HERMES:
Harmonised Econometric Research for Modelling Economic Systems

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Chapter 1

INTRODUCTION

E. DONNI, P. VALETTE and P. ZAGAME

This book features the 'HERMES' European system of models which was set up at the initiative of the Commission of the European Communities (Directorate-General for Science, Research and Development).

What it involves is a series of medium term, macrosectoral econometric models in which energy plays a special role as a production factor.

The different models are interlinked by a bilateral flow module, which describes for each product the trade between all the Community countries taken in twos. The United States, Japan and five zones are represented in this by simplified versions of the Commission's COMET model.

The original aspect of this arrangement is that the models have been developed in each of the Community countries and that use of the system is either decentralised (by each team) or centralised (by the Commission). Despite the high costs involved, it was essential for models to be developed and used by institutes already well versed in economic studies and forecasts in their countries and with very good knowledge of factual data and the peculiarities of each economy. This thus led to a veritable HERMES network of 12 institutes using harmonised data and relatively close analysis instruments for their work, which greatly facilitates dialogue, exchange and co-operation at European level. The downside of it all is that each party wanted to make its mark and that the final result differs somewhat from the initial project's aim of constructing perfect model 'twins'.

Although the results are not completely harmonised and the various models show the specific nature of each institute, this diversity, while sometimes complicating the task of the reader to a certain degree, is enriching once it is controlled.

Being designed at the time of the second energy crisis when economies were governed more by Keynesian principles, the HERMES system is now widely used in a radically different context. Its success has largely outstripped the framework of the initial national institutes, since numerous other users have joined in the work of forecasting and variant simulation. The HERMES operation can be quoted as an example of a successful meeting of scientific development and economic reality: the series of models became operational with the evaluation of the Single European Market.

The studies presented are those which have been incorporated into the models currently used. A system such as HERMES must, of course, be constantly updated and reappraised to take account of new data, but now it is in a veritable state of flux and is once again open to change in certain mechanisms which no longer seem to fit in with the scientific and factual context: enlargement of offer properties, better integration of certain financial variables, etc. We shall not be presenting studies which are still at the research stage.

However, in the form in which it is already in the reader will have a useful publication which will help him better to understand and interpret the numerous studies which have been undertaken with the help of the HERMES system. But that is not all: economists and researchers will find valuable information and figures, with a common nomenclature, on the economies of the different countries, both on structural data and on economic operators. This could be the point of departure for fruitful research on comparative European economics: we had so little time to start interpretation work that everything remains to be done in this field.

Chapter 2

HISTORY AND PERSPECTIVE OF THE HERMES PROJECT

E. DONNI and P. VALETTE

The energy problem has modified the economic relationship between the countries and economic zones in the world. Moreover, it has to be seen against the background of the structural changes that result from demographic pressure in the less developed countries, the evolution of lifestyles in the advanced industrialised societies, the relocalisation of industrial activities in the third world and the accelerated introduction of new technologies. Both the effects of the energy sub-system on the structure of the economy (relative prices, technology, factor substitution, balance of payments, exchange rates, investments) and the consequences of the structural shifts in the economy on the energy sub-system are of major interest to the policy maker.

In view of studying these structural mutations under the economic aspect, it was proposed by the Commission of the CEC (Directorate-General for Science, Research and Development) to create an integrated European quantitative instrument centred on the interaction between energy and economy. This project started in 1981. A dynamic econometric model was designed which could assess the relationship between the medium term economic performance, the structural shifts in the main branches of the economies and the energy sub-systems of the Member States. This model, the HERMES model, was conceived as an operational tool to be used by the Commission and by the Member countries. It must produce controlled projection of the future and contrasted simulations defined from alternative assumptions about the world environment and economic and energy policies.

The HERMES model combines the basic philosophy of three models at different levels: a multinational macroeconomic model (like COMET, as described in A. Barten *et al* [1], or as DESMOS-EURECA constructed by A. Dramais [2]), a macrosectoral model (like DMS described in D. Fouquet *et al* [3] or SERENA, described in G. d'Alcantara [4]) and an energy sub-model focusing on the interactions between the economic and the energy systems (interfuel substitutions model following a specification introduced by L. Christensen, D. Jorgenson and L. Lau [5]).

The project is oriented towards a balanced treatment of the economy on the one hand and energy on the other hand. The economy is described at a sufficient level of disaggregation to allow the measurement of specific sectoral effects which are macroeconomically significant and permit a sufficiently refined treatment of the energy problem. The model provided quantitative answers to a large number of questions which could not be answered otherwise because of the complexity, the dynamics, the simultaneity and the non-linearities of the international economic system.

Each national model was constructed by a team of economists and econometricians in the corresponding Member States. The list of those different research teams is the following:

Belgium	Bureau du Plan (Brussels)
Denmark	Riso National Laboratory (Roskilde)
Spain	Universidad Alcala de Henares - CEPREDE (Madrid)
France	Chambre de Commerce et d'Industrie de Paris, Ecole Centrale (Paris)
Greece	NTUA, KEPE (Athens)
Ireland	Economic and Social Research Institute (Dublin)
Italy	PROMETEIA (Bologna)
Luxembourg	STATEC (Luxembourg)
Netherlands	Stichting voor Economische Onderzoek University of Amsterdam (Amsterdam)
Portugal	Universidade Católica Portuguesa (Lisbon)
Germany	IFO (Munich)
United Kingdom	Cambridge Econometrics (Cambridge)

These different teams collaborate in developing and using the European HERMES model. They form the 'HERMES Club'.

In spite of this decentralisation, the same structure of equations and data was respected by all national teams. This point constitutes an originality of the project compared with projects of linking existing or different national models like the LINK project. Even although in a first stage, sufficient flexibility was asked by the national model builders to experiment with different specifications, it has been realised that there were great benefits in agreeing on the common structure and specifications of the models. The common structure has favoured good communication between the different countries. This has imposed a stimulating constraint upon the model builder (the structural specification requires to be conceived at a sufficiently high level of generality). And finally, it has allowed a complex instrument to be kept under control at the stage of model construction by the model builders but also at the stage of managing the model during its whole lifetime.

An important investment in data collection was necessary at the beginning of the project. The statistical concepts and the data were as much as possible in line with the data and concepts defined at the Statistical Office of Luxembourg. At this level, the task of the national teams consisted in completing that database with national sources. The second phase, the estimation of the behaviourial equations of the models, and third phase, the simulation of the model (residual check, static and dynamic simulations) have produced a set of fully operational models which have been used in many studies since 1985 (for the first available model).

