"ENERGY DEMAND IN PORTUGUESE MANUFACTURING : A TWO-STAGE MODEL"*

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ENERGY DEMAND IN PORTUGUESE MANUFACTURING: A TWO-STAGE APPROACH

INTRODUCTION

The estimation of energy demand systems has attracted considerable interest over the past ten years. The energy shocks of the 70's provided the original impetus. But even now that, rightly or wrongly, energy markets are perceived to have regained some stability, there is still a great deal of interest in an accurate estimation of the most important parameters determining the economy's response to changes in energy conditions. The economy-wide fluctuations caused by the oil price increases of the 70's now seem to be a problem of the past. Energy policy however continues to be a matter of concern for many governments. The problems of the past decade have exposed the vulnerabilty of countries relying too much on a single type of energy input, particularly if it is imported; and a consensus has emerged with respect to the important long term effects of significant changes in the relative prices of energy inputs. Policy has therefore changed focus. Diversification of energy supply is a major goal, even when it implies higher costs. And governments leaning towards intervention in energy markets have concentrated their attention on the long run allocative effects of energy prices and on efforts to change these. Both require an accurate knowledge of the determinants of energy demand: the possibility of substituting other inputs for energy, as well as the substitutability among energy forms are key to the definition of appropriate scenarios for long run energy policy.

Energy demand functions have been estimated since long ago. But it was only with the application of duality results to demand theory that it became possible to obtain estimates within a rigorous framework, consistent with economic theory and compatible with precise econometric methods. In the case of the demand for energy by the manufacturing sector, the appropriate setting is a model of cost minimization, within which optimal input demands are derived from output levels, given the prices of all factors of production. A complete system of input demand equations is obtained, providing estimates of own and cross price elasticities which depend on the substitutability or complementarity among all factors.

Since the pioneering work of Berndt and Wood (1975), the estimation of manufacturing energy demand systems has made considerable progress. The initial contributions of Berndt and Wood consisted in applying several innovations simultaneously:

- the characterization of the technology by the minimum cost function, from which input demand functions are derived using standard duality results;
- the use of a flexible functional form, the translog, thereby reducing the a priori constraints imposed on the structure of the demand systems;
- the precise definition of separability assumptions, justifying

the use of aggregate input composites : capital, energy, labor and materials;

- the construction of composite price indices which are desirable aggregators of individual input prices;
- the use of econometric estimators appropriate for a system of equations (Iterative Three Stage Least Squares), plus the construction of instrumental variables to replace price series which may not be exogenous;
- the verification of convexity conditions, which are not always met when a flexible functional form is used.

The results of Berndt and Wood remain quite valid today, and have substantial implications for energy policy. Their main findings may be summarized as follows: first, energy demand responds significantly to price changes; second, and related to the first finding, there exist non-negligible substitution possibilities between energy and non-energy inputs; third, there is evidence suggesting that energy and capital are complements rather than substitutes in production. All three of these results - which would have been difficult or imposible to detect and test with the previous reduced form approach - are quite important for a better understanding of the response in the manufacturing sector to changes in the relative price of energy inputs. As the authors point out, their results imply that: energy demand forecasts based on simple energy/GNP ratios ought to be dismissed ; policies based on the subsidization of energy prices will undoubtedly stimulate demand; the practice of compensating the business sector with tax breaks on profits when energy prices have to go up is in fact counterproductive since it will lead to higher energy consumption. Since this first contribution, which brought to energy demand studies a new and much more careful methodology - in terms of theoretical foundations and econometric precision - many other authors reproduced and improved the approach. Among some of the most quoted studies, a reference should be made to the following :

- Griffin and Gregory (1976), estimate demand functions based on a translog cost function with three inputs - capital, energy and labor - using pooled international data; their results confirm the significant value of energy own price elasticity but reject the finding of energy-capital complementarity ; the cross-section nature of the model leads the authors to claim that their estimates reflect better long term responses to energy price changes and to argue that complementarity may be observed in the short term only;
- Denny, May and Pinto (1978), reproduce the basic findings of Berndt and Wood for Canadian manufacturing; introducing another type of flexible functional form - the Generalized Leontieff cost function - and dropping the assumption of homothetic technology, this study obtains small but significant own price elasticities for all factors of production (capital, labor, energy and materials), confirms capital-energy complementarity and presents very large values for Allen elasticities of substitution; with these estimates, a simulation of the effects of a 50% increase in energy prices is shown to have a very small impact on average or marginal cost but to lead to significant substitution among factors;

- Berndt and Wood (1979) reconcile alternative estimates of the elasticity of substitution between capital and energy and provide an explanation for the seemingly contradictory econometric results indicating complementarity, and the engineering evidence in favor of substitutability; arguing for separability between a composite input, consisting of capital and energy, and all other inputs, they show that, if all other inputs as well as output are kept constant, energy and capital must be substitutes, confirming the engineering approach; but that if other inputs are allowed to vary, the demand for the capital-energy composite will fall, and that this scale effect may be dominant and lead to overall complementarity, a result also explained by Hogan (1979);
- Field and Grebenstein (1980) attempt to shed aditional light on the complementarity issue by distinguishing between physical capital and working capital; using data from ten sectors of US manufacturing, the authors estimate a cross-section state-level model and find no evidence of substitutability between physical capital and energy, but also no evidence of complementarity between working capital and energy.

Apart from any remaining uncertainty regarding the robustness of the energy-capital complementarity findings, these various studies - and many others along the same lines - consolidated a methodological approach which was to be applied in different aspects of energy demand analysis. If the separability assumptions underlying the capital-labor-energy-materials - or KLEM - model were accepted, it would be possible to deal independently with the energy submodel - that is, to estimate in a separate model the possibilities for inter-energy substitution within the energy composite. This problem consists in deriving the demand functions for electricity, coal, gas and petroleum products, given the prices of all these forms of energy and a total amount of energy that the manufacturing sector requires. The parameter estimates to be obtained from this energy submodel may provide important information about the substitutability among these inputs and, when combined with the parameters from the more aggregate model, about the own and cross price elasticities of demand for each form of energy. This was the approach followed in two well known studies:

- Halvorsen(1977) estimates a four-input energy submodel for two-digit SIC manufacturing industries in the US; the demand equations are derived from a translog energy unit-cost function and are estimated with cross section state data for 1971; the results indicate significant differences across industries, but in general suggest substantial own price elasticities of demand and non-negligible cross price elasticities; computing elasticities for the manufacturing aggregate, Halvorsen concludes that demand for each type of energy seems to be quite price responsive; he then combines his estimates with those of Berndt and Wood to obtain demand elasticities for each energy input allowing for change in total energy, which increases own-price and reduces cross-price effects;
- Griffin (1977) estimates a fuel submodel for the electricity generation industry, using pooled international data; although his

results are not relevant for comparisons with parameter estimates for the manufacturing sector, the methodology is the same: a translog model is used to estimate interfuel substitution as a function of relative prices, assuming separability with respect to capital and labor inputs.

Subsequent studies of energy demand went a step further and linked the estimation of the aggregate KLEM model to estimation of the energy submodel, using the information obtained from the latter to improve the precision of the estimators in the former. In fact, the unit cost function for the aggregate energy input contains all the information relative to the energy technology which is necessary to obtain an accurate index of the aggregate energy price. Using this price instead of some approximation in the estimation of the aggregate model should improve the precision of the results. This is the approach followed in two additional studies of the industrial demand for energy:

-Fuss (1977) estimates energy demand systems for Canadian manufacturing, using pooled data; he justifies the two stage procedure - the estimation of a six-input energy submodel and subsequently of a four-input aggregate model - on problems of size and multicollinearity if no separability assumptions are made and a single model is used; he explains how the normally used Thornquist price index for the aggregate energy input becomes exact when it is constructed using the estimates obtained in the energy submodel; and he obtains estimates which confirm significant own- and cross- price elasticities for the energy inputs, evidence of energy-capital complementarity, and own-price elasticity of -.5 for aggregate energy which is not far from the estimates obtained for US manufacturing by Berndt and Wood; he then goes on to simulate the impact of substantial energy price increases and indicates that his results reflect decreasing marginal rates of substitution among all inputs, as required by the concavity assumptions;

- Pindyck (1979) follows a very similar methodology to estimate a two-stage model with pooled annual international data; his results include a return to capital-energy substitutability - as in Griffin and Gregory (1976) - perhaps due to the fact that materials inputs are not included in the aggregate model; and evidence of larger estimates for the own-price elasticity of aggregate energy, but smaller for each individual type of energy.

These various studies of energy demand, plus many other less known exercises leading to similar conclusions, establish a clear-cut methodology, provide evidence of significant price elasticities of demand and leave somewhat unresolved the question of capital energy complementarity, which seems to be sensitive to model specification and data used. These conclusions imply that a careful study of energy demand is required before policy issues can be discussed, since interfuel, and in general inter-input substitution will determine the impact of decisions affecting relative prices; that such a study should use the most recent methodological advances, since the precision of the estimates is crucial for some of the most important issues; and that, since a consensus seems to have emerged as to the plausible values of the estimated elasticities, it would be desirable to obtain similar results in other contexts. This paper presents the estimation of a two-stage model of the demand for energy by manufacturing industry in Portugal. Translog cost functions are specified for energy unit cost and total output cost; homotheticity is assumed at both levels. The usual separability assumptions are applied to aggregate inputs into capital, labor, energy and materials composites. In the energy submodel, only electricity, fuel oil and coal are considered, given that all other fuels have negligible shares in total energy. The two models are linked by the price of energy. Estimation proceeds with a Full Information Maximum Likelihood method and annual data. The results are very encouraging. Both models fit the data quite well, and the estimates yield elasticity values that do not differ substantially from the consensus referred to above.

