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STRUCTURAL CHANGE AND EVOLUTION OF ENERGY CONSUMPTION IN FRENCH INDUSTRY BETWEEN 1970 AND 1982

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FOREWORD

Many of today's most significant socioeconomic problems, such as slower economic growth, the decline of some established industries, and shifts in patterns of foreign trade, are inter- or transnational in nature. Intercountry comparative analyses of recent historical developments are necessary when we attempt to identify the underlying processes of economic structural change and formulate useful hypotheses concerning future developments. The understanding of these processes and future prospects provides the focus for IIASA's project on Comparative Analysis of Economic Structure and Growth.

Our research concentrates primarily on the empirical analysis of economic structural change. This paper analyzes time-series data and helps to reveal the impact of structural change on energy consumption in France. It continues former analyses which were carried out for the USA and the FRG.

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Structural Change and Evolution of Energy Consumption in French Industry between 1970 and 1982

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INTRODUCTION

The evolution of energy consumption in the period following the oil shocks is often explained in two opposing ways: either one believes that there is now a completely new way of consuming energy, which has brought a steep decrease in the level of energy demand, or that the oil shocks have caused very little change in the pattern of energy consumption and that energy consumption has decreased, first, in line with a long-term trend, and, second, because of changes in the structure of the economy, which have resulted in a relative decline of the most energy-intensive sectors.

As discussed in Part 1, after the oil shocks the energy demand is no longer related to growth in the same way as before. The main indicator used in forecasts, i.e. the energy/GDP elasticity coefficient, has become unreliable since the first oil shock, both for the total economy and for industry alone. On the other hand, the level of industry's elasticity coefficient shows that the energy coefficient was decreasing even before 1973. Study of the energy consumption for each branch of industry should allow us to estimate the effect of structural changes.

One can see that the structure of French industry has evolved little when one examines the relative share of each sector in terms of total value added. Only a few sectors are clearly receding or expanding; the changes happen mainly within each branch. For this reason we will see that the effect of "structural change" on the energy consumption is limited. The study will show that the energy content of the value added of nearly all branches has declined, but at very different speeds for each sector, and that there is an alteration in this decrease of the energy coefficient for the industry as a whole and for most of its sectors after 1979, which is the most important alteration year of the 1970s.

There are two ways of studying energy consumption: the economic way, which relates the energy consumption to economic variables, and the technoeconomic way, which relates the energy consumption to the products and technologies of a sector. This present study is of the first type; energy consumption is considered in terms of the changes in the economic structure itself, and not in terms of the technical changes that may bring a decrease in energy demand. The latter type is suitable for a sectoral study, recomposing the total energy consumption from energy coefficients for each product and each process. Study of the energy consumption of the whole industry in this way would require a considerable amount of information, and would turn an economic study into a technical compilation.

This paper starts from aggregated data, and tries to decompose the energy consumption as much as possible, depending on the availability of economic indicators. It seems however that currently the availability of energy data limits the study to the aggregated branches; the consequences of structural change on energy consumption are therefore calculated by means of a simple arithmetic method. At a more disaggregated level, a study of growth is possible, with assumptions as to the consequences of differential growth on energy consumption within the individual branches .

The two fields of study (economic and technical) are not strictly separated, since development within each field has consequences for the other. Therefore some comparisons between these two fields are made. However the main objective of this paper remains economic, starting from the dynamics of development and leading to energy consumption.

The main economic indicator considered is the ratio between energy consumption expressed in quasi-physical units (tons of oil equivalent, t.o.e.), and the value added for a particular sector, either at constant or current prices. This ratio is basically different from a "physical" ratio that would consider the specific requirements of one unit product. In this ratio, the energy consumption is the result of an aggregation of different types of energy by means of conversion coefficients; its value is thus dependent on the chosen set of coefficients that are supposed to express both the calorific power of each energy carrier and the return associated with equipment using the type of energy considered. The value added is not only an indicator of "activity" of a sector (this could also be expressed by a physical indicator or an index of production), but it is also an indicator of the valorization of the activity, and in this respect it is rather more an economic indicator.

Thus defined this ratio appears meaningless from a technoeconomic point of view, but its evolution is not meaningless with respect to economic development. The "energy content" of the total industry can be expressed by this coefficient, and the energy content reflects the pattern of development during past decades. More than witnessing the long-term trend toward a relative decline of the role of energy in the economic growth, it indicates a clear alteration between the growth that was made possible by the availability of cheap energy, and the type of growth that took place after in the 1970s. This alteration is indeed more a consequence of the crisis of the 1970 to 1980s than the effect of an external shock. The changes in the structure of industry should indicate the reasons for the decrease in energy consumption.

1. EVOLUTION OF THE LINKS BETWEEN GROWTH AND ENERGY CONSUMPTION

1.1. The Elasticity between Energy and GDP

Before looking at industry itself, we should first consider the total economy. One can look at the evolution of the energy consumption from two points of view:

a) the elasticity coefficient, which assumes that there are stable links between energy demand and growth when each varies only marginally,

b) the energy coefficient, which is well known for its proverbial decrease, assuming a given decreasing trend , independent of growth.

The latter point of view supposes that those forces that prompted the past decrease of the energy coefficient will prevail in the future; the former supposes that energy demand varies with the rate of growth, the evolution of the energy coefficient being therefore linked to this rate.

Before the "oil shocks", the elasticity coefficient (calculated with econometric equations) worked perfectely well, and could thus express almost exactly the changes in energy consumption using the changes in GDP; the same relations with value added and energy demand of industry were excellent too. For the total economy, the elasticity coefficient is equal to 1.1 for 1962-1973, and has a tendency to increase slightly.

The first oil shock disturbed this stability: the energy demand dropped in 1975, whereas the GDP stagnated. It is impossible to isolate elasticities after 1974; between 1976 and 1979, the energy consumption increased at a yearly rate of 1.8%, and the GDP increased at a rate of 3.2% each year. For 1962-1973, the figures were 6.2 and 5.5%, respectively.

The second shock of 1979 was no better than the previous one. It is possible to isolate an elasticity coefficient for 1979-1982, but a negative one (minus 2.1),with the GDP increasing by 1.2% and energy consumption decreasing by 2.5%. A negative elasticity goes against common sense and would give surprising results if used for long-term forecasts. On the other hand, during 1962-1973 the energy coefficient *increased* and so forecasts using this trend would have been disastrous.

The elasticity coefficient between GDP and energy consumption was the main tool used in forecasts before the oil shocks, which explains the fact that all forecasts on energy consumption made for the post shock period were wrong, whereas forecasts of energy had some success before 1973 (see [1]). The consequence of this is that no official long-term forecasts on energy demand are made anymore. The errors made related to levels of activity and elasticity coefficient and until 1980 the official forecasts for 1985 were based on positive elasticities between GDP and energy demand.

This deep change in the patterns of growth can be examined with more detail in the various industries, in order to have a better idea of the structural change in the productive structure [2].

1.2. The Alteration of the Trend in Links between Energy Consumption and Growth of Value Added

Industry has seen its share of the total energy consumption decrease since 1962, when it was 50% of the total French energy consumption; this percentage was only 38% in 1973 and 31% in 1982. Since the beginning of the 1970s, the household and services sector has been the main French energy consumer.

At the same time the share of industry's value added in GDP grew in terms of constant prices until 1973 (Table 1), remained approximately constant until 1979, and decreased a little afterwards. On the other hand, note that because of relatively decreasing prices, the share in the total value added at current prices has decreased.