In this chapter, we shall not comment on the studies realised individually by each national team. They are too numerous. We shall only examine the exercises executed at a multinational level by the Commission in co-operation with national teams. These studies have approached fields very differently thus proving the large capabilities of the HERMES models.

To complete the historical record of HERMES, it remains to describe, in a few words, these different studies. The chronological order will be respected.

The Consequences of Oil Price Decreases (1986)[6]:

This study had the aim of answering questions about the oil prices decrease of 1986. In terms of the HERMES model, the oil prices decrease has had the following effects:

- a substitution effect in the household consumption functions and between the production factors in the production function;
- a revenue effect which depends on the manner of distribution between firms, households and public administration of the gains obtained on the rest of the world (oil producers).

The Convergence of the VAT Rates in the Community (1987 [7]*:*

This study describes the macroeconomic effects of the convergence of VAT for the European economies. This convergence has the following impacts in the models: price modifications in the consumption functions and structural modifications in the household consumption, revenue effects via consumption prices modifications, revenue transfer between households and public administration and finally competitiveness effects.

Alternative Financing for the Social Security Budget (1987) [8]*:*

The questions examined here were to compare different financing measures for the social security budget in the long term (social security contributions proportional to the wages but with alternative tax rates on employees and employers, social security contributions proportional to the firms value added, ...)

The Completion of the Internal Market (1988):

This topic is described in detail in another chapter of this book.

Reduction/Reorganisation of the Working Time (1988) [9]*:*

The HERMES model was useful to examine the consequences of the reduction/reorganisation of the working time (decrease in the working time but, due to a new organisation of the working teams, increases in the utilisation rate of production capacity) in an international context. The conclusion of the study was that macroeconomic advantages exist to that policy and that they are added to the microeconomic interests for the wage earners. The reduction/reorganisation processes improve the global macroeconomic situation and have positive impacts on the major aggregates: GDP, employment, prices, public and trade balance. This policy can also be a good complement for the internal market completion in the sense that it attenuates the initial negative effect on employment observed in the internal market simulations.

1992 – The Environmental Dimension (1989) [10]*:*

In order to evaluate the macroeconomic impacts of the completion of the internal market on the environment, a quantitative analysis with HERMES has been undertaken. The purpose of this analysis was to estimate the macro feedback effects caused by an increase, equal to 1% of GDP, in investments in the protection of the environment. The specific objectives were as follows: to evaluate the macroeconomic impact of the increase in emission-reducing investment and to evaluate the possibilities given by the completion of the internal market (more growth, gain in benefits) to finance the investment in prevention or abatement of pollution. The main macroeconomic effects include impacts on:

- private investment which is influenced by increases in pollution control requirements, changes in the GDP, ...;
- level of wages and prices, due to environmental costs;
- imports and exports which will also be affected by changes in pollution control expenditures in other Member States.

The results depend on the way investment is financed. Four types of financing were distinguished: increase in firms' indebtedness, price increases, crowding out effects, government financing.

The results show that our European economies can, in the short and medium term, support a major effort to guarantee the environmental conditions for sustainable development. And there is no evidence that expenditure at this level for the implementation of environmental policies would offset the benefits of the internal market at macro level.

Taxes on Energy as a Way to Reduce CO_2 Emissions (1990) [11]*:*

This work deals with energy and macroeconomic impacts of a tax increase on energy as a means to reduce CO_2 emissions. The study covered four countries (Germany, France, Italy and United Kingdom) and it was extended to the description of the accompanying measures which could be implemented to increase the efficiency of the tax, in particular:

- emissions reduction measures, i.e. energy consumption reduction measures (since for the present technological state of the art, the reduction of CO_2 emissions related to energy can only be achieved by a reduction in consumption, other than by fuel switching);
- general economic measures with an impact on growth, competitiveness, employment, … .

In that study, no distinction has been established between the different energy sources and it is the impact of a general tax equally applicable to all energy products which is analysed. The magnitude of the shock considered in the study was enough to produce 'significant' behaviour reactions. A tax of 20% on the energy prices was considered. A tax of this magnitude on its own does not spontaneously lead to considerable energy savings or substitution. Nevertheless, this results in a tax revenue which, for some countries, can reach 1.5% of GDP. This spontaneously induces a recession spiral with immediate and damaging impacts on production and employment. So, it was necessary to simulate accompanying measures where the administration will be expending the increased resources brought by the energy tax.

In a first stage, no accompanying measures have been considered and only the effects of increased taxation have been analysed. This allowed to study the adaptation behaviour of the economic agents faced with new energy prices and to evaluate the revenue effects, the substitution effects and the energy intensity change. On the other hand, macroeconomic consequences were also evaluated in terms of inflation, competitiveness, employment, budgetary surplus, … . Accompanying measures, i.e. the redistribution of the budget surplus, were considered in a second stage. Two possibilities were retained: subsidies which induce a more voluntary behaviour in terms of emission reduction and which can be focused on actions introducing new energy savings; and tax deductions assigned to the households (income tax of individuals) or to firms. In this last case different possibilities have been considered: a deduction of the general corporate tax of the firm and a reduction in the social contributions of the employers to encourage the utilisation of a production factor (labour).

Impact of New Information Technologies on Employment (1990) [12]:

The HERMES tasks in this research can be summarised as follows. Two long term macroeconomic solutions characterised by two polarised

hypotheses centred around development in Eastern Europe's economies were developed for the HERMES system limited to France, Germany, United Kingdom and Italy. These simulations were adopted as guidelines for sectoral forecasts. At the same time, a team of consultants was involved in assessing – by means of interviews with experts and sector operators and by questionnaires – the plausible range of diffusion in information and communication technologies and its main sectoral impacts on the capital output ratio, labour productivity and international competition. This information was then translated in terms of HERMES branches (investment, transport and communication, services branches) and used as exogenous input for a series of information and communication technologies scenarios: simulations which attempt to evaluate a range of possible impacts of new information technologies on future employment and on macroeconomic activity. In this way, HERMES represents a formal macroeconomic framework capable of ensuring consistency between results of special studies on phenomena that are usually analysed independently.

The aim of this research was particularly ambitious because the attempt to assess the macroeconomic consequences of alternative new technologies' diffusion rates requires important modifications in the mechanisms of the HERMES models. There are supply side effects (changes in labour and capital productivity, in intermediate inputs composition) demand effects (changes in consumer tastes because of new products, modifications in lifestyles, …) and foreign trade effects (changes in competitiveness).