The motivation for the paper has two components: first, no study of this type was ever attempted in the case of Portugal, in spite of the country's very high dependence on imported energy and vulnerabilty to oil price increases; second, a recent effort by the Portuguese government to define a National Energy Plan[1] led to the construction of alternative energy demand scenarios, which - in spite of considerable assistance from foreign experts - are based on the most naive projections, in particular by excluding any price responsiveness. It is therefore obvious that a study of this type is long overdue; and that its findings may have substantial policy implications. In particular, the evidence supporting significant price elasticity of energy demand may, on one hand, enable Portugal to avoid the demand forecasting errors that now plague other countries, thus leading to a more adequate planning of long term energy supply expansion; on the other hand, rechannel energy conservation efforts from costly campaigns imposing mandatory standards and subsidizing energy saving equipment, towards a more efficient approach based on price management, through taxes and the elimination of subsidies.

Certainly one of the main reasons why a study of this type was not attempted before is the unavailabity and inadequacy of published data. In fact, a very substantial proportion of the work leading to this paper was devoted to the obtention and treatment of reliable data. The data is presented in Appendix 1, together with a description of all the sources and of the methods used to obtain the final series used in the estimation.

Two important advantages of the data used in this paper should be pointed out. First, the period covered ends in 1979 and therefore includes a certain number of years after the first oil shock. The sample therefore contains substantial variability in prices, unlike most other studies. It is remarkable that the goodness of fit remains quite acceptable in spite of the drastic changes during the sample period. Second, all energy prices are government controlled in Portugal, and therefore do not necessarily reflect changes in local demand - and sometimes not even changes in world markets. Thus, the energy price variables should not be correlated with the disturbances of the demand equations, avoiding the need for instruments. This should improve the precision of the estimates.

THE MODEL

The KLEM model

The technology of manufacturing industry is assumed to be separable in four composite inputs: capital(K), labor(L), energy(E) and materials(M). It is also assumed that constant returns to scale exist and that any technological progress will be Hick's neutral, that is, will leave factor proportions unaltered. The technology can therefore be represented by a minimum cost function

$$C=G(P_K,P_L,P_E,P_M).Y$$

where C is total cost, Y is output and P_K, P_L, P_E and P_M are the prices of K,L,E and M respectively. To estimate the parameters of this cost function, a translog functional form is chosen. The cost function can be written as

$$\begin{aligned} \ln C = {} & \ln\alpha_0 + \ln Y + \alpha_K \ln P_K + \alpha_L \ln P_L + \alpha_E \ln P_E + \alpha_M \ln P_M \\ & + 1/2 \, [\, \gamma_{KK} (\ln P_K)^2 + \gamma_{LL} (\ln P_L)^2 + \gamma_{EE} (\ln P_E)^2 + \gamma_{MM} (\ln P_M)^2 \,] \\ & + \gamma_{KL} \ln P_K \ln P_L + \gamma_{KE} \ln P_K \ln P_E + \gamma_{KM} \ln P_K \ln P_M + \gamma_{LE} \ln P_L \ln P_E \\ & + \gamma_{LM} \ln P_L \ln P_M + \gamma_{EM} \ln P_E \ln P_M \end{aligned}$$

This expression for the translog already incorporates the usual symmetry assumptions, that is $\gamma_{ij}=\gamma_{ji}$.

Using standard duality results, namely Shephard's Lemma, the demand for each factor of production can be obtained by differentiating the cost function with respect to that factor's price; in the case of the translog, logarithmic differentiation yields the share of the factor in total cost. Denoting by Θ_i the share of factor i,

$$\Theta_K = \partial \ln G/\partial \ln P_K = \alpha_K + \gamma_{KK} \ln P_K + \gamma_{KL} \ln P_L + \gamma_{KE} \ln P_E + \gamma_{KM} \ln P_M$$

$$\Theta_L = \partial \ln G/\partial \ln P_L = \alpha_L + \gamma_{KL} \ln P_K + \gamma_{LL} \ln P_L + \gamma_{LE} \ln P_E + \gamma_{LM} \ln P_M$$

$$\Theta_E = \partial \ln G/\partial \ln P_E = \alpha_E + \gamma_{KE} \ln P_K + \gamma_{LE} \ln P_L + \gamma_{EE} \ln P_E + \gamma_{EM} \ln P_M$$

$$\Theta_M = \partial \ln G/\partial \ln P_M = \alpha_M + \gamma_{KM} \ln P_K + \gamma_{LM} \ln P_L + \gamma_{EM} \ln P_E + \gamma_{MM} \ln P_M$$

These four equations implicitly define a complete system of input demand functions, consistent with cost minimizing behavior on the part of producers and price taking in factor markets. To meet homogeneity constraints, the parameters in these equations should still satisfy the following equalities:

$$\alpha_K + \alpha_L + \alpha_E + \alpha_M = 1$$

$$\gamma_{KK} + \gamma_{KL} + \gamma_{KE} + \gamma_{KM} = 0$$

$$\gamma_{KL} + \gamma_{LL} + \gamma_{LE} + \gamma_{LM} = 0$$

$$\gamma_{KE} + \gamma_{LE} + \gamma_{EE} + \gamma_{EM} = 0$$

$$\gamma_{KM} + \gamma_{LM} + \gamma_{EM} + \gamma_{MM} = 0$$

These constraints will have to be imposed during estimation.

Finally, given the flexibility of the translog functional form, there is no guaranty that the estimates will correspond to a monotonic and concave cost function(2). It is therefore necessary to verify that these two conditions are not violated. Monotonicity requires that the estimated shares be always positive, which can be observed directly after estimation. There are a number of methods to check for concavity. The most obvious way is still the verification of the negative semidefiniteness of the Hessian determinant. However, since the second derivatives of the translog function are not constant, this test has to be performed for all the observations in the sample.

The energy submodel

A similar model is used to study the demand for each of the individual energy inputs as a function of relative prices, assuming that total energy input remains constant. Again, the technology of inter energy substitution is represented by a cost function that already assumes optimizing behavior on the part of producers. Here, the total cost of energy is the minimum level of spending necessary to achieve a certain level of energy input, given the prices of each form of energy. To be able to divide the optimization process of producers in two stages, it is necessary to assume homotheticity of the energy technology: factor proportions within the energy composite must be independent of the total amount of energy demanded. In this paper, the energy technology is assumed to satisfy constant returns to scale, which implies that the unit cost of energy does not depend on the total quantity of energy. Thus the cost function can be written in terms of the unit cost of energy as

$$P_E = g(P_e, P_f, P_c)$$

where P_E is the composite price of energy, as in the KLEM model, and P_e, P_f and P_c are the prices of electricity, fuel oil and coal, respectively. Again a translog functional form is chosen; it can be written as

$$
\begin{aligned}
\ln P_E = {} & \ln\beta_0 + \beta_e \ln P_e + \beta_f \ln P_f + \beta_c \ln P_c + \\
& + 1/2 \left[\delta_{ee} (\ln P_e)^2 + \delta_{ff} (\ln P_f)^2 + \delta_{cc} (\ln P_c)^2 \right] \\
& + \delta_{ef} \ln P_e \ln P_f + \delta_{ec} \ln P_e \ln P_c + \delta_{fc} \ln P_f \ln P_c
\end{aligned}
$$

where symmetry constraints - $\delta_{ij} = \delta_{ji}$ - are already incorporated. Logarithmic differentiation of this function yields the cost shares for each of the three energy inputs

$$
\begin{aligned}
\Theta_e &= \beta_e + \delta_{ee} \ln P_e + \delta_{ef} \ln P_f + \delta_{ec} \ln P_c \\
\Theta_f &= \beta_f + \delta_{ef} \ln P_e + \delta_{ff} \ln P_f + \delta_{fc} \ln P_c \\
\Theta_c &= \beta_c + \delta_{ec} \ln P_e + \delta_{ef} \ln P_f + \delta_{cc} \ln P_c
\end{aligned}
$$

which define a complete system of demand equations.

For the energy submodel, the homogeneity constraints are

$$
\begin{aligned}
& \beta_e + \beta_f + \beta_c = 1 \\
& \delta_{ee} + \delta_{ef} + \delta_{ec} = 0 \\
& \delta_{ef} + \delta_{ff} + \delta_{fc} = 0 \\
& \delta_{ec} + \delta_{fc} + \delta_{cc} = 0
\end{aligned}
$$

which will also have to be imposed during estimation.

Finally, concavity needs to be tested , and the negative semidefiniteness of the Hessian determinant should again be verified at every point in the sample.

ECONOMETRIC ESTIMATION

Introduction

The separation of the optimizing behavior of producers in two stages translates into an estimation procedure also in two stages. The energy submodel is estimated first and the parameters of the energy unit cost function obtained. With these it becomes possible to calculate an exact index for the price of energy - the predicted unit cost given the prices of each energy input - which is required for the aggregate KLEM model. Then the aggregate model is estimated, in a second stage.

Econometric estimation requires the introduction of random disturbances in the share equations of the model. Here these disturbances - introduced additively - should be interpreted as execution errors in the implementation of optimal decisions.