Table 1. Share of industry's value added in GDP (%).

	1962	1973	1979	1983
Current prices	27.79	26.58	25.22	24.23
Constant 1970 prices	22.84	27.58	27.48	26.55

sources: [3], [4], [5].

The relative decrease of energy consumption by the industrial sector is not a new phenomenon. It is reflected in the elasticity coefficients between value added and energy consumption: 0.56 between 1962 and 1973. As for the whole economy, there has been a trend toward the increase of this coefficient with time.

The coefficients are significantly smaller than one, and smaller than the elasticities for the total economy. Since 1962 at the latest, energy consumption of industry has increased less than its activity, which means that there was a decrease in the energy coefficients well before 1973. This is not a surprise as it fits with the traditional representation of development, where industrialization leads toward a less energy-intensive development, as well as with the post-World War II history of France. Martin *et al.* [6] note that this trend was slowed down by the post-World War II reconstruction period and by the the availability of cheap oil, which boosted some basic industries, such as chemicals.

The immediate effect of the two oil shocks (Table 2) was a drop in the energy coefficients (10% in 1975, 8% in 1980), but between 1975 and 1979 it seems that a new pattern of energy consumption took place, with a higher elasticity coefficient (0.75) than before, as if the first shock had been a disturbance that was absorbed. The drop of the coefficient in 1975 cannot be attributed to the effect of the medium-term trend mentioned earlier. It seems to be a direct consequence of the oil shock, not only in terms of energy (energy conservation measures taken after 1974), but also in terms of the industrial crisis of the 1970s. 1975 was a recession year for all industries, especially steel, paper and paperboard, organic chemicals and nonferrous metals, all energy-intensive activities.

Table 2. Decrease of the energy coefficient.

Years	(1) Industrial value added (billion FF 1970 prices)	(2) Industrial energy consumption (million t.o.e.)	(2)/(1) Energy coefficient
1962	99.457	39.178	0.3939
1963	107.986	40.373	0.3739
1964	118.112	43.164	0.3654
1965	123.02	44.097	0.3585
1966	135.547	44.993	0.3319
1967	140.669	45.914	0.3264
1968	148.409	47.682	0.3213
1969	166.303	51.505	0.3097
1970	178.188	54.112	0.3037
1971	189.145	55.174	0.2917
1972	201.823	57.468	0.2847
1973	216.271	61.132	0.2827
Average annual decrease in the energy coefficient: 3.0%			
1974	224.053	64.613	0.2884
1975	216.316	56.416	0.2608
1976	233.119	59.484	0.2552
1977	240.162	60.508	0.2519
1978	245.435	61.158	0.2492
Average annual decrease in the energy coefficient: 3.6%			
1979	250.777	63.383	0.2527
1980	259.264	60.204	0.2322
1981	252.671	55.835	0.2210
1982	254.453	50.5	0.1985
Average annual decrease in the energy coefficient: 7.8%			

Source: [3], [4], [5], [7].

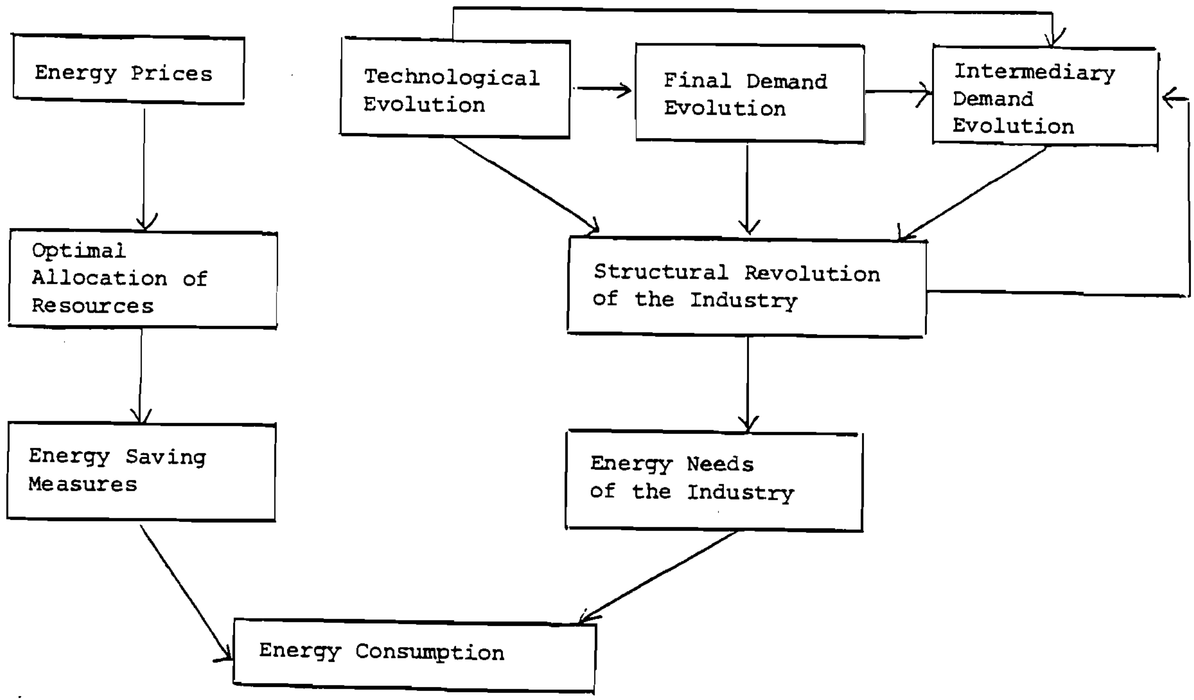
One must not underestimate the effect of the alteration of behaviors after the fourfold increase in oil prices. These prices incited the French authorities to base their energy policy on the availability of cheap oil (in 1973, 70% of the total energy consumption was supplied by oil products). Likewise, in industry, all behaviors were influenced by the belief in the stability of cheap oil supplies. Indeed, such supplies would allow a growth of the economy, partly freed from the energy constraint. In that respect, 1973 was a very unpleasant surprise. The past pattern of growth was questioned. The energy policy after 1974 has been an effort to diversify the energy sources and, to some extent, an attempt to return to abundant cheap energy with the development of the nuclear program. But at the same time, the necessity of a less energy intensive growth is acknowledged. With the new energy prices, the energy savings variable has an economic sense and some energy saving investments have become profitable.

It is difficult, if not impossible, to find to a definition of energy savings that is widely accepted, such a definition being a matter of convention. *In this paper, energy savings are any decrease in the energy consumption, whether in absolute terms or related to output.* In a restrictive sense, energy savings are simply a decrease in the energy consumption due to voluntary action, taken because of changes in the supply conditions or in the behavior of the agent, that moves toward a new "optimal" allocation of resources. Adopting this definition, one usually distinguishes the decrease in the energy consumption due to "structural changes", which is more or less independent of what is happening in the energy arena. Such a representation is given in Figure 1.

The fact that the decrease in energy content of value added did not start in 1974, but well before, seems to corroborate this representation at first sight. But it must be noted that a characteristic of the post-1973 period is not merely a decrease in the energy coefficient. The coefficient decreased only a bit faster after the first oil shock, but the rate of growth of the economy was much smaller than before, the consequence of this being an alteration of the elasticity coefficient.