Role of the Community Structural Fund (1990) [13]:

This study was first devoted to the Irish economy. It will be extended to other countries profiting by the European Structural Funds (Spain, Portugal, Greece). These Community Structural Funds have been evaluated as an aggregate in terms of how they will influence the evolution of the entire macroeconomy, where economy-wide feedbacks are allowed to take place. There are three main channels through which the Community Structural Funds will impact on the economy's long run supply potential: through changes in human capital (the skills and education of the labour force), through infrastructural investment and through direct assistance to the private sector of the economy reducing their costs or increasing their productivity. These mechanisms were quantified and introduced in the HERMES model on the basis of microeconomic studies. A particularly important aspect of the Structural Funds programme is the extent to which it induces a long run positive supply side stimulus to the economy, since these effects represent the permanent value of the Community support framework as distinct from the transitory demand shock which accompanies implementation. Finally, the study shows that, if successful, these policies could raise GDP significantly in the short to medium term. The long term effects could be even greater. However, considerable uncertainty remains about the precise quantification of the supply side effects of these measures.

Sectoral European Forecasts – Club HERMES Forecast (since 1988) [14]:

The HERMES Club brings together all the national research centres which collaborate in developing European HERMES models. Its main task is to provide, once a year, a macrosectoral forecast for the medium term of the European economy as a whole. This forecast may subsequently be used as a bench mark when studying the effects of different economic policies and of exogenous shocks. In 1990, for example, the following alternative assumptions were examined: assessment of the impact of German unification on the performances of the European economies [14] and consequences of oil price rises on the countries of the European Community [15].

This is the end of the overview of the multinational studies realised by the end of 1990. In the future, the use of the HERMES model will evidently continue both at the national and at the multinational level. Moreover, some new areas of research have yet to be designed.

- A more appropriate treatment of the monetary variables of the model. Presently, in the HERMES models, the monetary variables and the interactions between monetary and real variables are modelled in a simplified way. In view of the liberalisation of the money and capital markets, it has been proposed [16] to construct a supra EC monetary block where monetary indicators at the European Community level, like demand, supply and price – interest rate – of various sorts of money and capital will be determined.
- Improvements of the supply side properties of HERMES. The importance attached by the authors of HERMES to supply modelling was clearly signalled in the use of explicit production functions, the four factors model of inputs demand (the KLEM approach) and the sophisticated putty-clay model of capital accumulation. Nevertheless, the HERMES project appeared inadequate in the treatment of response to some supply shocks. For instance, difficulties have cropped up on how to treat exactly questions related to environment, or developments associated with the European internal market. Some attempts have already been made to meet these new concerns, mainly by adapting the external trade block [17] and the wage-price block [18]. Moreover concrete proposals have been put forward to modify the model more radically according to ideas associated with Halliwell and his collaborators and with the Bank of Canada [19].

- Development of an environmental module to link with the HERMES models [20]. The main purpose of this module will be to transform calculated information from HERMES to environmental variables, like emissions, and transform environmental information back into the HERMES format. In the end, the satellite will be a full endogenised part of the computerised mathematical model. Emission levels of various types of emittants can be evaluated by this module: SO_2, NOx, CO_2, heavy metals, solid wastes, noise, contaminated soils, ...

Other research activities have been undertaken at the national level (examination of the long term properties [21], high level of disaggregation of the branches [22] and linkage with a detailed energy model [23], ...). They are described in national publications presenting the HERMES models, their properties and their applications.

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Chapter 3

THE HERMES MODEL FOR THE MEMBER STATES OF THE EUROPEAN COMMUNITY

A. ITALIANER, G. D'ALCANTARA and P. ZAGAME

Introduction

Various HERMES models have been built on behalf of the Commission of the European Communities by Directorate-General XII with input from Directorates-General II and XVII. They were developed in response to a specific need identified not only at Commission level but also by the individual Member States of the Community, namely to provide interlinked macrosectoral econometric models based on nomenclature which is sufficiently fine-tuned as to permit in-depth analysis of productivity, employment, competitivity, external balances and energy requirements.

None of these phenomena lend themselves readily to a too global and purely macroeconomic approach. At the same time, if the number of sectors reviewed is too great, the whole becomes exceedingly cumbersome; and an instrument which, in its final form, should integrate a dozen models from a dozen different countries, loses its value as an operational tool.

For these reasons, the choice was ultimately limited to the nomenclature of nine NACE CLIO products. This compromise appeared satisfying to the extent that manufacturing is divided into three major sectors which have been demonstrated in numerous studies to be structurally heterogenous and because the service sectors are clearly identified individually.

The end result is that the Commission and the national teams have at their disposal sectoral, annual and medium term models which are identical in structure and which are interconnected by a bilateral flow module. This model, developed when the effects of the second oil shock were fully in evidence, exhibits a structure and mechanisms which make it readily adaptable to other situations; this was demonstrated when it was used by the Economic and Financial Directorate-General to evaluate the impact of the completion of the Single European Market (*cf.* Catinat M., Donni E., Italianer A. (1988) and, in this book, Chapter 12).

In the following we shall look at the principal features of the model and the dynamics of supply, before going on to examine domestic conditions, determine nominal values and offer an analysis of external factors.

1. General Characteristics of the HERMES Models

The HERMES model system comprises one model for each Member State of the European Community to which are added simplified models for the other OECD areas and the rest of the world. Each model contains between 1500 and 2000 equations and is divided into two parts: a conventional macroeconometric model and an energy sub-model determining the energy demand requirements for different products.

The model architecture is traditionally 'neo-Keynesian' and, as such, is significantly weighted towards demand components; this said, the mechanisms which have been incorporated – notably that in respect of sector-by-sector production – permit supply dynamics to be clearly encompassed. Finally (and this is an important feature of the project as a whole), one has at one's disposal – for the first time – a system of interactive models linked by bilateral exchange flows and each developed by institutional sources which have a solid grounding in their respective national economies.

1.1 A 'Neo-Keynesian' Structure Compatible with Supply Mechanisms

The first matter to be resolved is whether the various country models should be 'twinned', i.e. whether they should be identical in structure. In effect, there are two principal arguments in favour of such 'twinning':

- First, it greatly facilitates exchanges of information between the national teams by virtue of providing a common database and identical specifications. (Incidentally, this process of exchanging information played an important part during the construction and utilisation phases.)
- Second, it greatly facilitates manipulation of the country model system.

  Management of the system is, to all intents and purposes, 'centralised' in a team at the European Commission. The sole means of coping with the overall mechanisms is by providing an identical structure for all the countries concerned; additionally, this means that comparison of functions can be effected promptly.

Nevertheless, the diverse economic structures which apply in the various Member States of the Community and the different methods of collating and processing statistics (despite their subsequent 'homogenisation' by the Commission Statistical Office) must inevitably contribute to a weakening of the 'twinning' principle. In other words, structural 'identity' must be conceived in the broad sense as relating to functions which are generally comparable: certain relationships differ not only with respect to the coefficients applied but also as regards their specification.