The estimates were obtained for both models with Full Information Maximum Likelihood (FIML) based on the assumption of a joint normal distribution for the disturbances of the estimated equations(3). This represents an improvement with respect to previous studies which normally use an iterative version of Zellner's Joint Generalized Least Squares or Iterative Three Stage Least Squares. FIML is the most efficient of all consistent estimators and by definition handles completely across-equation restrictions and simultaneous equation bias. Furthermore, as is well known, the condition that the cost shares add up to one implies that the disturbances of the share equations are linearly dependent, since they must add up to zero; therefore, the variance-covariance matrix of the disturbances is singular; to make estimation possible, one equation must be dropped; FIML estimation also assures that the results are invariant with respect to the equation that is dropped. It should be pointed out that the final results obtained from the maximization of the likelihood function are somewhat sensitive to the choice of initial guesses. This is due to the limitations of the algorithms available and the lack of precision of computer calculations. The initial guesses should therefore be chosen with great care. The method used here consists in obtaining preliminary estimates with Ordinary Least Squares to be used as guesses, and if necessary modifying these to improve the fit - as measured by the log of the likelihood function - without endangering concavity.

Both models are estimated with annual data(4). The sample used for the energy submodel covers only the period 1970-1979, for lack of quantity data for previous years. Since two equations are used, and given the constraints imposed on the parameters, there are fifteen degrees of freedom. The parameters of this function are then used to compute the price of energy for the aggregate KLEM model. Since there is reliable data on energy prices, a series can be constructed for years not included in the energy sample.

The KLEM model is estimated with data for the years 1959-1978. Three equations are fitted and, given the constraints, only nine independent parameters are to be estimated. There are therefore forty-eight degrees of freedom.

The construction of the data is presented in Appendix 1.

Estimation of the energy submodel

Parameter estimates, standard deviations and t-statistics for the

Table 1

Estimates for the Energy Submodel

Coefficient	Estimated Value	Standard Deviation	t-Statistic
β_e	0.507231	0.0241980	20.9616
β_f	0.337266	0.0243663	13.8415
β_c	0.155503	0.0141058	11.0240
δ_{ee}	0.111599	0.0455041	2.45250
δ_{ef}	-0.168078	0.0551672	-3.04670
δ_{ec}	0.056479	0.0400550	1.41003
δ_{ff}	0.199335	0.0973246	1.98668
δ_{fc}	-0.025275	0.0348370	-0.72552
δ_{cc}	-0.031204	0.0580796	-0.53726

energy submodel are presented in Table 1. Some key statistics for each equation are presented in Table 2. Since only the electricity and fuel oil equations were estimated, the values corresponding to the coal equation were obtained from the others.

Table 2

Key Statistics of The Energy Share Equations

Equation	R^2	Durbin-Watson
Electricity	0.9876	0.210
Fuel Oil	0.9549	0.065
Coal	0.9594	0.665

The estimates obtained are quite encouraging. In particular, the low standard errors for the estimated coefficients indicate a level of precision which is seldom found in studies of this nature. As a consequence, most of the t-statistics are quite acceptable, justifying the effort to estimate a flexible functional form. Similarly, the measures of goodness of fit are also unusually high. The single negative aspect in this brief discussion of the estimates is the very low value for the Durbin-Watson statistics - a result which is not uncommon in this type of study. A closer look at the residuals seems to indicate that this is evidence more of specification problems than of serial correlation in the error terms. Three explanations can be suggested for this result: the possible existence of biased technological progress, which is not contemplated in the share equations estimated here; the impact of adjustment costs, leading to systematic deviation from the shares predicted by a static model - an explanation which is not quite compatible with the assumption of separability between energy and capital; or the lack of homotheticity in the energy submodel - which would rule out the two stage optimization procedure assumed throughout this paper. Any of these hypotheses requires further investigation which is beyond the scope of this paper, and which may only be possible in the future as more data points become available.

The acceptability of the estimates obtained depends also on the verification of the regularity conditions required by the cost function. Monotonicity translates, in the case of the translog, into the requirement that all predicted shares be positive. This is verified at every point in the sample. Concavity can be verified by the negative semidefiniteness of the Hessian determinant, which in this case is checked by computing all the minors for every year. These must alternate in sign - or vanish -, starting with negative for the minor of order one. The Hessians themselves are zero, given the linear homogeneity assumptions. The first minors are all negative and the second ones are all positive. The estimated cost function is therefore concave for every sample point. (More detailed estimation results are presented in Appendix 2).

Finally, it may be appropriate to test whether a simpler specification would be sufficient to explain the behavior of energy demands. It is common in studies of factor demands based on the translog to find that the Cobb-Douglas specification cannot be rejected. To check this frequent result in the case of the model presented here, a likelihood ratio test is used. The model is estimated again, under the constraint that all second order parameters be zero - which transforms the translog into a Cobb-Douglas. The log of the likelihood function is computed with and without these additional constraints: the double of the difference between the two values is distributed as a χ^2 with K degrees of freedom, where K is the number of additional constraints imposed - in this case 3. The value obtained is 7.657, which is very close to the critical value leading to the rejection of the Cobb-Douglas specification at a level of significance of 0.05. This was naturally expected, given the values of the t-statistics associated with the second order coefficients, indicating that most are significantly different from zero.

The KLEM model

The aggregate KLEM model can only be estimated after the results for the energy submodel are available. The energy unit cost function is used to obtain an energy price index which becomes an instrument in the estimation of the aggregate model. (This index is presented in Appendix 2).

Parameter estimates, standard deviations and t-statistics are presented in Table 3. Again, only the capital, labor and energy equations were estimated; the parameters of the materials equation were obtained from the constraints across equations.

Additional statistics relative to the equations in the KLEM model are presented in Table 4.

Although not as exceptional as those of the energy submodel, the results of the estimation are still quite good. Among the many previous studies of this type, it is rare to find such goodness of fit, and larger standard errors are quite common. The quality of these results may be due to the use of FIML, or to the better quality of the data which contains substantially more price variability than what was usually the case in most of the pre-1974 samples. Again, Durbin-Watson statistics provide the most significant negative point. As in the energy submodel, the residuals suggest more than a simple problem of serial correlation in the error terms. Biased technological progress, adjustment costs or lack of homotheticity may be useful leads in additional research to correct this finding.

Table 3

Estimates for the KLEM Model

Coefficient	Estimated Value	Standard Deviation	t-Statistics
α_K	0.418681	0.0302516	13.83990
α_L	0.231596	0.0234378	9.88128
α_E	0.056779	0.0043697	12.99390
α_M	0.292945	0.0317565	9.22415
γ_{KK}	-0.177740	0.1422520	-1.24947
γ_{KL}	-0.030100	0.1053250	-0.28578
γ_{KE}	0.004001	0.0312615	0.12800
γ_{KM}	0.203838	0.0397806	5.12404
γ_{LL}	0.155757	0.1046100	1.48893
γ_{LE}	-0.011739	0.0167312	-0.70163
γ_{LM}	-0.113918	0.0919174	1.23935
γ_{EE}	-0.018303	0.0144296	-1.26841
γ_{EM}	0.026040	0.0300416	0.86680
γ_{MM}	-0.115960	0.1307012	0.88721

Table 4

Key Statistics of The KLEM Share Equations

Equation	R^2	Durbin-Watson
Capital	0.979	0.489
Labor	0.919	0.104
Energy	0.986	0.668
Materials	0.937	0.055

The regularity conditions that the cost function must meet were verified at every sample point. Monotonicity is assured by the positive values of predicted shares every year. Computation of the minors of the Hessian determinant for every year as well, showed that they alternate in sign, starting with negative, while the Hessians themselves vanish. This is exactly what is required for concavity under constant returns to scale.(Appendix 2 contains the relevant detail about the estimation of the KLEM model).

Finally, the likelihood ratio test does not allow the rejection of the Cobb-Douglas specification. In spite of the significance of the second order parameters, and even though many elasticities of substitution are different from 1, the simpler specification cannot be rejected at the 1% or even the 5% level of significance.

ANALYSYS OF THE RESULTS

Introduction

The estimates obtained for both models have significant implications which will now be discussed. The adequacy of the translog specification implies that the Allen elasticities of substitution are not constant and may take any values. Own and cross price elasticities of demand can also take any values, apart from sign restrictions. The magnitude and sign of many of these elasticities have significant consequences for energy policy, and should therefore be calculated and presented.

Since the two models were estimated separately, the Allen elasticities of substitution and the price elasticities of demand will also be presented separately; it is however important to compute the price elasticities of the demand for energy when total energy input is allowed to vary; this requires the use of information from both models.

Using Uzawa's well known result(5), Allen elasticities of substitution can be obtained from the cost function as

$$\sigma_{ij} = C\, C_{ij} \,/\, C_i\, C_j$$

where σ_{ij} is the elasticity of substitution between factors i and j, C_i denotes the first derivative, $\partial C/\partial p_i$, and C_{ij} the second derivative, $\partial^2 C/\partial p_i \partial p_j$. In the case of the translog these become

$$\sigma_{ii} = [\ \lambda_{ii} + \Theta_i^2 - \Theta_i\ ] / \Theta_i^2$$

and

$$\sigma_{ij} = [\ \lambda_{ij} + \Theta_i\ \Theta_j\ ] / \Theta_i\ \Theta_j$$

where λ_{ij} is the second order parameter associated with the prices of the two factors of production i and j, and Θ_i is as before the cost share of factor i.

Own and cross price elasticities of demand can be obtained directly from the Allen elasticities of substitution and the cost shares. If ϵ_{ij} is the elasticity of demand of factor i with respect to the price of factor j, it can be obtained from

$$\epsilon_{ij} = \Theta_j\ \sigma_{ij}$$

Thus, even though the Allen elasticities of substitution are symmetric, the cross price elasticities need not be.

