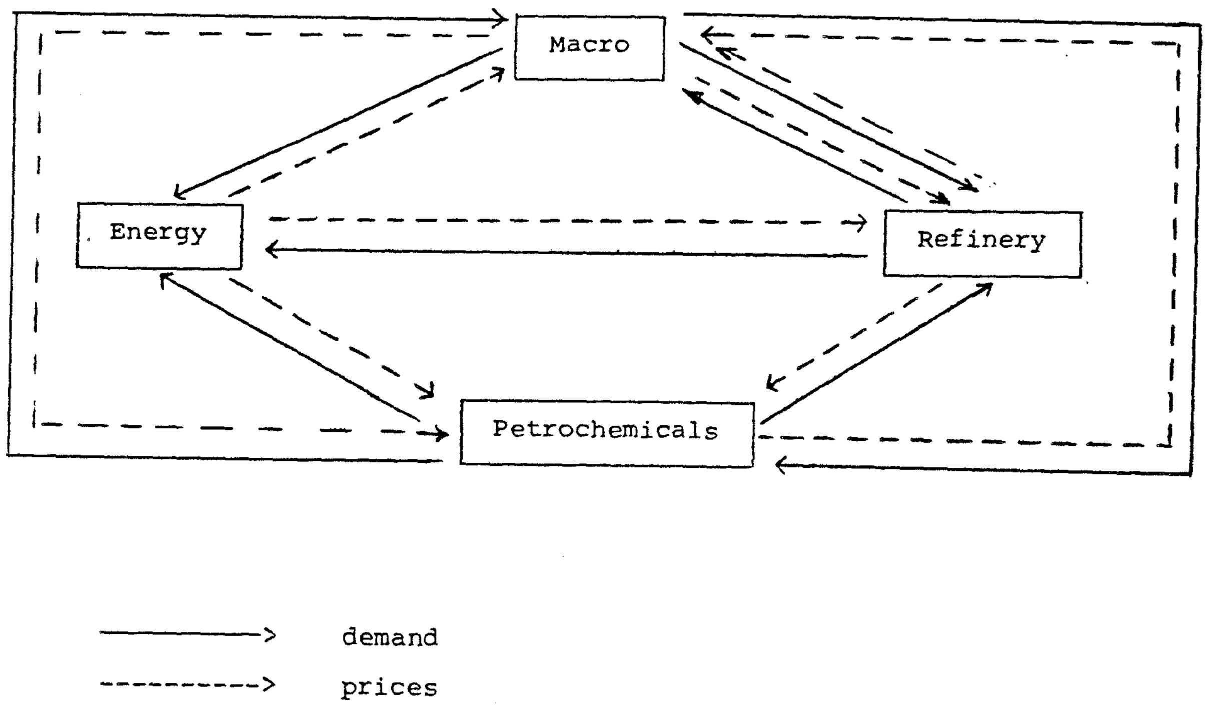
2.3.6. Prices

Broadly speaking the price determination submodel follows the sequence starting from the macroeconomic prices, wages and exchange rates and from the crude oil and energy prices which are transmitted to the refined products and consequently to the petrochemicals.

The price determination for the refined and petrochemical products follow an theoretical pricing rule and an error correction mechanism taking into account market structure and transfer prices. Both marginal costs and fixed costs, determined under a given cost allocation rule for the joint output model are taken into account. Cost conditions which are crucial for the computation of transfer prices, are directly related to the optimal technologies resulting from the production economics. The effective domestic prices are adjusting towards these costs taking into account mark-ups. The export prices in addition includes the competitive export price when the zone behaves as a price taker on the international market. They also fluctuate according to the market clearing process which is represented by the degree of capacity utilization.

Figure 10 below shows in a flowchart how the main price transmission and the main quantitative demand impulses are channeled through the main submodels.