Thus, there are at times departures from standard nomenclature (as in the case of the Republic of Ireland, which does not distinguish three industrial sectors).

As a result, the model presented in the following is not necessarily that which is systematically used by each of the country models; it is, however, the model which has served as a basis for the estimates proposed to the national teams. A marked divergence is discerned in the respective contributions of said teams.

The generation of models to which HERMES belongs is profoundly marked by the neo-Keynesian synthesis approach that was predominant in macroeconomics up to the beginning of the 1980s[1]. Operation of these models is dependent in the short term on demand conditions: the functions of final demand estimated econometrically (consumption, investment, exports, imports, inventories, etc.), linked to production via an industrial exchange matrix, and subsequent calculation of utilisation rates by reference to installed production capacities.

It would be erroneous to suppose that supply side considerations are absent from the overall model mechanisms. Thus, corporate behaviourial functions in HERMES are dependent on production capacity utilisation rates, a variable which provides insights into profit-generating supply capacities at any given moment.

The econometric methodology is certainly traditional to the extent that it

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[1] For a discussion of neo-Keynesian model structure, *cf. inter alia* Muet (1979)

does not equate to that used to describe situations where disequilibrium prevails (in this respect, see, for example, Fair, Jaffee (1972)). However, although Keynesian disequilibrium (demand insufficiency) or classic disequilibrium (supply scarcity due to an excess in real wages or an insufficiency of profits) cannot be described in strict terms, the variations identified offer invaluable information on the type of regime that should apply: a low rate of utilisation is clearly associated with a Keynesian regime, whereas a high rate translates as the classic regime of capital shortage.

This information is not purely theoretical, because the variable rate of utilisation impacts on various behaviourial functions, such as production price determination, and import and export flows. In the latter case, the model can be used to describe situations where poor export performance is attributable to competitive supply shortcomings.

Moreover, the model is such that the mechanisms of choice as a function of price (allocation) are present at every level:

- choice of the best allocation of energy products;
- choice of the best allocation of production factors;
- choice of the best allocation of consumer products; or
- choice of the optimal geographical structure in respect of imports.

The study of the substitution of factors has been made within the framework of a 'putty-clay energy' production function, the aim being to delineate with some degree of precision the complex phenomena associated with changing production technology and its impact on the productivity of various factors: in effect, this type of model allows production technology selection aspects to be taken into account, as well as building in factors for technological progress and scrapping.

All these considerations result in the model's function – even in the short term – being extremely dependent on supply side considerations such as production capacity utilisation rates, production costs, and so on.

The final point to be stressed is that the HERMES model is a 'dynamic' one to the extent that it facilitates description of progress over any simulation period specified, offering detailed conjunctural data for the initial years in particular. In this context, the utilisation rate is also important, inasmuch as it provides information on current economic conditions and influences patterns (investment, employment) which will impact on the future. Lags between variables create dynamic relationships within the model; with great regularity, these differences stem from the formulation of

anticipative (generally, adaptive) values, or delays in adjustment to the desired values (e.g. employment and productivity cycle). In an instrument of this kind it was essential to estimate adaptation times as accurately as possible. This holds particularly true in the case of certain techno-economic energy ratios, for example, because substituting production factors or other forms of energy consumption implies time needed to modify technological installations. In such an instance, price sensitivity will depend to a vital degree on the respective timeframe which applies.

Accordingly, time lags were studied in minute detail; retardation procedures, such as ECM (error correction mechanism, *cf.* Davidson and Hendry (1978)) and interactive adjustments (*cf.* Nadiri, Rosen (1972)) were applied; these procedures included certainly some of the most elaborate on record used to collate annual information.

1.2 Energy Options and the Interaction Between Energy and the Macroeconomy

Each country model contains an energy sub-model which determines both energy requirements and the average cost of energy. The energy allocation model is common to the analysis of private household and corporate sector behaviour. As a result, on the basis of energy demand as a function of sectoral production of manufacturing firms, input-output tables for other firms, and household consumption, the model subdivides overall energy demand into eight energy products: coal and lignite, coke, crude oil, petroleum products, natural gas, derived gas, electricity and other (steam, hot water, air and nuclear).

This subdivision emerges essentially as a function of the prices of the various energy products (allocation model); the prices are calculated for each production sector as a function of the costs of production salaries, intermediate consumption, and applicable energy policies. The majority of studies over the past 15 years in respect of energy substitution have applied the dual functions of cost and, more especially, translog[2] – homogenous and linear functions of aggregate E. These functions are written as follows:

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[2] For utilisation of cost functions and, especially, translog functions, see *inter alia* Berndt and Christensen (1973), Berndt and Wood (1979), Christensen, Jorgenson and Lau (1973), Fuss and McFadden (1979), Jorgenson, Fraumeni (1980), Lesourd (1981), André, Bossier, Gouzée, Rigaux (1985)

$$\text{Ln } PE = \textit{constant term} + \sum_i a_i \text{ Ln } PE_i + \frac{1}{2} \cdot \sum_j \sum_i b_{ij} \text{ Ln } PE_i \text{ Ln } PE_j + Ci_i{}^{3}$$

where, PE is the unit cost of energy and PE_i the price of energy product i, and Ln the normal logarithmic function.

Application of the lemma developed by Shepard (1953) to this cost function – which must be concave – enables the calculation of optimal ratios, i.e. those which minimise unit expenditure of energy:

$$\frac{E_i}{E} = a_i + \sum_j b_{ij} \text{ Ln } PE_j + Ci_t$$

These components are expressed as a fraction of the total energy costs. Additionally, classic conditions of homogeneity and symmetry afford an invaluable input to econometric calculation, viz.

$$\sum_j b_{ij} = 1$$

$$b_{ij} = b_{ji}$$

Nevertheless, it is observed that such substitutions involving the various forms of energy are only valid within the framework of comparatively rigid technical constraints (in the short term, at least). In practice, a change in the source of energy supply will entail high adjustment costs linked to the installation of new plant and equipment. For these reasons, analysis of the behaviour of such components must necessarily be dynamic, which is to say that it must distinguish between less pronounced short term elasticities on the one hand, and possible longer term energy supply options on the other. As a result, a number of adjustment models which describe the optimal adaptation procedure were tested, including such complex variants as cross-adjusted models[4] which treat the speed of adaptation to a new energy source as dependent on the lack of adaptation present with regard to other sources of energy.

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[3] This complement is introduced when technical progress is not neutral in the sense of the term as used by Hicks.