It is important to point out that the elasticities computed for each model assume that output remains constant. Thus, ϵ_{KE} describes the change in the demand for capital when the price of energy changes, assuming that total output, as well as the prices of inputs other than energy, remains constant; similarly, ϵ_{fe}

describes the change in the demand for fuel oil when the price of electricity increases, assuming that the total amount of energy input, as well as the prices of other fuels, remains constant. It may be of interest to compute the elasticities for the energy submodel, allowing for changes in total energy input. As the price of one form of energy increases, the composite price for the energy aggregate will go up, and given the price elasticity ϵ_{EE} in the KLEM model, total energy input will fall. Therefore, the global own price elasticity of demand is larger in absolute value than the elasticity in the energy submodel; on the other hand, cross price elasticities, when they are positive, will be lower if total energy input is allowed to vary. Similarly, the Allen elasticities of substitution in the energy submodel do not reflect appropriately the substitutability or complementarity among energy inputs; if total energy input is allowed to change, the demand for a certain type of fuel may fall when the price of another increases, even though within the energy submodel they may be termed substitutes, given a positive Allen elasticity of substitution.

The relationship between these elasticities is given by

$$E_{ij} = \epsilon_{ij} + \Theta_j \, \epsilon_{EE}$$

where E_{ij} is the total elasticity of the demand for fuel i when the price of fuel j changes and total energy input changes, ϵ_{ij} is the same price elasticity but without allowing for changes in total energy - that is, the partial elasticity within the energy submodel

-, Θ_j is the share of fuel j in total energy cost, as before, and ϵ_{EE} is the own price elasticity of energy demand in the KLEM model. Thus, even though two forms of energy may be substitutes within the energy submodel ($\epsilon_{ij}>0$), if the share of j in energy Θ_j is large or the elasticity of demand for energy in the KLEM model ϵ_{EE} is high (in absolute value), the final outcome may be a fall in the demand for i when the price of j increases ($E_{ij}<0$), that is, complementarity.

The elasticities of substitution and own and cross price elasticities of demand will be presented for each model, followed by global elasticities of demand for energy inputs.

Elasticities in the KLEM model

Since the value of the elasticities depends on the shares, it is clear that it will not be constant; Allen elasticities of substitution and price elasticities of demand were computed for every point in the sample. They are presented in Tables 5, 6, 7.

The most striking result among the elasticities of substitution presented is the evidence of significant substitutability between energy and capital. Other elasticities do not suggest any surprises. An elasticity of substitution between capital and labor of around 0.7 falls within the bounds obtained in similar studies

Table 5

Allen Elasticities of Substitution for the KLEM Model

Year	σ_{KL}	σ_{KE}	σ_{KM}	σ_{LE}	σ_{LM}	σ_{EM}
1960	0.687	1.152	2.623	0.038	-0.957	2.633
1961	0.686	1.157	2.629	0.067	-0.845	2.586
1962	0.686	1.165	2.636	0.076	-0.739	2.578
1963	0.690	1.168	2.662	0.107	-0.679	2.565
1964	0.695	1.166	2.692	0.137	-0.678	2.571
1965	0.703	1.166	2.744	0.182	-0.639	2.574
1966	0.704	1.158	2.755	0.205	-0.684	2.545
1967	0.697	1.167	2.754	0.222	-0.558	2.474
1968	0.688	1.177	2.751	0.225	-0.460	2.424
1969	0.692	1.170	2.569	0.248	-0.493	2.417
1970	0.702	1.177	2.862	0.295	-0.411	2.446
1971	0.708	1.192	2.853	0.342	-0.299	2.468
1972	0.715	1.195	3.094	0.384	-0.259	2.481
1973	0.720	1.190	3.139	0.407	-0.273	2.483
1974	0.731	1.213	3.388	0.442	-0.190	2.625
1975	0.711	1.254	3.495	0.440	-0.050	2.584
1976	0.688	1.291	3.635	0.446	0.044	2.533
1977	0.617	1.324	3.596	0.435	0.137	2.255
1978	0.494	1.405	3.836	0.422	0.228	2.062

Table 6

Own Price Elasticities of Demand for the KLEM Model

Year	ϵ_{KK}	ϵ_{LL}	ϵ_{EE}	ϵ_{MM}
1960	-0.935	-0.051	-1.259	-1.145
1961	-0.962	-0.066	-1.259	-1.124
1962	-0.988	-0.082	-1.267	-1.106
1963	-1.006	-0.096	-1.266	-1.103
1964	-1.006	-0.104	-1.260	-1.115
1965	-1.018	-0.120	-1.255	-1.127
1966	-1.007	-0.117	-1.241	-1.139
1967	-1.050	-0.127	-1.243	-1.103
1968	-1.089	-0.133	-1.248	-1.071
1969	-1.078	-0.133	-1.237	-1.087
1970	-1.110	-0.156	-1.239	-1.097
1971	-1.163	-0.178	-1.244	-1.097
1972	-1.190	-0.189	-1.240	-1.113
1973	-1.187	-0.192	-1.231	-1.130
1974	-1.246	-0.206	-1.249	-1.159
1975	-1.355	-0.209	-1.268	-1.105
1976	-1.460	-0.210	-1.277	-1.066
1977	-1.606	-0.208	-1.263	-0.956
1978	-1.874	-0.205	-1.257	-0.852

Table 7

Cross Price Elasticities of Demand for the KLEM Model

Year	ϵ_{KL}	ϵ_{KE}	ϵ_{KM}	ϵ_{LK}	ϵ_{LE}	ϵ_{LM}	ϵ_{EK}	ϵ_{EL}	ϵ_{EM}	ϵ_{MK}	ϵ_{ML}	ϵ_{ME}
1960	0.14	0.07	0.72	0.31	0.00	-0.26	0.53	0.01	0.73	1.19	-0.20	0.15
1961	0.15	0.07	0.71	0.30	0.00	-0.24	0.51	0.02	0.73	1.16	-0.18	0.15
1962	0.15	0.07	0.77	0.29	0.00	-0.22	0.50	0.02	0.71	1.13	-0.17	0.15
1963	0.16	0.07	0.78	0.29	0.01	-0.20	0.50	0.03	0.71	1.12	-0.16	0.15
1964	0.16	0.07	0.77	0.29	0.01	-0.20	0.49	0.03	0.74	1.13	-0.16	0.15
1965	0.17	0.07	0.78	0.29	0.01	-0.18	0.48	0.05	0.73	1.13	-0.16	0.15
1966	0.17	0.07	0.77	0.29	0.01	-0.19	0.48	0.05	0.71	1.15	-0.17	0.15
1967	0.17	0.07	0.81	0.28	0.01	-0.16	0.46	0.06	0.72	1.09	-0.14	0.15
1968	0.17	0.07	0.84	0.26	0.01	-0.14	0.45	0.06	0.74	1.04	-0.12	0.14
1969	0.18	0.07	0.83	0.27	0.02	-0.15	0.45	0.06	0.73	1.06	-0.12	0.15
1970	0.19	0.07	0.85	0.26	0.02	-0.12	0.44	0.08	0.72	1.06	-0.11	0.15
1971	0.21	0.07	0.88	0.25	0.02	-0.09	0.41	0.10	0.73	1.04	-0.09	0.15
1972	0.22	0.07	0.89	0.24	0.02	-0.07	0.40	0.12	0.72	1.04	-0.08	0.15
1973	0.23	0.07	0.88	0.24	0.02	-0.08	0.40	0.13	0.70	1.06	-0.09	0.15
1974	0.26	0.07	0.91	0.23	0.03	-0.05	0.38	0.16	0.71	1.07	-0.07	0.16
1975	0.26	0.07	1.02	0.20	0.02	-0.01	0.35	0.16	0.75	0.98	-0.02	0.15
1976	0.26	0.07	1.12	0.17	0.02	-0.01	0.32	0.17	0.78	0.91	0.02	0.14
1977	0.22	0.08	1.30	0.13	0.02	-0.05	0.29	0.16	0.82	0.78	0.05	0.13
1978	0.17	0.08	1.62	0.08	0.02	-0.10	0.24	0.15	0.87	0.65	0.08	0.12

for many other countries, using flexible functional forms. Labor and energy are substitutes - although moderately - as in most other countries. Complementarity between labor and materials is not shocking.

The value of the elasticity of substitution between capital and energy does not leave any doubt as to the substitutability of these two inputs. It seems therefore that the results obtained by Berndt and Wood for the US or by Denny, May and Pinto for Canada do not apply in the case of Portugal. On the other hand, the studies of Griffin and Gregory and of Pindyck, covering various countries, obtained elasticities of substitution between capital and labor that do not differ significantly from the values obtained here. In spite of Berndt and Wood's article reconciling and explaining alternative estimates for this elasticity of substitution, the controversy around its value is not completely dead.

Two explanations for the high substitutability between energy and capital can be given for the case of Portugal, along the lines of previous research: following Griffin and Gregory, who argue that capital energy complementarity is only a short term phenomenon, that surfaces in time series studies because of the small variability of prices typical of those studies, it can be pointed out that the sample used for this paper includes substantial variation in relative prices and covers a period of very fast growth in output - and very high levels of investment in Portuguese manufacturing -, all of which would induce faster adjustment than what is found in studies for the US or Canada. Alternatively, the explanation provided by Field and Grebenstein also applies in the case of this study: the capital share includes expenses with all types of capital - the distinction between fixed and working capital is not made. If, as those two authors argue, working capital is a good substitute for energy while fixed capital is a complement, then the fact that both are lumped together may explain why the final result indicates substitutability. There is no data at this point that would permit a better analisys of this issue.