FIGURE 10 : Dominating price and quantity interactions between submodels



2.3.7. International trade

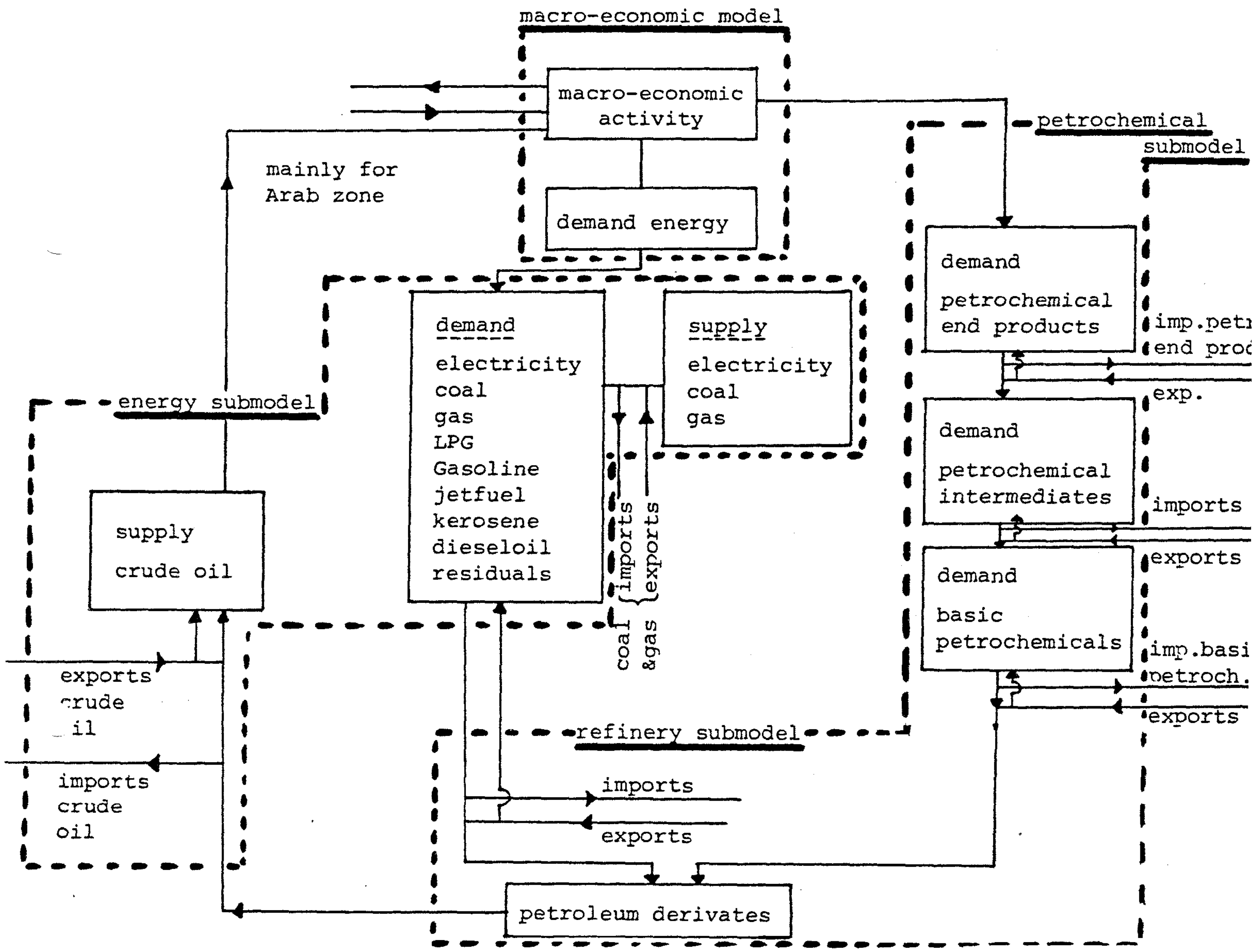
The international trade submodel is crucial because it is the key to the interdependence of the OAPEC and European economies. The most appropriate model approach has been used which determines demand and supply of each product in a bilateral trade relationship between each pair of zones identified in the model. Total imports are first determined from an econometric relation, revised according to production economic conditions in the L.P., and then allocated to the different exporters. The total export volumes are then obtained as a simple identity from the bilateral trade flows. One important feature of this model is that bilateral import and export volumes add up to the total import and export volumes. For the trade prices, one starts from the export price equations and derives the import prices as a weighted sum of export prices where the weights are given by the bilateral imports. In practice full bilateral trade flow models for the 7 refined products and 34 petrochemicals are included for the 57 bilateral trade flows.

2.3.8. Flowchart of the interdependence between the macroeconomic and the industry models

In the preceding subsections the fields covered by the submodels were described. The relationships between the different submodels and between the zones are visualized in the flowcharts of figures 11 and 12.