[4] In this respect, *cf.* Nadiri-Rosen (1972) and Pouchain (1980)

However, households and industry use different energy sources extremely unevenly. As for an energy source which comparatively is less used, severe distortion can appear in the estimation of its share in the total consumption; these energy sources (often the case with natural or derived gas, for example) were systematically grouped together.

The final element required to run these equations consists in the determination of prices for various forms of energy product. To this end, three separate approaches have been applied: exogenous determination; a simple extrapolation from the posted prices of the energy utilities suppliers (e.g. in certain countries the cost of electricity is effectively geared to movements in GDP prices); and, as regards other energy sectors, the price expressed in terms of unit wage costs, intermediate consumer costs and the costs of imports by sector (to translate a competitive effect, despite the fact that this effect is ambiguous inasmuch as, in certain sectors – oil, for example – import costs approximate to intermediate consumer costs).

At this juncture, one can resume operation of the energy model in relation to the economic model.

Function of energy sub-model and integration with macroenergy

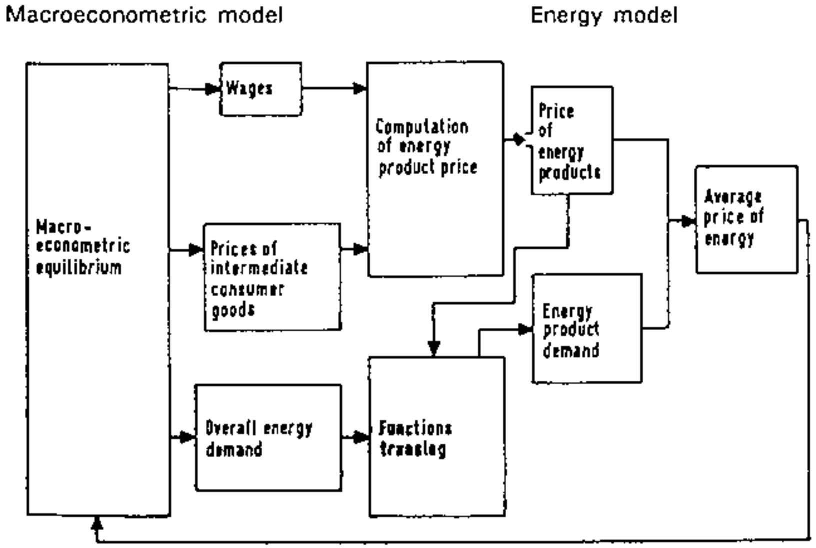

Fig. 1

Wage variables, intermediate consumer prices, and overall energy demand are determined by the economic model. The energy model thus computes the prices of each of these energy products, taking costs into account and enables energy demand to be broken down into various products; in other words, it is possible as a result to determine an average price for energy. This price, in turn, will play an extremely important part in the macroeconometric model both in terms of the corporate sector (demand factors) and households (functions linked to energy consumption). This is the key variable in the economy/energy integration. The diagram in Figure 1 illustrates how the whole operates.

1.3 *Bilateral Flows and Model Interdependence*

The pronounced degree of integration which obtains among the countries of Europe and analysis of European political trends prompted adoption of a system of linked models. Although capital flows and trade in services cannot be ignored, trade in goods is the most important factor in prompting intra-country shocks and price shocks.

The HERMES linkage module distinguishes between five distinct categories of goods corresponding to the five leading sectors of export of goods present in the country models: agricultural products, energy products, intermediate products, equipment and consumer goods. In essence, the treatment applied is identical for each of these; in practice, the framework is sufficiently broad to accommodate the specifics of each category of goods.

The main object of MS LINK is to endogenise a certain number of variables such as volume of exports/price of imports (which would otherwise be determined by exogenous variables).

In a model functioning in isolation, the volume of exports is typically dependent on a variable of global demand, a competitivity indicator, and information on supply conditions (unit production/capacity ratios). Import prices depend in general on world prices expressed in a foreign currency and prevalent rates of exchange. In simulations operating in isolation, the models do not accommodate the reverse impact of foreign trade, such as increased imports for a developing country increasing exports and, by extension, overall world demand, which will reduce outflows of foreign trade; further, low capacity utilisation can stimulate export supply but to a degree less pronounced if other countries also exhibit low production capacity utilisation; finally, exported inflation can also return in the form of higher import prices.

All these effects can be endogenised via the linkage module where the variables which are endogenous in the national models are exogenous for MS LINK and vice versa.

The process can be illustrated schematically as shown in Figure 2.

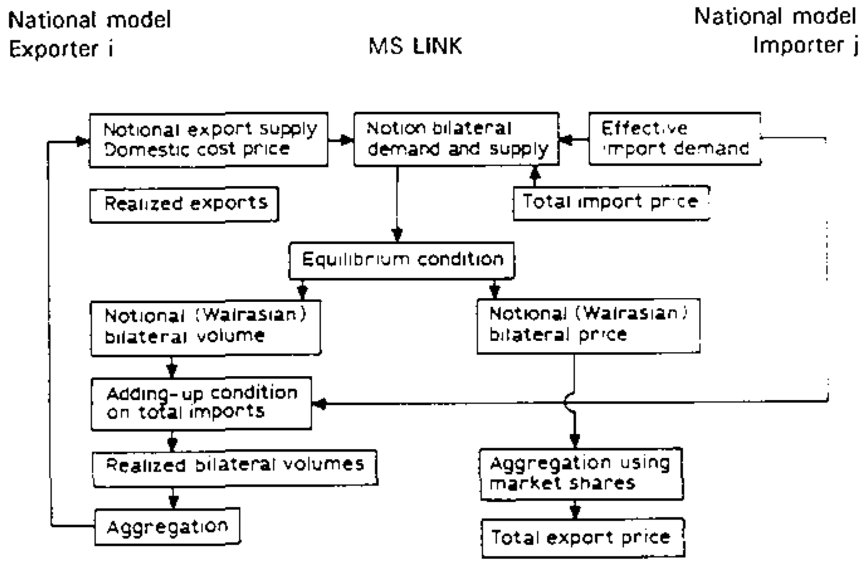

Fig. 2.

In its most general formulation, this system functions in respect of each category of goods as follows.

In the national models, equations of behaviour determine worldwide import demand and export supply volumes; import demand is assumed to be realised whereas supply is notional, i.e. the effective transaction can deviate from the initial amount of supply. The country models also determine a price index for domestic costs; this price, the total import demand, and total export supply, comprise the inputs to MS LINK.

These variables reappear in MS LINK in the form of notional demand and supply equations for bilateral industrial exchange flows, together with the price of overall imports and the price of bilateral trade.