Berndt and Wood argue that a positive elasticity of substitution between capital and labor has been obtained only in studies that do not explicitly consider materials inputs; and that it is not impossible to have substitutability in a KLE model, that becomes complementarity when materials are added in a nonseparable way. In the case of this study, materials are included as in the work of Berndt and Wood, but with an important correction: the share of materials excludes those inputs that come from the industry itself, as explained in Appendix 1. It is however hard to tell whether the lack of this correction in other studies biases their estimates of the elasticities of substitution in any predictable way.

The results obtained for own price elasticities of demand are quite revealing. Labor seems to be the only factor whose demand is somewhat inelastic. Although it doubles during the sample period, the elasticity of the demand for labor remains rather low (between -0.1 and -0.2). For the other factors of production, on the contrary, demand seems quite elastic. The elasticity of the demand for capital increases throughout the sample period and remains above 1 in absolute value Similarly, the demand for materials is also fairly elastic, since the elasticity stays around -1, which is not as implausible as it may appear given that only materials originating outside of manufacturing are considered.

The most significant result obtained is the high value of the own price elasticity of demand for energy. It remains at about -1.25 for the whole sample period, a value that was quite robust across the many estimations performed in the search for the best fit. This is considerably higher than the value obtained in other studies, which, although significantly different from zero, does not quite imply such an elastic demand for energy. The main explanation for this result is likely to be the same as for the substitutability between energy and capital: given the substantial changes in relative prices observed and the fast rate of growth of output, the responses to price changes captured by the values of the elasticities are probably closer to long term responses than what has been obtained in other studies. The implications are very clear: any change in the relative price of energy will have a very substantial impact on its demand, due to the possibility of substituting other factors of production for energy.

The values for the cross price elasticities of demand follow the pattern of the elasticities of substitution. It is however clear that, given the small share of energy in total cost, the impact of an increase in the price of energy on the demand for capital is rather small. In the case of the demand for labor, changes in energy prices have a virtually negligible impact. The price of capital has a more visible effect on the demand for energy; labor prices have some effect, but much less than capital prices.

Elasticities for the Energy Submodel

Tables 8, 9 and 10 display the elasticities of substitution, the own price elasticities and the cross price elasticities of demand, respectively, for the energy submodel.

Table 8

Allen Elasticities of Substitution for the Energy Submodel

Year	σ_{ef}	σ_{ec}	σ_{fc}
1970	0.0175	1.7161	0.5181
1971	0.0041	1.7068	0.4611
1972	0.0005	1.6977	0.4786
1973	0.0021	1.7042	0.4608
1974	0.1177	1.9580	0.4884
1975	0.1024	1.9008	0.4761
1976	0.1431	2.1687	0.5167
1977	0.1355	2.1643	0.5363
1978	0.1413	2.2509	0.5320
1979	0.1411	2.3682	0.5342

The positive sign of all elasticities of substitution indicates that all forms of energy are substitutes of each other, as expected. However, it is clear that the possibilities of substituting electricity for fuel oil are rather restricted. Coal seems to be a better substitute for electricity than for fuel oil, a somewhat surprising result which may be due to the limited use of coal in Portuguese manufacturing. The general increase in the elasticities of substitution during the sample period is a consequence of the significant relative price change. As oil and coal prices went up, producers moved along the isoquants towards points where the substitution posibilities increased somewhat. The changes in the values of these elasticities and the sugnificant differences among them are addtional evidence of the advantages of using a flexible functional form. If a more rigid structure had been imposed, none of these results would have been detected.

Table 9

Own Price Elasticities of Demand for the Energy Submodel

Year	ϵ_{ee}	ϵ_{ff}	ϵ_{cc}
1970	-0.2728	-0.0894	-1.0452
1971	-0.2556	-0.0709	-1.0603
1972	-0.2595	-0.0733	-1.0515
1973	-0.2553	-0.0700	-1.0595
1974	-0.2891	-0.1165	-1.1287
1975	-0.2805	-0.1110	-1.1184
1976	-0.3121	-0.1196	-1.1614
1977	-0.3157	-0.1189	-1.1510
1978	-0.3196	-0.1165	-1.1680
1979	-0.3249	-0.1116	-1.1847

Own price elasticities are all negative, as they should, but rather small in absolute value. This is a consequence of the low values for the elasticities of substitution. As the price of one fuel goes up, if total energy input remains constant and the possibility of substituting this fuel by another one is limited, the demand must not decrease very much. Still, even keeping energy constant, own price elasticities are far from zero: the effect of price increases on demand must not be neglected.

Table 10

Cross Price Elasticities of Demand for the Energy Submodel

Year	ϵ_{ef}	ϵ_{ec}	ϵ_{fe}	ϵ_{fc}	ϵ_{ce}	ϵ_{cf}
1970	0.0059	0.2668	0.0089	0.0805	0.8704	0.1747
1971	0.0013	0.2543	0.0022	0.0687	0.9152	0.1451
1972	0.0001	0.2593	0.0002	0.0731	0.8996	0.1519
1973	0.0007	0.2546	0.0011	0.0688	0.9149	0.1446
1974	0.0470	0.2421	0.0561	0.0604	0.9336	0.1951
1975	0.0389	0.2416	0.0505	0.0605	0.9377	0.1807
1976	0.0660	0.2462	0.0609	0.0586	0.9233	0.2381
1977	0.0633	0.2524	0.0564	0.0625	0.9003	0.2506
1978	0.0684	0.2512	0.0572	0.0594	0.9106	0.2574
1979	0.0716	0.2534	0.0544	0.0571	0.9137	0.2709

Similarly, cross price elasticities are quite small, especially between electricity and oil. A doubling of the oil price will induce an icrease in the consumption of electricity of only 6 to 7%, in the final years of the sample. Since own and cross price elasticities must add up to zero, this is again a reflection of the small absolute value of the former.

Global Elasticities of the Demand for Energy

Tables 11 and 12 present own and cross price elasticities of demand for each energy form, when total energy input is allowed to vary, but total manufacturing output remains fixed.

These are the most important results for policy purposes, from a two stage model. In fact, under the assumption that, given the small share of energy in total output cost, an increase in energy prices will not affect substantially the level of output, the response of manufacturing with respect to the demand for each type of energy is given by these elasticities. They incorporate, as discussed above, the substitution of the now more expensive form of energy by alternative energy sources, plus the possibly more intensive use of other inputs to replace energy.

The values obtained are necessarily higher for own price elasti-

Table 11

Global Own Price Elasticities of the Demand for Energy

Year	E_{ee}	E_{ff}	E_{cc}
1970	-0.901	-0.507	-1.238
1971	-0.923	-0.463	-1.241
1972	-0.916	-0.467	-1.243
1973	-0.916	-0.456	-1.243
1974	-0.885	-0.616	-1.283
1975	-0.906	-0.593	-1.280
1976	-0.856	-0.708	-1.306
1977	-0.841	-0.709	-1.298
1978	-0.828	-0.725	-1.308
1979	-0.810	-0.749	-1.319

cities than those obtained in the energy submodel. They indicate that fuel is the least elastic, or price responsive, of all sources of energy; that the demand for electricity is still fairly inelastic; and that coal is the only fuel which responds more than proportionately to a price increase. In any case, and for all three sources of energy, global price elasticities of demand are sufficiently large to imply the rejection of any method of energy analysis, demand forecasting or policy simulation, which does not include the impact of prices on demand.

Global cross price elasticities of demand are negative, with the

Table 12

Global Cross Price Elasticities of the Demand for Energy

Year	E_{ef}	E_{ec}	E_{fe}	E_{fc}	E_{ce}	E_{cf}
1970	-0.412	0.074	-0.620	-0.112	0.241	-0.243
1971	-0.390	0.069	-0.665	-0.117	0.248	-0.247
1972	-0.393	0.070	-0.657	-0.116	0.242	-0.242
1973	-0.386	0.071	-0.660	-0.115	0.254	-0.242
1974	-0.452	0.088	-0.539	-0.094	0.338	-0.304
1975	-0.443	0.080	-0.575	-0.101	0.312	-0.301
1976	-0.523	0.101	-0.483	-0.086	0.379	-0.351
1977	-0.527	0.105	-0.469	-0.085	0.375	-0.340
1978	-0.540	0.111	-0.451	-0.081	0.402	-0.351
1979	-0.566	0.119	-0.430	-0.077	0.429	-0.367

exception of those involving coal and electricity. This is a consequence of the high value of the own price elasticity of demand for energy in the aggregate model, combined with the small positive cross price elasticities in the energy submodel. The interpretation is that, when the price of fuel, for example, increases, the limited substitutability with electricity or coal implies that the price of the energy composite increases considerably; this induces producers to try and reduce total energy input by using more intensively capital, labor and materials; the reduction in energy input translates into lower demand for electricity and coal, as well as fuel; and this scale effect is more important than the incentive to use electricity or coal more intensively as a substitute for fuel.