This representation allows energy savings a minor role, by definition, when separating the effects of structural change from energy variables. The bulk of energy consumption would be determined by industry's evolution alone. But one may wonder why energy is not integrated as a determinant of the structure's evolution too and not only as a consequence. If, as Martin *et al.* [6] have pointed it out, the 1960s period was itself an alteration compared to the long-run evolution (the decrease in the energy coefficient was slowed down during this period), is this not because of the characteristics of the energy markets at the time? If one reintegrates energy as an element of the structural evolution of the economy in general and of industry in particular, one is able to capture all the determinants of the development pattern. This approach is illustrated in Figure 2. In the traditional representation, "energy savings" are always separated from the consequences of changes in the structure of the economy. This corresponds to the view that energy savings are the result of the action of industrialists. But for a whole country, the changes in structure may be the result of a voluntary action, whether to reduce energy consumption or not. It seems then a bit artificial to separate "energy savings" from structural change.

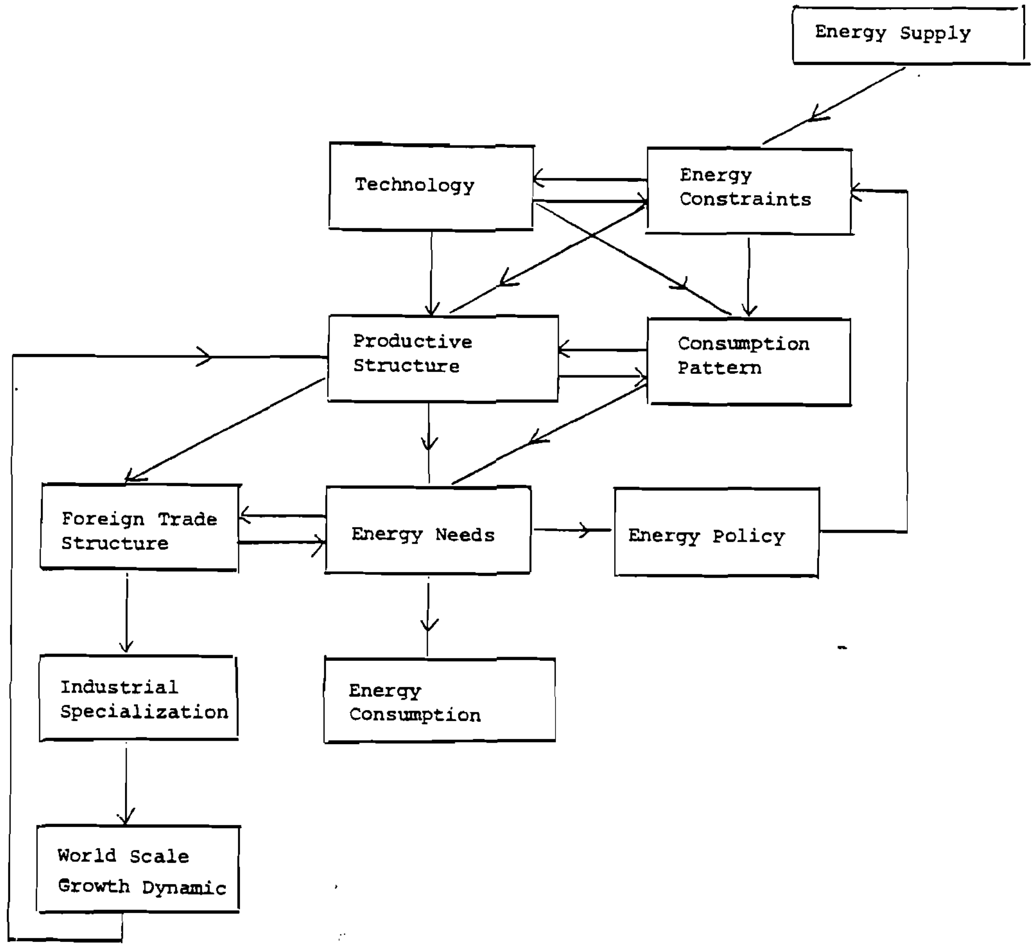
Figure 1. A traditional representation of energy savings.



A look at the energy coefficient figures reveals that the second oil shock of 1979 was followed by a rapid decrease in the coefficients (7.8% per year), and, unlike the preceding shock, the bulk of the decrease was not made in one year, but was constant over this short period. In the energy market , the post-1979 period is characterized by the fact that no one believes in a return to stable or even decreasing prices, in the short term at least, whereas during the 1975-1978 period the oil prices did remain approximately constant. For France, the price of energy must include another variable: the exchange rate between the dollar and franc; a rise in the dollar increases oil prices too, independently of any oil market conditions.

The alteration of the trend relative to the pre-shock period can be seen easily (Table 3) when one makes energy demand forecasts on the basis of 1962-1974 energy-value added elasticities. The energy coefficient forecasted is then the ratio between the forecasted energy demand and the value added of industry; in addition, according to other representations of energy consumption, one takes the decreasing trend of the energy coefficient as given and calculates the hypothetical energy coefficient for a continuing 1962-1973 trend (minus 3.0% each year).

Figure 2. An integrated representation of energy savings.



The actual consumption for 1974 is bigger than that forecasted, but the effect of the oil shock is, of course, ignored, which means a gap between forecasts and actual consumption after 1975. One can see once again that the energy coefficient was decreasing in forecasts made on the basis of pre-shock elasticities [9].

The errors made when one takes fixed elasticity coefficients are enormous for the year 1982: 32.2 and 36.2% for the 1962-1974 and 1968-1974 periods, respectively. This is an indication that the evolution of the energy demand after the shock is not merely the continuation of a trend.

Table 3. Continuation of the 1962-1973 trend.

Years	Energy consumption Forecast	Energy consumption Actual	Energy coefficient Forecast	Energy coefficient Actual	Energy coefficient Hypothetical
1974	61.92	64.613	0.2764	0.2884	0.2742
1975	60.65	56.416	0.2804	0.2608	0.2660
1976	63.38	59.484	0.2719	0.2552	0.2580
1977	64.50	60.508	0.2686	0.2519	0.2503
1978	65.33	61.158	0.2662	0.2492	0.2428
1979	66.17	63.383	0.2638	0.2527	0.2325
1980	67.48	60.204	0.2603	0.2322	0.2284
1981	66.46	55.835	0.2630	0.2210	0.2216
1982	66.74	50.5	0.2623	0.1985	0.2149

On the other hand, since there was already a decreasing trend in the energy coefficients, the hypothetical coefficient for 1982 differs only by 8% from the actual one; the actual energy coefficient is bigger than the hypothetical one for the 1975-1980 period, because the calculation of the latter starts from the year 1973, thus ignoring the increase in the former in 1974. It is interesting to note that the trend fits well with the actual coefficients in 1976 and 1981. This makes relative the "alteration of the energy coefficient"; over the 1970-1982 period, there was no tremendous decrease, *except after 1979.* Nevertheless, it must not be forgotten that the decrease in the energy coefficient is not a natural property of industry, but is linked to a certain pattern of growth. The 3.0% decrease trend was achieved when industry was growing at an annual rate of 7.3%, whereas the growth was reduced to 1.6% each year on average after 1974. Had industry grown at the same rate as before, the energy forecasts would have been much better. There is no obvious reason for the trend to continue when the economic growth occurs at a completely different rate. Whether the trend is the result of structural change within industry is examined in Section 2. There is no reason to separate "technical progress", whose effects would be to lower the energy requirements, from the rate of economic growth either; this "technical progress" is not a natural characteristic of industry and it seems logical to associate it with the growth of a period [10].