These notional equations of bilateral supply and demand can be resolved to provide notional levels (Walrasian equilibrium) of volume and price. The reduced form of these two variables depends on import demand, export supply, domestic costs and total imports; further, notional bilateral trade volumes are proportionally adjusted (homothetised) in such a way that the amount per importer country coincides with total imports; in terms of disequilibrium theory, this corresponds to a proportional allocation: the bilateral prices thus obtained can be regrouped to provide, for each category of goods, the import and the export price per country. It should be noted that supply effects play a part in this approach but only as regards other trading partners.

2. Supply Dynamics and the Sectoral Approach

It is superfluous to stress the importance of enterprise behaviour to the overall functioning of the model. Decisions taken at production unit level influence overall productivity, investment, employment, price levels, and so on. In this context, the specific support provided by the model is considerable, particularly in the light of the sectoral approach it adopts: this allows a clear differentiation between sectors and, above all, avoids to a very great extent structural distortions due to amalgamation of sectors which are highly heterogenous from the production point of view.

That said, if it is to retain its validity and value, the relatively detailed approach must be accompanied by a relatively thorough econometric analysis. The production model used must be sufficiently ambitious in construction to be able to provide input on a certain number of phenomena which could impact on supply conditions: choice of production techniques, incorporation of technological progress, scrapping of production assets, impact of energy utilisation (and, accordingly, price) on the productivity of other factors (ditto for other intermediate consumption) because all of these phenomena have become progressively important in the course of the past 15 extremely uneven years, what with energy price shocks, interest rate fluctuations, falling-off and subsequent resurgence of productive investment, and accelerated deterioration of certain categories of consumer goods.

In the following, we shall examine the production function, factor demand and sectoral aspects of the HERMES model.

2.1 *The 'Putty-Clay Energy' Production Function*

This affords a means of translating into a formalised approach all the phenomena cited above and developing a production function in terms of:

- *vintage:* this feature permits distinction between technological substitutions prior to the investment being realised, a complementarity which is, most frequently, the main characteristic of existing production assets; in addition, this vintage function enables incorporated technical progress to be identified; finally, by identifying the various capital goods categories individually by date of acquisition, it allows for appropriate treatment of scrapping by assigning to each successive generation a lifespan which can be endogenised in accordance with prevalent economic conditions;
- *several production factors:* as far as several production factors are concerned, in more than two, respective productivity over the past decade and a half reveals that the cost of energy has very significantly impacted on the amount of energy consumed and, as a result, on labour and capital productivity. At the same time, larger variations observed in the amount of intermediate consumption have clearly also affected productivity where other factors are concerned.

For these reasons, and in an attempt to define as precisely as possible the conditions which govern supply, the HERMES model uses an output function comprising four factors: employment, capital, energy and intermediate consumption.

In examining several output factors where specifications are extremely complex, econometricians have often had recourse to dual functions which permit translation of a structure comprising a vast number of output functions; in this respect, see Fuss-McFadden (1979) or, more specifically, the translog function which is a second-order approximation to a unit cost function (*cf.* in this respect Berndt and Wood (1975, 1979), Griffin and Gregory (1976), Lesourd (1981) and work done in the present model to break energy down into its various components).

Nevertheless, the characteristics deemed of priority relevance to the analysis of supply conditions militate strongly in favour of an explicit output function. In effect, it has emerged that intra-factor substitutions have been responsible for some of the production distortions which have been increasingly frequently observed in the course of the past 15 years. Thus, precise analysis of substitutability phenomena depends on application of a putty-clay model in which the substitutability between capital and employment is feasible prior to investment, whereas output techniques are 'locked-in' once said investment has been effected. As we have seen, the successive generations approach used permits such a distinction: the output function retained thus applies to the choice of output permutation obtaining in the most recent generation; in other words, this option precludes the use of dual cost functions.

A large number of studies have been carried out to date using the putty-clay approach featuring two factors (*cf.* in this context Ando, Modigliani, Rasche, Turnovsky (1974)). Initially specified in the form of a Cobb Douglas function, the model has subsequently been extended to cover production factors with constant substitution elasticity different from one (*cf.* Bischoff (1971)).

The question that must be asked in terms of the HERMES model is, however, more complex, since swingeing fluctuations in the cost of energy and raw materials have had a major influence on traditional productivity factors. It was felt appropriate to take this phenomenon into account by applying output functions comprising four factors: capital, employment, energy and raw materials (K, L, E, M). This perspective has relied on existing specifications set out by Mukerji (1963) or the two-level approach adopted by Sato (1967). In the latter specification (*cf.* Alcantara (1979)), the estimation method consists first in grouping the factors in twos in order to obtain two composite factors which are then combined into one production function to determine product level.

At that point, several questions can arise.

Certain intermediate consumption series do not lend themselves to in-depth econometric scrutiny. It is true that the 'core' of the intermediate consumption matrix sometimes obscures the basic information contained in the initial series; this is the case in 'RAS' type methods designed to regulate the intermediate consumption matrix coefficients to adjust for resources/deliveries equilibrium. Accordingly, certain countries – such as France, for example – have opted to limit themselves to a three-factor (K, L, E) production function.

A further question relates to grouping production factors. Here, the choice cannot be arbitrary; in effect, it is dictated by separability tests which are applied using the translog cost function. These tests boil down in practice to a standard test of coefficient limits for retained equations (*cf.* in this respect Christensen, Jorgenson, Lau (1973), and Artus, Peyroux (1981)); unfortunately, the tests are somewhat brittle but, this said, the most significant groupings have emerged as those between investment and energy on one hand and employment and intermediate consumption on the other. At one level, the grouping is effected by interposing a CES function; thus, the first 'composite' factor is a CES function of investment and energy, and the second composite is a CES function of employment and intermediate consumption. The product of the two is a Cobb Douglas type function of the two composites.

Overall, this emerges as the following specification:

$$Y_t = A\, e^{rt} \left(\delta\, I_t^{-\mu} + (1-\delta)\, E_t^{-\mu}\right)^{-\frac{\beta}{\mu}} \left(\epsilon\, L_t^{-\gamma} + (1-\epsilon)\, M_t^{-\gamma}\right)^{\frac{(1-\beta)}{\gamma}}$$

where:

Y_t represents production capacity at the level of capital goods I_t installed at time t (gross investment);

X_{it} represents the production factor used on this new production capacity (marginal input) (L = jobs);

E = energy;

M = other intermediate consumption;

r = rate of technical progress;

δ and ϵ are distribution parameters applied to composite factors;

β represents the distribution of inter-factor composites; and

μ and γ are CES function parameters.