A Brief International Comparison of Estimated Elasticities

It is now possible to attempt a systematic comparison of the results obtained in this study with those of similar studies for other countries. The comparisons are not always entirely valid: the other studies referred to use data from different years; the definition of the variables is not exactly the same; in most countries other sources of energy are also important; etc. However, with this qualification, the comparison can still provide interesting insights, by highlighting differences and similarities. The first results to be compared are the Allen partial elasticities of substitution in the KLEM model. They are displayed in Table 13. It is clear from this table that the results obtained in this study are much closer to those of the international studies of Griffin and Gregory, and Pindyck, than to those obtained for the U.S. or Canada alone. The elasticity of substitution between capital and labor falls between the values obtained in each of those international studies. Energy and Capital seem to be more substitutable in Portugal than the average of the nine or ten countries reported by Griffin and Gregory and by Pindyck; labor and energy, on the other hand, display a much lower elasticity of substitution in Portugal. The results of Berndt and Wood for the

Table 13

Comparison of Allen Elasticities of Substitution in the KLEM Model

	(1) Portugal	(2) U.S.	(3)* Intern.	(4) Canada	(5)* Intern.
σ_{KL}	0.68	1.01	0.39	4.7	0.84
σ_{KE}	1.24	-3.25	1.04	-10.6	0.80
σ_{KM}	3.12	0.54	na	-0.97	na
σ_{LE}	0.37	0.64	0.83	4.27	0.96
σ_{LM}	-0.08	0.59	na	0.40	na
σ_{EM}	2.38	0.75	na	0.11	na

Notes:

* : KLE model, materials not included.

na : not applicable.

(1) - This study (elasticities at the means of the exogenous variables)

(2) - Berndt and Wood (1975) - (averages of five years)

(3) - Griffin and Gregory (1976) - (averages of 9 countries)

(4) - Denny, May and Pinto (1978) - (averages of 4 years)

(5) - Pindyck (1979) - (averages of 10 countries)

Table 14

Comparison of Price Elasticities in the KLEM Model

	(1) Portugal	(2) U.S.	(3)* Intern.	(4) Canada	(5)* Intern.	(6) Canada
ϵ_{KK}	-1.31	-0.48	-0.35	-0.19	-0.46	-0.76
ϵ_{KL}	0.22	0.28	0.22	na	na	0.20
ϵ_{KE}	0.07	-0.15	0.13	na	na	-0.004
ϵ_{KM}	1.02	0.34	na	na	na	0.57
ϵ_{LK}	0.20	0.06	0.12	na	na	0.20
ϵ_{LL}	-0.19	-0.46	-0.23	-0.62	-0.43	-0.49
ϵ_{LE}	0.02	0.03	0.11	na	na	0.04
ϵ_{LM}	-0.02	0.37	na	na	na	0.25
ϵ_{EK}	0.36	-0.17	0.31	na	na	-0.05
ϵ_{EL}	0.12	0.18	0.48	na	na	0.55
ϵ_{EE}	-1.26	-0.47	-0.79	-0.49	-0.84	-0.49
ϵ_{EM}	0.78	0.47	na	na	na	-0.02
ϵ_{MK}	0.92	0.03	na	na	na	0.25
ϵ_{ML}	-0.02	0.16	na	na	na	0.11
ϵ_{ME}	0.14	0.03	na	na	na	0.00
ϵ_{MM}	-1.03	-0.22	na	-0.04	na	-0.36

Notes: see next page

U.S. and of Denny, May and Pinto for Canada cannot be reproduced in Portugal. The main differences are the complementarity between energy and capital which those two studies have found, plus the significantly different values of the elasticities involving materials; this latter discrepancy may be due to the fact that in this study materials input has been defined to include only those not originating in manufacturing, which seems to be more appropriate for the type of model used in these papers.

A second comparison is based on the price elasticities of the KLEM model. This comparison, as displayed in Table 14, includes also the results of Fuss for Canada. The most striking conclusion from this comparison seems to be that own-price elasticities of demand are

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<u>Notes (Table 14):</u>

* : KLE model, materials not included.

na : not available or not applicable.

(1) - This study (elasticities at the means of the exogenous variables)

(2) - Bendt and Wood (1975) - (averages of 5 years)

(3) - Griifin and Gregory (1976) - (averages of 9 countries)

(4) - Denny, May and Pinto (1978) - (averages of 5 years)

(5) - Pindyck (1979) - (average of 10 countries)

(6) - Fuss (1977) - (elasticities at the means of the exogenous variables)

higher in Portugal than in other countries, with the remarkable exception of labor. The elasticities of the demand for capital, energy and materials are higher than the highest values obtained in all other studies. In the case of labor, however, the own-price elasticity, although not far from the value obtained by Griffin and Gregory, is still below the figure for any other country. Cross price elasticities reflect the values of the Allen elasticities of substitution: there are no surprising values. It should be emphasized though that energy prices seem to have a very small impact on the demands for capital or labor. Finally, the cross-price elasticities between capital and labor are not far from the values obtained in almost all the other studies.

A similar comparison of elasticity estimates should also be made for the energy submodel. Here it is possible to include some additional studies covering countries which are not as developed as those mentioned in the above comparisons. Estimates obtained for India and Korea provide a comparison with countries in a state of development below or similar to that of Portugal. However, it should be pointed out again that these comparisons are not completely valid since the sources of energy considered in each study are not always the same. The elasticity estimates relevant for comparison with those obtained for Portugal are presented in Table 15.

The comparison shows that the estimates obtained for Portugal are not far from those usually found in other countries. Most of the values for Portuguese elasticities in the energy submodel fall in the interval of values for other countries. A closer look shows that own price elasticities do not diverge very much, with the possible exception of oil. For this fuel, the price elasticities obtained for the U.S. and for Canada are significantly larger than what is common in other countries. Clearly the structure of energy demand in North America is sufficiently different to explain the finding of a rather different - and more elastic - response of oil demand to its price. Electricity demand seems to be the least elastic, while coal demand shows strong price responsiveness.

Cross price elasticities do not display significant discrepancies across countries, in the studies quoted here. Besides, the lack of validity of these comparisons is particularly pressing in the case

Table 15

Comparison of Price Elasticities in the Energy Submodel

	(1) Portugal	(2) U.S.	(3)* Intern.	(4) India	(5) Korea	(6)* Canada
ϵ_{ee}	-0.30	-0.66	-0.12	-0.14	-0.85	-0.52
ϵ_{ef}	0.06	0.30	0.06	0.09	0.18	0.27
ϵ_{ec}	0.25	0.09	0.12	0.10	0.68	0.09
ϵ_{fe}	0.06	1.27	0.17	0.12	0.11	0.77
ϵ_{ff}	-0.12	-2.75	-0.35	-0.09	-0.30	-1.22
ϵ_{fc}	0.06	0.69	0.35	0.15	0.19	0.30
ϵ_{ce}	0.90	0.31	0.27	0.16	0.83	0.27
ϵ_{cf}	0.23	0.74	0.38	0.13	0.39	0.32
ϵ_{cc}	-1.13	-1.46	-1.50	-0.15	-1.22	-1.41

Notes:

* : other sources of energy included in the model.

(1) - This study (elasticities at the means of the exogenous variables)

(2) - Halvorsen (1977) - (weighted averages of 10 sectors)

(3) - Pindyck (1979) - (averages of 10 countries)

(4) - Uri (1979)

(5) - Shin (1981)

(6) - Fuss (1977) - (elasticities at the means of the exogenous variables)

Table 16

Comparison of Global Price Elasticities of Energy Demand

	(1) Portugal	(2) U.S.	(3) Intern.	(4) Canada
E_{ee}	-0.86	-0.92	-0.60	-0.74
E_{ef}	-0.49	0.23	-0.10	0.19
E_{ec}	0.09	0.04	-0.03	0.02
E_{fe}	-0.50	0.74	-0.31	0.55
E_{ff}	-0.67	-2.82	-0.50	-1.30
E_{fc}	-0.09	0.63	0.19	0.23
E_{ce}	0.34	0.07	-0.21	0.05
E_{cf}	-0.32	0.69	0.22	0.24
E_{cc}	-1.29	-1.52	-1.66	-1.48

Notes:

* : other sources of energy included in the model.

(1) - This study (elasticities at the means of the exogenous variables)

(2) - Halvorsen (1977) - (weighted averages of 10 sectors)

(3) - Pindyck (1979) - (averages of 10 countries)

(4) - Fuss (1977) - (elasticities at the means of the exogenous variables)

of cross price elasticities, which will depend crucially on how many alternative sources of energy are being considered. This said, it is nevertheless worth noting that the cross price elasticities between electricity and fuel oil in Portugal are surprisingly low. An increase in the price of either of these two types of energy will leave the demand for the other virtually constant - if total energy input in manufacturing remains constant. This seems to indicate that electricity and fuel oil are used in rather different circumstances or applications, and therefore are hardly substitutable.

As mentioned above, the most interesting results are the global price elasticities of demand, which represent the response in the demand for a particular type of energy when prices change, allowing for a change in the total energy input in manufacturing. These global price elasticities obtained in four different studies are presented in Table 16. Unfortunately it is no longer possible to compare the estimates for Portugal with those for countries in a similar level of development. However, because Table 16 includes the results obtained by Pindyck in a study of ten countries, the comparison is based on a fairly diversified sample.

As can be inferred from the previous analysis, this comparison does not display any particular surprises. The estimates obtained for Portugal are quite compatible with the evidence from other studies. The emerging pattern seems to show that the demands for electricity and fuel oil are less elastic than for coal, although, as pointed out before, fuel oil is very price responsive in North America. In all studies surveyed the demand for coal is very elastic. In the case of the other two sources of energy, although demand responds less than proportionately to price increases, the absolute value of the elasticities is large enough to force the rejection of any assumption that demand is not price responsive.