On the other hand, it would also be strange to consider that the decrease in the energy coefficient has to stop after the oil shocks and interpret the post shock decrease as a result of the shocks. To clear this point, it is necessary to study in detail the energy consumption of each sector from two points of view, technical and economic, before and after the shocks, in order to see if the energy content of production evolves differently before and after. The aim of this paper is much more limited [11]. It is to examine the evolution of the energy consumption of industry after 1970 from an economic point of view. We can repeat the exercise, taking the first oil shock into account (Table 4).

Once again the alteration is obvious; after 1979 the energy consumption decreases sharply and the difference between forecast and actual figures is 25.5% for 1982. The evolution of the hypothetical energy coefficient is not much different from that in Table 3; the difference with the actual coefficient would have been larger if we had taken into account the

Table 4. Continuation of the 1975-1979 trend.

Years	Energy consumption		Energy coefficient		
	Forecast	Actual	Forecast	Actual	Hypothetical
1979	62.71	63.383	0.2501	0.2527	0.2402
1980	65.26	60.204	0.2478	0.2322	0.2316
1981	63.06	55.835	0.2496	0.2210	0.2232
1982	63.38	50.5	0.2491	0.1985	0.2152

increase in the coefficient in 1979. In any case, the rate of decrease after 1979 is much higher than before.

The alteration in the pattern of energy consumption in industry is unclear after 1974. The links of energy consumption with economic growth were disturbed by the first shock, but everything seems to return to the previous trends after 1975. The energy consumption after 1979 is more surprising. The important decrease cannot be related to previous decreasing trend. For this reason, 1979 can be considered as a more important alteration year than 1974 and, in the following sections, three benchmark years are examined: 1970, 1979, and 1982. The choice of the benchmark years is a direct consequence of the data availability. 1979 is the main alteration year, much more than the first oil shock period and 1982 is the last year for which data are available. It is unfortunate that longer time series are not available in order to appreciate the decrease in the energy consumption after 1979, but some results have been obtained so far concerning the new direction of the energy demand in industry.

2. CHANGES IN THE STRUCTURE OF FRENCH INDUSTRY

2.1. Comparisons for the years 1970, 1979, 1982

In the first section the alteration of the trend at the end of the 1970s decade was discussed. In order to understand these changes, it is possible to separate the changes in energy consumption into three effects [12]:

a) The "content" effect, which expresses the decrease in the amount of energy needed to produce the same amount of value added between two periods.

b) The "structure" effect, which is the effect of the changes in the structure of industry on the total energy consumption.

c) The "activity" effect, which is the consequence of the changes in the level of activity of industry.

These three effects are calculated simply :

$$EC_i = \frac{EC_i}{VA_i} \cdot \frac{VA_i}{VA} \cdot VA$$

$$\Delta(EC_i) = \Delta\left[\frac{EC_i}{VA_i}\right] \cdot \frac{VA_i}{VA} \cdot VA \qquad (1)$$

$$+ \frac{EC_i}{VA_i} \cdot \Delta\left[\frac{VA_i}{VA}\right] \cdot VA \qquad (2)$$

$$+ \frac{EC_i}{VA_i} \cdot \frac{VA_i}{VA} \cdot \Delta VA \qquad (3)$$

$$+ \varepsilon, \qquad (4)$$

where: (1) is the content effect; (2) is the structure effect; (3) is the activity effect; (4) is the residual; EC_i is the energy consumption of the sector i, VA_i is the value added of the sector i, and VA is the total value added ($\sum_{i=0}^{i=n} VA_i$).

The separation into the three effects has been completed for 12 branches within industry for the three years under consideration. The branches are: mining; nonferrous metals (N F M); electrometallurgy (E M); metal processings (M P); machinery and electric equipment (M E E); cement, plaster, and lime (C P M); other building materials (O B M); glass; chemicals (chem.); textiles, leather, and clothing (T L C); rubber; paper and paperboard (paper); miscellaneous (misc.); iron and steel (steel) . Only a lack of data prevented a more in-depth analysis. *It would have been interesting to add another year to this study (after the first shock), but it was not possible to find the necesary data on value added at a sufficiently disaggregated level.* In this mode of calculation, which is the one adopted by IEJE, the energy coefficients are assumed fixed, *which is just a convention for the calculations of the three effects.* Had we had data concerning the evolution of sectoral energy coefficients before the shock, it would have been interesting to study the effects of relative changes in the structure in relation to different rates of decrease of the energy coefficients. The structure effect would have been presumably higher, but it seems arbitrary to apply to all sectors the same "natural" rate of decrease of the coefficient. Moreover, this decrease is linked to a previous evolution of industry, and it is as arbitrary to assume that the coefficients follow a decreasing trend, whatever is the development of industry, as to assume that these coefficients are fixed.

Table 5. Structure of industry in 1970.

Sector	Industrial value added (%)		Industrial energy consumption (%)		Energy coefficient (t.o.e./thousand F)	
Mining	2.00		1.84		0.2493	
N F M	0.20	2.94	0.82	8.39	1.1187	0.7769
E M	0.39		5.75		4.0458	
M P	2.35		1.81		0.2104	
M E E	45.34		11.40		0.0700	
C P L	1.28		8.27		1.7578	
O B M	2.16		2.83		0.3563	
Glass	1.48		2.62		0.4807	
Chem.	10.30		18.93		0.5001	
T L C	11.89		5.96		0.1364	
Rubber	2.35		1.51		0.1742	
Paper	2.98		5.28		0.4825	
Misc.	12.16		2.54		0.0568	
Steel	5.12		28.32		1.5057	
Total	100.00		100.00		0.2721	

The structure of industry in 1970 was as shown in Table 5. The energy-intensive sectors (nonferrous metals, electrometallurgy and metal processings [13], cement, other building materials, glass, chemicals, paper and paperboard, and steel) accounted for 26.3% of the value added of industry and 74.6% of its energy consumption. In order to make energy coefficients and structure comparisons simultaneously, we compare the structure of industry in 1970 with those in 1979 and 1982 using constant 1970 prices.

In 1979, the structure of industry was as shown in Table 6. The share of energy-intensive sectors in total value added is 26.2%, as in 1970, and these sectors represent 74.7% of the total energy consumption, nearly the same figure as in 1970.

Table 6. Structure of Industry in 1979.

Sector	Industrial value added (%)		Industrial energy consumption (%)		Energy coefficient (t.o.e./thousand F.)	
Mining	1.18		1.91		0.3437	
N F M	-		0.82		-	
E M	-	3.17	5.83	8.71	-	0.5841
M P	-		2.06		-	
M E	51.81		12.25		0.0502	
C P L	1.07		6.78		1.3523	
O B M	1.91		2.75		0.3061	
Glass	1.48		3.04		0.4369	
Chem.	11.28		24.43		0.4601	
T L C	8.53		4.16		0.1035	
Rubber	1.89		1.53		0.1722	
Paper	2.74		4.90		0.3801	
Misc.	10.36		3.72		0.0762	
Steel	4.58		[illegible]		1.1186	
Total	100.00		100.00		0.2124	

The structure for 1982 is shown in Table 7. The share of energy-intensive sectors is 26.7% of the value added, a higher percentage than in other years, and 73.9% of the energy demand. The only energy-intensive sector that regressed noticeably is steel, the other ones either slowly declining or progressing. Among the nonferrous metal activities, some have had a considerable growth, but the lack of data prevent us from looking at the evolution of a more accurate energy coefficient.