In the case of three production factors, the equation appears as follows:

$$Y_t = Ae^{rt} \left(\delta\, I_t^{-\mu} + (1-\delta)\, E_t^{-\mu}\right)^{-\frac{\beta}{\mu}} L_t^{(1-\beta)}$$

It should be noted that the assumption as to the number of retained factors is not without impact on the substitution elasticity values which one is attempting to obtain. Thus, Berndt and Wood (1979) have demonstrated that the omission of non-energy raw materials will bias the elasticity of estimated substitutions (*cf.* in this context Artus, Peyroux (1981)).

2.2 *Optimal Manufacturer Behaviour*

The producer will take account of his immediate economic environment (demand, anticipated cost of factors and products) to choose the optimal combination of factors and the best scale of product and scrapping.

2.2.1 *Choice of production technique*

This relates to selection of the mix of factors which will minimise production costs per unit of anticipated capital investment. It relates to anticipated costs of production and to the reduction to a minimum of costs engendered throughout the lifespan of the capital good T_t.

Taking K''_{it} as the optimal marginal coefficient relative to factor i,

$$K^{\cdot}_{it} = \frac{X^{\cdot}_{it}}{Y^{\cdot}_{t}}$$

unit costs arising can be expressed as follows:

$$C_t = \sum_{j=0}^{T_t''} \sum_{i \neq k} \frac{PX_{it+j}}{(1+R_t)^j} \cdot K^{\cdot}_{it} + PI_t \cdot K^{\cdot}_{t}$$

where PX_{it} represents unit cost of the factor i at moment t and R_t represents the actualisation rate. The above cost function can be expressed in more simplified form by 'smoothing' the anticipated factor costs. Assuming that until a limit date $t + T_t''$, the average rate of cost increase of factor i is π_{it}, and postulating:

$$\pi_{it} = \left[1 - \left(\frac{1+\pi_{it}}{1+R_t}\right)^{T_t''+1}\right] \Big/ \left[1 - \frac{1+\pi_{it}}{1+R_t}\right]$$

(cf. d'Alcantara 1979)

the producers' problem can be written:

$$Min\ C_t = \sum_i K^{\cdot}_{it}\ PX_{it}\ \pi_{it} + PI^{\cdot}_t\ K^{\cdot}_t$$

subject to the constraint of the marginal production function which, taking into account the yield of scaled units (a first degree homogenous production function), can be written as follows:

$$F\ (K^{\cdot}_{1t}, K^{\cdot}_{2t} \ldots, K^{\cdot}_{it} \ldots, K^{\cdot}_{t}) = 1$$

Use of the Lagrange multipliers method enables calculation of K_t'' and K''_{it} marginal technical coefficients which are solely dependent on the anticipated production factor costs.

In this context, it should be noted that treatment of investment cost is different since the expenditure of capital takes place once and for all at the beginning of the period in question whereas expenditure in respect of the other factors is renewable each year. All the same, a certain dissymmetry emerges between the different factors to the extent that investment is effected prior to the entry into application of the other factors.

The formula derived from this optimalisation is as follows:

$$K^{\cdot *}_{it} = f_i\left(PX_{jt} \cdot \pi_{jt} \forall j, PI_t, t\right) \forall i$$

The technical coefficient of factor i is dependent on the costs of all factors of production.

2.2.2 *Determination of scale of production*

Determining the scale of production will depend on anticipated capacity needs perceived by the manufacturer, assuming that the latter makes continuing adjustment in this respect. In that event, investment and the production factors will best be computed by multiplying the optimal coefficient by the level of capacity desired.

Thus, for investment:

$$I^{*}_t = K^{\cdot *}_t \ .\ Y^{\cdot *}_t$$

and for other factors

$$X^{\cdot *}_{it} = K^{\cdot *}_{it} \ .\ Y^{\cdot *}_t$$

This said, the capacity required on the most recent production unit is dependent on the scrapping of capital goods and on a variant of the global capacity for the sector as a whole, according to the equation:

$$\Delta Y^{*}_t = Y^{* \cdot}_t - D_t$$

Moreover, the prior act of investment can lead to a mode of determination which is completely dissymmetrical, depending on the various production factors involved.

For example, the investment may be decided on the basis of demand considerations, but it may also be decided in terms of finance availability (realised profits, indebtedness, interest rates). Seen in the latter perspective, overall production functions slightly differently: it relies on an autonomous investment function which, in turn, is dependent on traditional variables – anticipated demand, interest rates and costs of capital, employment costs, profit. This autonomous function thus determines the scale of production, the optimal demand of the other factors being deduced on the basis of the optimal coefficients computed previously.

Both modes of determining investments (production function-led or autonomous) are discerned in the approaches adopted by the various national HERMES teams. The perceived impact of profits on investment experienced of late in the world's industrial economies militates in favour of the autonomous investment approach.

2.2.3 Scrapping behaviour

Optimal scrapping is reached when profit on the least productive equipment is equal to zero[5]. Several hypotheses must be accommodated so that write-off applies to the oldest equipment. Accordingly, the profit function with regard to the most recent equipment must be constant and decreasing with age and the residual value of the equipment written down must be zero. It should also be noted that the hypothesis of technical progress improving new equipment productivity approximates to the first condition (constant); however, this hypothesis is not sufficient to ensure that scrapping priority is applied to the oldest equipment. If anticipated costs of production factors vary too severely, it can happen that equipment generations installed with a specific cost factor configuration can be radically scrapped whereas other – even older and less productive – equipment can prove to be more profitable because it is better adapted to the new factor cost structure[6]. On the other hand, there is a condition which lies between that of technical progress and that of anticipated costs which excludes such phenomena. Using adaptive anticipations is conducive to that condition.

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[5] In the case of two factors, the condition for scrapping is very simple, to the extent that the capital acquisition cost has been incurred once and for all and equipment running costs are strictly limited to operational expenditures. The condition gives rise to an equalisation of real wage costs and productivity on the oldest equipment.

[6] In the case of two factors and for the same reasons as those indicated earlier, the hypothesis of the rate of technical progress being superior to the rate of real wage growth is, to all intents and purposes, adequate.

In practice, calculating the production content with endogenous scrapping requires access to extensive information and relatively lengthy statistical series because of the number of parameters that have to be taken into account – six for the production function alone. For these reasons, certain national teams have retained the hypothesis of 'en masse' scrapping which is not broken down into individual equipment generations and to which varying rates are applicable.

2.3 *From Optimal Values to Effective Values*

It should be noted from the outset that the factors as calculated in the preceding section assume full production capacity utilisation. In practice, therefore, a correction has to be applied to these values to arrive at capacity utilisation rates which reflect marginal desired values.