As for cross price elasticities, the only striking result is the negative sign of the elasticity of the demand for fuel oil (electricity) with respect to the price of electricity (fuel oil). This result was also found in Pindyck's study, and is a consequence of the small - but positive - cross price elasticity in the energy submodel, combined with a significant value for the price elasticity of the demand for energy in the KLEM model. Additionally, coal seems to respond more strongly in Portugal than in other countries to changes in the price of oil. This is however a consequence of the small share of coal in energy in Portugal. In fact, and referring again to Table 15, a similar strong cross price elasticity is found in Korea, a country where coal also represents a small share of the total.

Implications for Energy Policy

The Portuguese government has been preparing over the last few years a National Energy Plan(6). This represents a substantial effort to unify energy policy, outline available options and plan investments associated with the expansion of energy supply. Many of the studies required by the National Energy Plan were undertaken by teams of foreign experts, supported by the United States Department of Energy, under a program of assistance in the definition of an energy policy for Portugal. The Plan is the first serious effort to address energy issues coherently and with a sound technical basis, provided partly by foreign assistance.

Preliminary versions of the Plan have been presented in 1982 and 1984 for public discussion. Although no final approval has yet been granted, it is possible to summarize what seem to be the dominant lines of government policy as embodied in the National Energy Plan. These include:

- plans to meet a projected rapid increase in energy consumption, leading to a substantially higher energy/GNP ratio in the future; the growth in consumption is projected to be led by the demand for energy in manufacturing;
- a policy of diversification of energy sources, with a more intensive use of coal and the introduction of natural gas and nuclear energy as new sources;
- a quite substantial share of nuclear power in the supply of electricity.

As a consequence of this orientation, the Plan predicts a very large investment effort in the supply of energy, which naturally becomes quite capital intensive.

Although commended by many policy makers as the first comprehensive study of energy policy, the Plan has also been attacked due to the existence of some serious methodological flaws. In particular, all projections of energy demand used in the Plan were based on models where prices play no role. The growth in the consumption of energy follows GNP growth and expected changes in the structure of the economy; but, as pointed out elsewhere (World Bank, 1984), if energy prices were to double, the predicted levels of consumption would remain unaltered.

The assumption of a negligible price elasticity of energy demand should be discarded, at least as far as manufacturing energy demand goes. According to the results of this study, all forms of energy used in Portuguese manufacturing display significant price elasticities, which in fact fall within the values obtained for other countries. Only coal seems to have elastic demand; but both fuel oil and electricity display sufficient price responsiveness to justify the most serious misgivings with respect to demand forecasts based on the assumption that prices do not matter.

Portuguese energy prices, in particular in the manufacturing sector are expected to increase in real terms. A policy of subsidizing energy prices - followed over the last twelve years - has been abandoned. As a consequence, energy in manufacturing will be priced according to long run marginal cost, which will imply a significant increase in real prices.

It is difficult to believe, given the evidence obtained in this study, that energy consumption will continue to grow rapidly, as if prices were to remain low. Therefore, the current plan to expand supply - at great cost - based on an inflated forecast of energy demand growth is likely to create in Portugal the same problems and difficulties that beset the energy industry in other countries: overcapacity and the inability to pay back investments which are not warranted by demand growth[7].

SUGGESTIONS FOR FURTHER WORK

In spite of the encouraging results obtained, this study must be considered only a first step towards a better understanding of the determinants of energy demand in Portuguese manufacturing. In fact, although the methodology was sound and may be considered state-of-the-art as far as energy demand studies go, it is possible to envision a series of improvements which, with a more complete data set and a more comprehensive model, may lead to subsequent improvements in the quality and richness of the results.

There are two basic areas where further research may prove rewarding. The first one consists in maintaining the approach used here and the main structure of the model but adding to it some refinements which essentially correspond to an assumption of a somewhat more complex - and more realistic - behavior on the part of producers. The second one would be related to an introduction of dynamic aspects in the model, carefully distinguishing between short and long-term responses to price changes, within the context of explicit adjustment costs.

The areas where the model assumptions relative to producer behavior may be considered too simplistic have to do with the measurement of the costs of two factors of production: labor and capital. As explained in Appendix 1, the price of labor is represented by an index of average wages, while for the price of capital a traditional index of the user-cost of capital is constructed. Both measures are to a certain extent inappropriate.

If the only measure of the price of labor is the immediate cash-disbursement when labor is utilized, it is implicitly assumed that labor is a variable factor of production, which can be discarded at no extra cost when it becomes redundant. In fact, this was not the case at all during the sample period covered by this study. The termination of a labor contract was always rather difficult, becoming virtually impossible after the change in political regime in 1974/75. Thus labor should be treated to a large degree as a fixed factor of production, which certainly changes the way its cost should be measured. At the very least, a risk premium should be added to the wage rate to capture the cost of having to maintain the level of employment when, given unpredictable changes in demand, some labor becomes redundant. Since employment regulations changed considerably in 1974/75, this risk premium would normally change as well, leading to a perhaps substantially different series for the price of labor. The steady increase in unemployment in Portugal since 1974, in spite of dramatic drops in real wages, and independently of swings in aggregate demand, seems to indicate that Portuguese producers take this risk premium quite seriously and attribute a large - and perhaps growing - value to it.

Similarly, the construction of the series for the user-cost of capital involved simplifications which may have non-negligible consequences for energy demand analysis. In fact, it was assumed that producers hold static expectations with respect to capital good prices, which implies that possible capital gains associated with future increases in the price of the stock of capital are not taken into account in the measurement of the user cost of capital. This assumption was necessary for two types of reasons: first, various attemps made to specify more sophisticated expectation formation mechanisms led to unacceptable values for the user cost of capital series; second, the full integration of the impact of inflation on the cost of capital required that at least two other effects be taken into account - the changes in the real level of taxation of capital and the impact of liquidity constraints. Both of these effects are likely to be important in Portugal, given that the tax system is very partially indexed and given the existence of credit ceilings in nominal terms. Both effects will also work to offset any reduction in the user cost of capital due to an acceleration of inflation, implying that the net effect of ignoring inflation is posibly small. In any case it is not clear what the impact of these simplifications is on the computation of the user cost of capital and ultimately on the estimation results; but in future research on this topic it would be very desirable to use a more comprehensive measure of the cost of capital, based on a better treatment of the consequences of inflation.

The other area where a more sophisticated approach might yield interesting results is the introduction of dynamic aspects in the decision making process of producers. It would be particularly appropriate to deal explicitly with adjustment costs, especially with respect to changes in the demand for capital and labor(8). Both of these factors - labor for the reasons indicated above -

should be treated as quasi-fixed; and temporary deviations between the desired and the actual level of these inputs may be optimal in the context of significant adjustment costs. The static nature of the model used here implies instantaneous and costless adjustment to optimal long term levels. If adjustment costs are important, predictions based on this model may be quite inaccurate.

CONCLUSIONS

This paper uses a two stage model of factor demand to estimate the parameters determining energy demand in Portuguese manufacturing. In the first stage, a capital-labor-energy-materials framework is used to analize the substitutability between energy as a whole and other factors of production; in the second stage, total energy demand is decomposed into oil, coal and electricity demands. The two stages are fully integrated since the energy composite used in the first stage and its price are obtained from the second stage energy submodel.

The functional form used in both models is the transcendental logarithmic cost function. Estimates are obtained with Full Information Maximum Likelihood. The methodology incorporates all the advances introduced in recent studies of energy demand, both in model specification and in econometric estimation.

The results are very encouraging. Goodness of fit and statistical significance are quite acceptable, given the values usually obtained in similar studies. The elasticities of substitution as well as the price elasticities of demand derived from the estimates fall within the intervals corresponding to a consensus among researchers in this field. In one specific point, the elasticity of substitution between aggregate energy and capital, this study finds evidence of substitutability - as in other international studies of manufacturing energy demand - instead of complementarity - as seems to be the standard result for the cases of the U.S. and Canada.

The implications of the results are substantial. As expected, the estimates obtained confirm a significant price elasticity of the demand for energy, with different values for different energy forms. Thus, in Portugal, as in all the countries for which these studies have been undertaken, all the evidence indicates that energy demand in manufacturing responds significantly to price changes, given important substitution possibilities among energy forms and between energy and other factors of production. The role of price changes in energy demand forecasting as well as in energy policy in general is clearly established. At a time when Portugal is about to embark on a comprehensive National Energy Plan, this point is worth emphasizing, since it justifies by itself the present study.

FOOTNOTES

(1) - The first public version of the National Energy Plan was published in 1982; see D.G.E. (1982).

(2) - In fact, a recent theorem due to Lau states that a linear-in-parameters and parsimonious functional form for a unit cost function cannot be simultaneously globally theoretically consistent and flexible for all theoretically consistent data; see Lau (1985).

(3) - Although FIML is traditionally used under the assumption of normality, there are some potential problems in the case of systems of share equations. In fact, the implicit distribution of the error term in the equation which is not estimated will not be normal. Furthermore, the normal distribution does not rule out the occurrence of very large positive values, which would imply negative disturbances for the non-estimated equation and perhaps negative shares.

(4) - All the estimations were performed with version 3.5 of TSP, on a DEC System 2060.

(5) - See Uzawa (1962).

(6) - See D.G.E. (1982).

(7) - For a discussion of the dangerous consequences of demand forecasting errors in the case of the U.S. electric utility industry see Houthakker (1983).

(8) - For a recent attempt to introduce explicit adjustment costs in the context of a factor demand model see Pindyck and Rotemberg (1984).