Notice that the role of energy-intensive sectors is roughly the same throughout the period, both for energy consumption and value added. It seems that there are no changes in the structure of industry, but this is the result of the inclusion in energy-intensive sectors of the nonferrous metals and chemical activities. If we remove these activities, we find a share of the

Table 7. Structure of Industry in 1982.

Sector	Industrial value added (%)		Industrial energy consumption (%)		Energy coefficient (t.o.e./thousand F)	
Mining	0.99		1.81		0.3283	
N F M	-		0.92		-	
E M	-	3.82	5.54	8.61	-	0.4064
M P	-		2.16		-	
M E E	49.96		13.04		0.0470	
C P L	1.03		6.52		1.1448	
O B M	1.84		2.73		0.2669	
Glass	1.55		3.31		0.3845	
Chem.	11.96		25.71		0.3875	
T L C	7.97		3.90		0.0883	
Rubber	1.62		1.35		0.1501	
Paper	2.76		5.34		0.3485	
Misc.	11.00		4.93		0.0807	
Steel	3.76		21.65		1.0373	
Total	100.00		100.00		0.1802	

energy-intensive sectors of 13.0% of the value added and 47.5% of the energy consumption in 1970, 11.8% of the value added and 41.6% of the energy consumption in 1979, and finally 10.9% of the value added and 39.6% of the energy consumption in 1982. These activities are then clearly recessive, and their role in the determination of industry's energy consumption has decreased. The inclusion of the nonferrous metals and chemical sectors makes the share of energy-intensive branches in both value added and energy consumption stable over the period, but these two groups of activities must be separated from the others because:

a) The chemical industry is a key sector for the development of total industry and it has experienced important internal structural changes over the period, changes that do not appear at this level of disaggregation.

b) The case of the industries based on nonferrous metals is unclear, as shown later; production has had an important increase in its valorization, without any apparent physical changes.

It is then useful to separate these growing industries from the recessive ones.

Table 8. Evolution of the energy consumption 1970-1979.

Sector	Change in consumption	Content effect	Structure effect	Activity effect	Residual
Mining	+ 0.16	+ 0.34	- 0.36	+ 0.40	- 0.22
N F M, E M, and M P	+ 0.71	- 1.01	+ 0.32	+ 1.83	- 0.43
M E E	+ 1.19	- 1.60	+ 0.81	+ 2.54	- 0.56
C P L	- 0.29	- 0.92	- 0.66	+ 1.80	- 0.51
O B M	+ 0.14	- 0.19	- 0.16	+ 0.62	- 0.13
Glass	+ 0.40	- 0.12	0	+ 0.57	- 0.05
Chem.	+ 4.22	- 0.73	+ 0.87	+ 4.12	- 0.04
T L C	- 0.61	- 0.70	- 0.82	+ 1.30	- 0.39
Rubber	+ 0.11	- 0.01	- 0.14	+ 0.33	- 0.07
Paper	- 0.13	- 0.54	- 0.21	+1.15	- 0.53
Misc.	+ 0.81	+ 0.42	- 0.18	+ 0.55	+ 0.02
Steel	- 0.51	- 3.53	- 1.45	+ 6.17	- 1.70
Total	+ 6.20	- 8.59	- 1.98	+ 21.38	- 4.61

(All figures in millions of t.o.e.)

Table 9. Evolution of the energy consumption 1979-1982.

Sector	Change in consumption	Content effect	Structure effect	Activity effect	Residual
Mining	- 0.22	- 0.05	- 0.17	- 0.02	+ 0.02
N F M, E M, and M P	- 0.83	- 1.43	+ 0.18	- 0.07	+ 0.49
M E E	- 0.74	- 0.42	- 0.24	+ 0.10	+ 0.02
C P L	- 0.73	- 0.56	- 0.14	+ 0.06	+ 0.03
O B M	- 0.26	- 0.19	- 0.05	- 0.02	0
Glass	- 0.15	- 0.20	+0.08	- 0.02	- 0.01
Chem.	- 1.61	- 2.08	+ 0.80	- 0.20	- 0.13
T L C	- 0.49	- 0.33	- 0.15	- 0.03	+ 0.02
Rubber	- 0.22	- 0.11	- 0.12	- 0.01	+ 0.02
Paper	- 0.24	- 0.22	- 0.02	-0.04	+ 0.04
Misc.	+ 0.22	+ 0.12	+ 0.12	- 0.03	+ 0.01
Steel	- 3.29	- 0.95	- 2.33	- 0.19	+ 0.18
Total	- 8.56	- 6.42	- 2.04	- 0.79	+ 0.69

(All figures in millions of t.o.e.)

The three effects mentioned before are shown in Table 8 for the 1970-1979 period, and in Table 9 for the 1979-1982 period. Between 1970 and 1979, the main agent of change in energy consumption was the change in the total activity of industry. Over the period, the industrial value added grew by 45%. The growth was made both by energy-intensive sectors (chemicals) and by less energy-intensive ones (machinery and electric equipment). This explains the low structure effect, which contributes to the lower energy consumption by 2 million t.o.e. only, most of this being due to the decline of the iron and steel sector. The energy content effect is not to be neglected: the most energy intensive activities (all metal activities: iron & steel, electrometallurgy, nonferrous metals,etc.) have seen a decrease of the energy content of one value added unit, and the machinery and electric equipment sector makes an important contribution to the content effect, despite its already low coefficient.

Table 10. Average annual decrease of the energy coefficient between 1970 and 1979.

1	Machinery & electric equipment	- 5.4%	7	Other building materials	- 2.5%
2	Iron & steel	- 4.8%	8	Glass	- 1.6%
3	Nonferrous metals, Electrometallurgy, & Metal processings	- 4.6%	9	Chemicals	- 1.4%
4	Textiles, leather, & clothing	-4.5%	10	Rubber	0.0
5	Cement, plaster & lime	- 4.3%	11	Miscellaneous	+ 5.0%
6	Paper & paperboard	- 3.9%	12	Mining	+ 5.5%
Total Industry: - 4.0%					

The contribution of each sector for that period is summed up in Table 10. The existence of a nonnegligible residual for the 1970-1979 period indicates that the three effects are more related to each other than one would initially assume. It has been shown in Section 1 that the period was not really an alteration of *trend*, but rather an alteration in the *level* of the energy consumption. After the oil shock, the energy demand grew according to the previous trend. On the other hand, the 1979-1982 period appears much clearer.

Contrary to the previous period, both activity and energy demand went down, but at different paces: the value added decreased by 1.5% whereas the energy consumption dropped by 16.4% . As shown in Table 9, the activity effect contributes 9% only to the general decrease of the energy consumption. The structure effect is more important (24% of the total decrease), but most of it is due to the iron and steel sector alone, just as before. Notice the positive structure effect due to the chemical industry, which is nearly as high between 1979 and 1982 as it was between 1970 and 1979, with the share of chemicals in the total industrial value added continuing to increase after 1970. But the bulk of the decrease of energy consumption (75%) is due to the content effect. This effect is particularly high for energy-intensive activities (metal activities, chemicals). Once again, the evolution of the energy coefficient is contrasted according to industries, as shown in Table 12.

The residual for 1979-1982 (see Table 9) can be considered as negligible; the evolution of the energy demand after the second oil shock is mostly the consequence of the decrease of the energy content of value added. Over 1970-1982 the role of each effect is shown in Table 11.

Table 11. The three effects over 1970-1982.