Flowcharts should by no way be seen as complete representations of the models but rather as partial illustrations of important relationships.

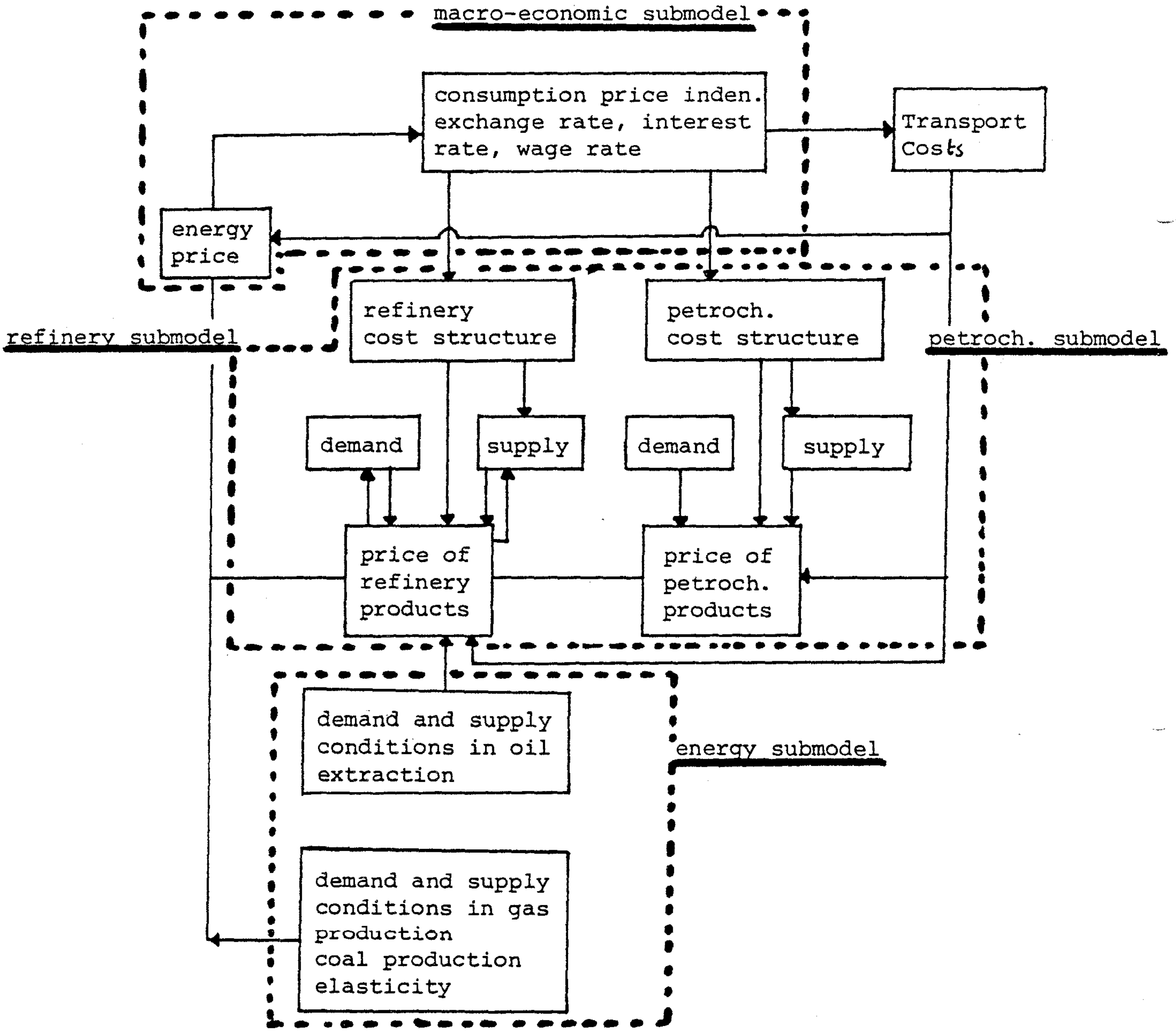
FIGURE 11 : Flowchart of the quantity interactions of the levels



→ represents the direction of causal relation and impulses

Demand = Consumption + Exports
Supply = Capacities + Imports

FIGURE 12 : Flowchart of the price interactions of the levels



costs = short and long term input and factor prices and marginal technical coefficients