Moving from marginal desired values to total desired values is achieved by taking into account and by applying the following formula[7]:

$$\Delta X_{it}^{**} = QR_t\left(K_{it}^{**} \;.\; \Delta Y_t^{*}\right)$$

where ΔX_{it}^{**} is the variation in demand derived from factor *i* and where ΔY_t^{*} represents the production capacity on most recent investment unit. This last variable is equal to the total variation in production capacity plus scrapping. QR_t is the production capacity utilisation rate.

Adjustment to desired values takes time because all the variations in these economic values derived from 'adjustment costs': this applies to all production factors (adjustment costs relating to employment and linked to training or redundancy costs are very frequently taken as an example). The scrapping process also takes time to reach the required level.

These delays in adaptation – irrespective of their theoretical basis – are conducive to delays which 'smooth' variations in value and thus stabilise to some extent the dynamic of the model. Specifying these delays is thus an important element in that dynamic. For a long time, econometricians used the partial adjustment procedure (see Koyck (1954)) which gives rise to geometrically progressive coefficient weighting. In the case of demand factors, this procedure can be presented as follows:

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[7] Throughout, we use * to designate optimal values and ** to designate desired values; effective, i.e. real values are shown without an asterisk. It is assumed for the purposes of this equation that no utilisation rate variation is present.

$$\Delta X_{it}^{**} = \lambda\left(X_{it}^{**} - X_{it-1}\right)$$

Pursuant to Hendry, we have opted here to use an error correction mechanism as used for adjustments to the model overall. In effect, this takes account of dimensional analysis constraints and confers better long term applicability to the model. Thus:

$$\Delta X_{it} = \lambda_1\left(X_{it-1}^{**} - X_{it-1}\right) + \lambda_2\,\Delta X_{it}^{**}$$

At any given moment, variation in the effective value depends on its divergence from the desired value applicable in the preceding time period and on the variation of the desired value.

The first term corrects error in the effective value; it will be noted that the geometrical adjustment is specific to an ECM model when $\lambda_1 = \lambda_2$. This said, there is absolutely no reason for this to be the case from an econometric point of view.

2.4 *The Problems of Estimation: Interpretation of Results*

The national teams will emphasise the difficulties that they encountered in their estimations. For the present purposes we shall stick to general principles. In fact, each national team has three options open to it: three or four production factors; endogenous or exogenous scrapping; and treatment of investment as an autonomous or production-led function.

2.4.1 Construction 'data'

The specific technical coefficients of successive vintages of equipment are not observed directly. Two options are available to the econometrician:

- to construct hypothetical data on the basis of chronological series observation regarding the real levels of production-related demand factors, or
- to derive algebraic formulae to develop equations which allow identification of technical coefficients and estimation of constant parameters with respect to determination of observed variables.

In practice the national teams which apply *ex ante* four-factor marginal production functions have used the first method; by the same token those teams that opt for the three-factor approach rely on the second.

In both cases it is clear that much is 'read in' to the data available; an improvement in the statistics relating to the technology of annual investment would make for an improvement in the precision of the estimates given.

A certain number of constraints have nonetheless been introduced to ensure that the marginal technical coefficients obtained exhibit a minimum of realism:

- the technical coefficients of capital and investment lifespan are compatible with the existing production capacity;
- production levels and demand factors observed are below the maxima implied by 100% production capacity utilisation; and
- equipment lifespan or the application of depreciation rates provide results which are compatible with the level of full utilisation or, at worst, extensive utilisation of production factors at the extensive margin.

2.4.2 Production function parameter calculation

Once the 'data' have been assembled, the *ex ante* production coefficients are estimated via the equations established in respect of demand factors per production unit, i.e. the marginal technical coefficients corresponding to the investment generation for the year in question.

In the case of an *ex ante* three-factor marginal production function, calculating all the production coefficients is by way of the investment function only. In the case of an *ex ante* four-factor marginal production function, this is not feasible; accordingly, recourse is made to estimation of total factor demand system by product unit.

Both methods have been used.

2.4.3 Simulation generation model result interpretation

The apparent substitutability between factors stems from a triple modification: first, the effect of measurable substitution on the isoquant of the *ex ante* production function corresponding to technologies available for the new investment; second, the effect of the substitution coupled with selective scrapping of generations of capital deemed to be definitively non-productive; and, third, the effects of utilisation adjustment of broad-margin factors following variations in real production; this third factor does not arise as a result of substitution in the strictest sense of the term because it is independent of the relative costs of production factors; that said, it does impact on the relative intensity of production factor by unit of output.

In effect, we are able to distinguish via the simulations the separate structural effects which derive from the decomposition of traditional (as opposed to *ex ante*) cost elasticities:

- price elasticity of scrapping
- price elasticity of replacement by a new production technology, the total for which comprises the traditional price elasticity defined at constant production capacity. These concepts prove to be of great relevance in the analysis of structural changes in national economies at macrosectoral level.

Price elasticity of scrapping is calculated on the basis of the relative variation of production factor price, with relative variation of factor demand corresponding exclusively to the capacity scrapped.

Replacement cost price elasticity is calculated by the relative variation in factor demand corresponding to replacement of the capacity scrapped by new generation capacity which is exactly equal but uses new technical coefficients.

Studies carried out in Belgium reveal, for example, the following for the totality of the industrial sector:

Table 1

	Labour	Energy
Scrap elasticity		
– by reference to labour costs	– .84	– .67
– by reference to energy costs	– .16	– .12
Replacement elasticity		
– by reference to labour costs	.24	.33
– by reference to energy costs	.05	.06
Total elasticity		
– by reference to labour costs	– .60	– .34
– by reference to energy costs	– .11	– .06

SOME CHARACTERISTICS OF SUPPLY

SUPPLY AT TIME T: QUANTITIES, COSTS, REMUNERATION, PROFITS, ETC.

Variations in anticipated demand, prices, profits earned

↓

Rational behaviour of manufacturers

↓

1. Calculation of projected returns on different capital goods installed or to be installed.
2. Selection of technology best adapted to the new production conditions (for the final vintage of capital goods investment).
3. Determination of non-profitable units to be scrapped.
4. Selection of production scale.
5. Determination of supply price.

↓

Decisions, adjustment times required for desired volume

↓

RESULTS

- Profitable production capacities
- Factor demand
- Production factor productivity
- Price and price competitivity
- Product capacity utilisation rate (U)

DIFFERENT CASES:

- Where U at a high level: insufficient return capacity
- Where U weak: insufficient demand

STUDIES OVER EFFECTS OF VARIATIONS IN:

- Demand, price, profits, taxes applicable, technical progress, productivity, new processes, sustained investment, etc.