Change in energy consumption	Content effect	Structure effect	Activity effect	Residual
- 2.36	- 15.01	- 4.02	+ 20.59	-3.92

(All figures in million t.o.e.)

Table 12. Average annual decrease of the energy coefficients between 1979 and 1982.

1	Nonferrous metals, Electrometallurgy, & Metal Processings	-11.4%	7	Glass	- 4.2%
2	Chemicals	- 5.6%	8	Paper & paperboard	- 2.9%
3	Cement, plaster, & lime	- 5.4%	9	Iron & steel	- 2.5%
4	Textiles,leather, & clothing	- 5.2%	10	Machinery & Electric Equipment	- 2.3%
5	Rubber	- 4.5%	11	Mining	- 1.5%
6	Other building materials	-4.5%	12	Miscellaneous	+ 0.02%
	Total industry: - 5.3%				

The evolution of each energy coefficient is more differentiated than for 1970-1979. For total industry, the decrease of the energy content accelerated after 1979, with the most energy-intensive sectors, except iron and steel and paper and paperboard, accelerating this decrease after this date (the first three energy-saving sectors for 1979-1982 are energy-intensive ones). This is obvious for the nonferrous metals sectors, whose rate of decrease doubled, and for chemicals, which made limited savings over 1970-1979 and larger than average ones after 1979. The case of glass is similar to that of chemicals, with a limited decrease for 1970-1979, but this decrease more than doubled after 1979. In general, the less energy-intensive sectors had a slower decrease of energy content relative to the most energy-intensive ones, with the notable exceptions of rubber, a sector that made no savings during 1970-1979, and textiles overall, which made important savings for the two periods, despite being a relatively recessive activity. One can discount the mining and miscellaneous sectors, the former being a recessive activity with few changes in its structure, and the latter being too heterogeneous a sector to be studied in detail. They are the only sectors in which the energy content actually increases. Machinery and electric equipment has swapped places in the energy savings ranks: for 1970-1979 it was the sector that had achieved the most important savings, but after 1979 it is the sector in which these savings are the least important.

The opposition between content and activity effects is obvious, and the structure effect is only a secondary factor. The most energy-intensive sectors over the whole (1970-1982) period are as shown in Table 13.

Table 13. Evolution of the energy coefficients between 1970 and 1982.

1	Nonferrous metals, Electrometallurgy, & Metal processings	- 47.7%	7	Other building materials	- 25.1%
2	Textiles, leather, & clothing	- 35.3%	8	Chemicals	- 22.5%
3	Cement, plaster, & lime	- 34.9%	9	Glass	- 20.0%
4	Machinery & electric equipment	- 32.9%	10	Rubber	- 13.8%
5	Iron & steel	- 31.1%	11	Mining	+ 31.7%
6	Paper & paper board	- 27.8%	12	Miscellaneous	+ 42.9%
Total industry: - 33.8%					

There is no clear separation between the fastest and slowest growing industries. Some recessive branches (cement, iron and steel, textiles) have achieved important energy savings and some growing activities (chemicals and, to a lesser extent, machinery and electric equipment) have lower than average savings. The same could be said for energy intensities, although, on the whole, the most energy-intensive activities are declining. We could say, then, that the level of disaggregation (imposed by data availability) is not satisfactory for estimating what are the effects of changes in the production structure; most of the changes are internal to each branch.

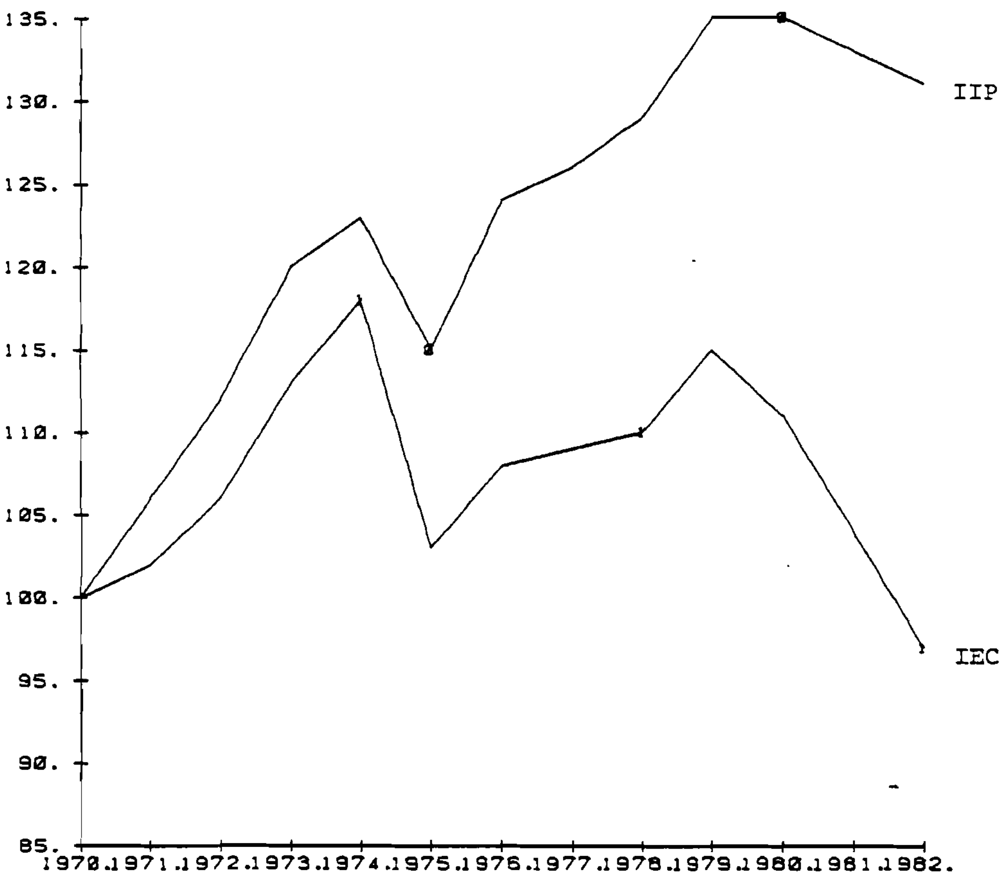
3. THE DECREASE OF THE ENERGY CONTENT OF VALUE ADDED

At the level of 12 branches, changes in the structure of industry are not the main factors for a decrease in the total energy coefficient. The bulk of the structure effect can be attributed to the decline of two or three energy-intensive branches, especially iron and steel. One may wonder, though, what the "content effect" exactly is. The content effect studied above is determined by a ratio between the energy consumption (in t.o.e.) and the value added expressed in ***constant prices;*** it is thus a technoeconomic coefficient *(E/VA)*. If we put aside all problems concerning the exact determination of the energy consumption, the weakness of the coefficient concerns the expression of value added at constant prices. As stated in the introduction, there are two types of studies. Had this one been a look at a single branch, and especially an energy-intensive one, we could have considered an output indicator in physical terms (tons of steel, etc.). The *E/VA* coefficient is often taken as a subsidiary to a physical indicator, which it is not. In order to use the *E/VA* coefficient of iron and steel as a subsidiary of the ratio between the energy consumption of the sector and its production in physical terms, we have to assume that the value added content of the production is constant, which is an unlikely case especially in times of important "structural changes". Since this is a survey of the whole French industry in terms of changes in its structure, we can only consider output indicators in monetary terms. And, in order to study over time the evolution of the energy coefficient thus defined, the output indicator must be in constant prices. One can look at changes in the structure of total industry with value added at current prices, but constant prices remove the evolution of relative prices. Of course, using constant prices neglects things such as changes in products and technologies, but it still represents a worthwile output indicator [14]. If one had to consider a "purely technical" coefficient, it would be necessary to remove the effect of changes in the value added content of the products, and this content may change considerably, as for the case of nonferrous metals. In fact, there is no such thing as a "pure technical" coefficient, especially in the case of an economic study; the analysis of a technical coefficient would require the study of links between energy, technologies, and products, which is outside the scope of this paper.