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APPENDIX 1
DATA CONSTRUCTION

Table A1.1

Actual Expenditure Shares: KLEM Model

Year	Expenditure (10^6 Esc.)	Capital	Labor	Energy	Materials
1960	19183.5	.391327	.134108	.048545	.426090
1961	20904.7	.388087	.136423	.052728	.422762
1962	22035.4	.394211	.141350	.052437	.412002
1963	24349.1	.382443	.141946	.054569	.421042
1964	26900.0	.383241	.151821	.054896	.410042
1965	29987.0	.376228	.157385	.055865	.410522
1966	32478.0	.387833	.170212	.055015	.386940
1967	33530.4	.398650	.178051	.054736	.368563
1968	36436.8	.391611	.184835	.056728	.366826
1969	39723.6	.427299	.189843	.058672	.324186
1970	42626.6	.408132	.203864	.068916	.319088
1971	54623.0	.357666	.257691	.055906	.328737
1972	67642.5	.330437	.275151	.051832	.342580
1973	86975.8	.327856	.263259	.048554	.360331
1974	117267.0	.272756	.293300	.045776	.388168
1975	122258.0	.151999	.380253	.054709	.413039
1976	151563.0	.151734	.371291	.054119	.422856
1977	215707.0	.192632	.311179	.053896	.442313
1978	283013.0	.213469	.277098	.060091	.449342

<u>Data construction</u>:

The series in Table A1.1 were essentially obtained from data published in 'Estatisticas Industriais', (Manufacturing Sector Statistics). An intertemporally consistent sample of the manufacturing sector is considered. It represents 85 to 95% of the global sample for which published data is available over the period 1960-1978. Both total expenditure and expenditure with each individual input are obtained by aggregating entries at 6-digit level of disaggregation of the Standard Classification of Economic Activities. Careful efforts were in order to make each of the series defenitionally compatible for the period 1960-1978.
Total expenditure is not reported and was obtained from the reported information by adding the expenditures in energy and materials to value added. As to expenditures in individual inputs, those of labor and energy are directly reported. Capital expenditures were computed as a residual in the value added. Expenditure in materials are obtained from the reported series, by netting out the intra-manufacturing flows under the input/output expenditure structure for 1959, 1964, 1970, 1974 developed by Instituto Nacional the Estatística (National Institute of Statistics).

Table A1.2

Price Indices: KLEM Model

Year	Capital	Labor	Energy	Materials
1960	.82756	.83817	.99871	.98862
1961	.88483	.87957	.97493	.98342
1962	.94249	.93232	1.01366	.97983
1963	1.00000	1.00000	1.00000	1.00000
1964	1.03327	1.06253	.97703	1.03902
1965	1.11404	1.19105	.95242	1.09695
1966	1.22080	1.30439	.96262	1.23445
1967	1.38782	1.41717	.98244	1.26067
1968	1.53364	1.49808	1.02266	1.27008
1969	1.62268	1.61436	1.01296	1.38282
1970	1.80398	1.92528	1.01412	1.45319
1971	2.12539	2.43460	1.04026	1.55261
1972	2.41155	2.94798	1.02333	1.69302
1973	2.66610	3.36212	1.04386	1.89458
1974	3.48765	5.22099	1.28139	2.28197
1975	4.90469	7.15822	1.67006	2.68206
1976	6.51514	9.24711	1.97241	3.07546
1977	10.37210	10.78240	2.53138	3.97177
1978	16.40500	12.60820	3.16390	4.82657

<u>Data construction</u>:

The price index of capital P_k is obtained according to $P_k = P_i(r+d)$, where P_i is the Divisia price index of investment goods, r is the interest rate on long run (1 to 7 years) credit and d is the depreciation rate of capital. The Divisia price index of investment goods aggregates the price series of structures, machinery and transportation equipment implicit in the gross capital formation series published in 'Contas Nacionais' (National Accounts). The quantity weights are the constant price series for the three components of gross capital formation, also from 'Contas Nacionais'. The long run interest rate is administratively set. The corresponding series was obtained from 'Diário do Governo' (Official Government Bulletin) as simple annual average rates. The depreciation rate of capital is obtained from the 'Inquéritos Industriais' 1958, 1964, 1971 (Census of Manufacturing) as the implied rate for the inter-survey period, given investment and capital in the survey years. For the remaining years, it is a linear extrapolation. The depreciation rate averages 7% over the period 1960-1978.

The price index of labor is a Divisia index aggregating the hourly average price of production and non-production labor. These are obtained from total expenditures and the number of hours of work for each of the two types of labor. Expenditure in both types of labor and hours of work by production workers are reported in 'Estatisticas Industriais'. The number of hours of work by non-production workers is obtained from the total number of non-production workers, as reported in 'Estatisticas Industriais', under the hipothesis that the average number of hours per worker is the same for production and non-production workers.

The energy price index is estimated according to the unit cost function obtained for the energy sub-model. It aggregates the price indices of electricity, fuel and coal which will be described following Table A1.4.

The price index of materials is a Divisia index aggregating the implicit output price deflators for agricultural goods, mining, and services, as published in 'Contas Nacionais'. The quantity weights were obtained from the input/output tables for 1959, 1964, 1970, 1974. For the remaining years simple interpolated values are used.

Table A1.3

Actual Expenditure Shares: Energy Sub-Model

Year	Expenditure (10^3 Esc)	Electricity	Fuel	Coal
1970	2219990	.571693	.204693	.223614
1971	2791160	.609253	.205454	.185293
1972	2740960	.612320	.246519	.141160
1973	3109710	.623463	.246235	.130302
1974	3928550	.536246	.350634	.113120
1975	4729210	.485076	.350484	.164440
1976	6548620	.425906	.434983	.139111
1977	8733160	.430478	.431104	.138418
1978	13007900	.452765	.426631	.120604
1979	17731200	.451182	.440457	.108361

Data construction:

The series in Table A1.3 were constructed from data published by 'Direcção-Geral de Energia' (Department of Energy). Total energy expenditure was obtained from quantity and price series for electricity, fuel (which represents an average of 91% of the total input of petroleum products) and coal products. It should be pointed out that total energy expenditures in Tables A1.1 and A1.3 differ in a sistematic way. This is a result of the different samples used in each source.

Table A1.4

Price Indices: Energy Sub-Model

Year	Electricity	Fuel	Coal
1960	1.01739	1.00000	.93817
1961	.98261	1.00000	.89965
1962	1.04565	1.00000	.94385
1963	1.00000	1.00000	1.00000
1964	.95870	1.00000	.98742
1965	.89348	1.00000	1.05306
1966	.91739	1.00000	1.03543
1967	.94130	1.00000	1.08832
1968	1.05000	1.00000	.98449
1969	1.04565	.94400	1.06095
1970	1.06522	.77800	1.45810
1971	1.07174	.72200	1.92529
1972	1.07391	.72200	1.71054
1973	1.07826	.72200	1.92229
1974	1.07826	1.18900	2.92001
1975	1.45652	1.44400	3.83219
1976	1.45652	2.22200	4.18680
1977	1.87609	2.91100	4.80777
1978	2.22609	3.81100	6.19495
1979	2.55653	4.96699	7.44149

<u>Data construction</u>:

Energy prices are administratively set. The corresponding disaggregated series were obtained from 'Diário do Governo'. For electricity and fuel ordinary indices were used. The coal price index is a Divisia index aggregating prices of different types of coal. The quantity weights were obtained from D.G.E.

A Final Note

Two different sources of data are used for the KLEM model and the energy sub-model. This however should not create any problem. In fact, given the broad base of the samples for the two cases, it is fair to assume that both samples accurately reflect the caracteristics of the whole population, and are therefore mutually compatible.

APPENDIX 2
ESTIMATION RESULTS

Table A2.1

Estimated Shares: Energy Sub-Model

Year	Electricity	Fuel	Coal
1970	.507231	.337266	.155503
1971	.536228	.314744	.149029
1972	.529894	.317339	.152767
1973	.536860	.313743	.149395
1974	.476798	.399554	.123647
1975	.493296	.379602	.127102
1976	.425732	.460753	.113515
1977	.416006	.467383	.116611
1978	.404525	.483863	.111612
1979	.385843	.507170	.106987

Table A2.2

Estimated Shares: KLEM Model

Year	Capital	Labor	Energy	Materials
1960	.455298	.217494	.057820	.275768
1961	.440782	.217494	.057825	.283899
1962	.427218	.224625	.056586	.291571
1963	.418681	.231596	.056778	.292945
1964	.418747	.235970	.057620	.287663
1965	.412890	.245608	.058461	.283041
1966	.418003	.243434	.060639	.277924
1967	.397082	.249857	.060353	.292708
1968	.379329	.254180	.059560	.306931
1969	.384345	.254548	.061299	.299808
1970	.370341	.273126	.060926	.295607
1971	.347725	.296911	.060084	.295280
1972	.337096	.313242	.060898	.288764
1973	.338312	.317649	.062322	.281717
1974	.316065	.354514	.059322	.270099
1975	.279954	.371891	.056340	.291815
1976	.250344	.385681	.054989	.308986
1977	.216204	.363546	.057140	.363110
1978	.170211	.349524	.058078	.422187

LIST OF INSEAD RESEARCH WORKING PAPERS

80/01 "Identifying cognitive style determinants of retail patronage, by Christian PINSON, Arun K. JAIN and Naresh K. MALHOTRA, January 1980.

80/02 "Dimensions culturelles des conceptions de management - une analyse comparative internationale", par André LAURENT Février 1980.

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