The particular importance of the content effect is a direct consequence of the rather aggregated level for which energy consumption figures are available. For each level of disaggregation, one can associate a structure effect, which effect is likely to grow as the disaggregation increases. It is not unsatisfying, though, to notice that at the level of 12 branches, the structure effect is a secondary factor. If the changes in the level of energy consumption can be explained by structural change, then one must distinguish between structures. It is obvious from the previous analysis that the structural change is within each main branch and not between each branch. The energy accounting does not give enough detailed data to allow us to appreciate a deeper structural change. Thus, without the support of energy figures, we can only look at the development of the branches and within each branch, making common sense assumptions on the relative energy efficiency of the different subsectors.

Even at the level of 12 branches, it is possible to complete the general outlook by comparing the results using the energy coefficient calculated with value added at constant prices (hereafter referred to as the *E/VA* coefficient) with a coefficient calculated with the Index of Industrial Production *(IIP)* [15] (the *E/IIP* coefficient). Reference is also made to the ratio between the share of one sector with respect to the total energy consumption of industry and the total value added at ***current prices***, the *ESVA*

Figure 3. *IEC* and *IIP* for total industry.



ratio. For total industry, *ESVA* is equal to 1 by definition, energy-intensive industries have an *ESVA* superior to one, and sectors with low energy consumption have an *ESVA* inferior to one. This ratio is a typically ***economic*** ratio, taking into account the real valorization of the activity of a sector (by the means of value added at current prices). The evolution of *ESVA* indicates whether the energy content decrease of a particular sector is larger (decrease of *ESVA*) or smaller (increase of *ESVA*) than that of total industry. *IVA* is the index of value added at constant prices, and *IEC* the index of energy consumption (1970=100 for all indexes).

For total industry, the values of these coefficients are given in Table 14. Before 1973, the *E/IIP* decreased at an annual rate of 2% (over 1970-1973), just as for 1974-1979, but for 1979-1982, the rate was a 5% decrease each year. For comparison, figures with *E/VA* are, respectively, 2.5, 2.8, and 5.2%.

Figure 3 shows the evolution of *IIP* and *IEC* for total industry. It is clear here, too, that the major alteration year is 1979, in which a large decrease in the level of energy consumption occurred. The increase of the value added content of the production explains the difference in results the of *E/VA* and *E/IIP*.

Table 14. *IIP*, *IVA*, and *E/IIP* for total industry.

Years	*IIP*	*IVA*	*E/IIP*	Years	*IIP*	*IVA*	*E/IIP*
1970	100	100	1.00	1977	127	136	.85
1971	106	-	.95	1978	131	141	.83
1972	112	-	.94	1979	136	145	.83
1973	120	121	.93	1980	136	146	.80
1974	124	126	.94	1981	134	142	.76
1975	115	121	.88	1982	132	143	.72
1976	125	131	.86				

For each sector we examine the evolution of the energy content of physical products where possible (iron and steel and paper and paperboard), then the *E/IIP* coefficients, *IIP* being taken as a pseudo-physical indicator expressing the growth of the total production of a sector, and finally we examine *ESVA* ratio. Figures showing the evolutions of *IIP* and *IEC* are given for each sector. All rates of change are given in annual average, unless otherwise stated.

3.1. Iron and Steel

This sector is the primary contributor to the decrease of the energy consumption of total industry. Between 1979 and 1982, its decline alone accounts for 27% of this decrease.

Between 1962 and 1970, the energy content of crude steel decreased each year by 1% on average, the rate for 1970-1982 being slightly smaller. The decrease for 1970-1979 is very small, but equals 1.6% for 1979-1982. Such figures are well below the drop of *E/VA* (3% per annum during 1970-1982). The production of crude steel is not the only activity of the iron and steel sector. Since it is not possible to aggregate all finished products into an indicator in physical terms, we resort to the pseudo-physical indicator *(IIP)*.

The rate of decrease of *E/IIP* (Table 15) was 1.2% per annum between 1965 and 1970, and 1.8% between 1979 and 1982. Before 1975, *IIP* and *IEC* were closely linked (Figure 4); the divergence starts around 1977-1979 but does not widen in 1979 or after. The decrease of *E/IIP* is a bit larger than that of the energy content of crude steel, the global activity of the sector growing more than crude steel production alone, and presumably with less energy-intensive activities (transformation of crude steel). But the difference between *E/VA* and the other coefficients is due to the increase of the value added content of the production , although the value added at current prices is not as high as that in constant prices (Table 16).

The value added content of the activity tends to increase; the sector as a whole is in a deep crisis at a world level, and the norms of production as well as the norms of consumption have changed. On the whole, the trend goes toward more sophisticated and diversified products (see[16]), the share of special steels is increasing: 11% in 1973, 15% in 1982.

figure 4. *IEC* and *IIP* iron & steel

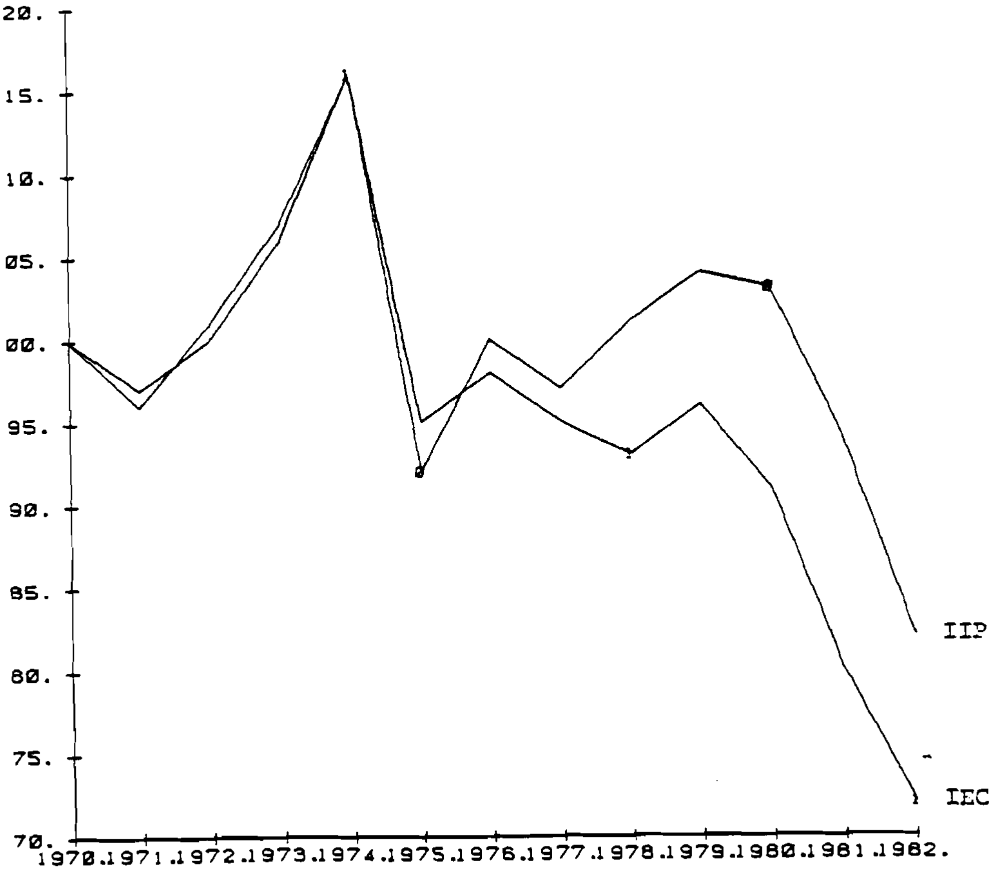


Table 15. Energy coefficients for iron and steel.

	1962	1965	1970	1974	1979	1982
Energy content of crude steel (t.o.e. per ton)	0.63	0.61	0.58	0.58	0.57	0.54
E/IIP	-	1.06	1.00	1.00	0.93	0.88
ESVA	-	-	5.53	-	5.97	6.24

The evolution of *ESVA* shows that the savings of the sector are below the average of industry, whatever the technical energy savings may be, and the value added of the sector decreases relatively more than the energy consumption. One can notice the particularly high value of *ESVA*, showing the energy intensity of the sector.

Table 16 Economic indicators for iron and steel.

	1970	1979	1982
Industry's value added at constant 1970 prices (%)	5.12	4.58	3.76
Industry's value added at current prices (%)	5.12	4.04	3.47
IVA	100	130	105
IIP	100	104	82
IVA/IIP	1.00	1.25	1.28

The iron and steel sector demands a growing part of the energy consumption relative to its contribution to value added. The rapid growth of *ESVA* shows that the real achievements of the sector in terms of energy savings are much more modest than what one could have thought when looking at *E/VA*.

3.2. Paper and Paperboard

The total decrease of the energy content of paper is 17.42% between 1970 and 1979 (2.1% each year), 5.46% between 1979 and 1982 (1.9% each year), and 21.93% over the whole period. As for steel, but to a minor extent, this decrease is inferior to that of *E/VA* (the decrease of *E/VA* is negligible between 1970 and 1973, but after 1973 it goes down at the rate of 3.4% each year until 1979, and 1% for 1979-1982). It follows approximately the trend of *E/IIP* (Table 17).

The closeness between *IIP* and the physical indicator may be explained by the fact that the latter includes both paper and paperboard production, and there were no major changes in the product mix of the sector except for the slower growth of pulp production compared to paper and paperboard. The decrease of *E/IIP* is observable since 1965 .

After 1975, the *IEC* grew at a smaller rate than *IIP*, and after 1979 it decreased whereas the *IIP* remained approximately constant. The rate of decrease of *E/IIP* was approximately 4% per year between 1965 and 1970, which is more than most sectors. Between 1970 and 1975, the average decrease was 2% each year, just as between 1975 and 1979, but after 1980, the rate went up to 4%. On a long period, there is no big change of the *E/IIP*, only the 1980-82 evolution being opposed to that after 1970.

The value added of the sector has slowly increased in current prices from 1970 on, which is not the case in constant prices (Table 18). In general, the value added (at constant prices) content of production is increasing, since within the sector the production of paper and paperboard grew faster than that of pulp. When one takes value added at current prices, the values of *ESVA* indicate better than average energy savings between 1970 and 1979, but a negative evolution between 1979 and 1982. This fact is also observable with *E/IIP*. According to these coefficients, the paper and

Figure 5. *IEC* and *IIP* for paper and paperboard.

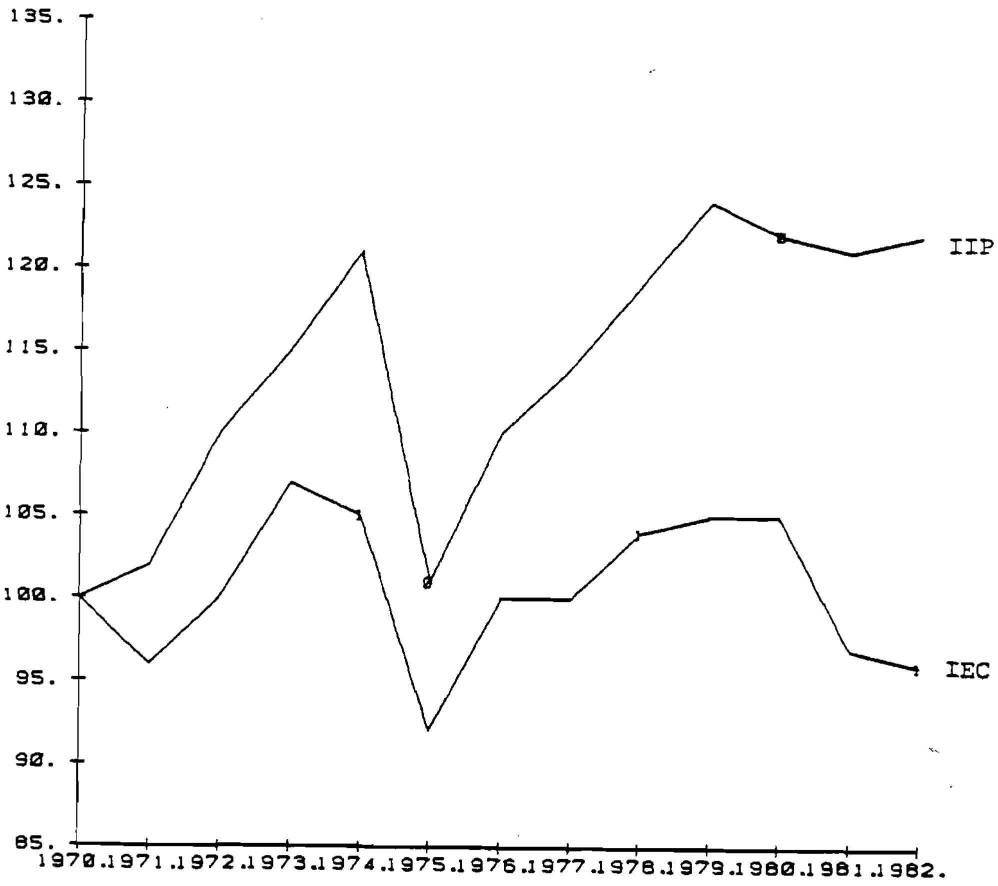


Table 17. Energy coefficients for paper and paperboard.

	1965	1970	1974	1979	1982
Energy content of paper	-	0.62	0.53	0.51	0.48
E/IIP	1.23	1.00	0.87	0.85	0.79
ESVA	-	1.77	-	1.63	1.76

paperboard sector has either not followed the trend toward an acceleration of the decrease of the energy coefficient after 1979-1980 or has done so only to a lesser extent.

For all other sectors, it is not possible to isolate a physical indicator (the cement sector includes also all plaster products), and thus there can only be comparisons with the pseudo-physical index, *IIP*.

Table 18. Economic indicators for paper and paperboard.

	1970	1979	1982
Share in industry's value added at constant prices (%)	2.98	2.74	2.76
Share in industry's value added at current prices (%)	2.98	3.01	3.04
IVA	100	133	133
IIP	100	124	122
IVA/IIP	1.00	1.07	1.09

3.3. Cement, Plaster, and Lime

Figure 6. *IEC* and *IIP* for cement, plaster, and lime.

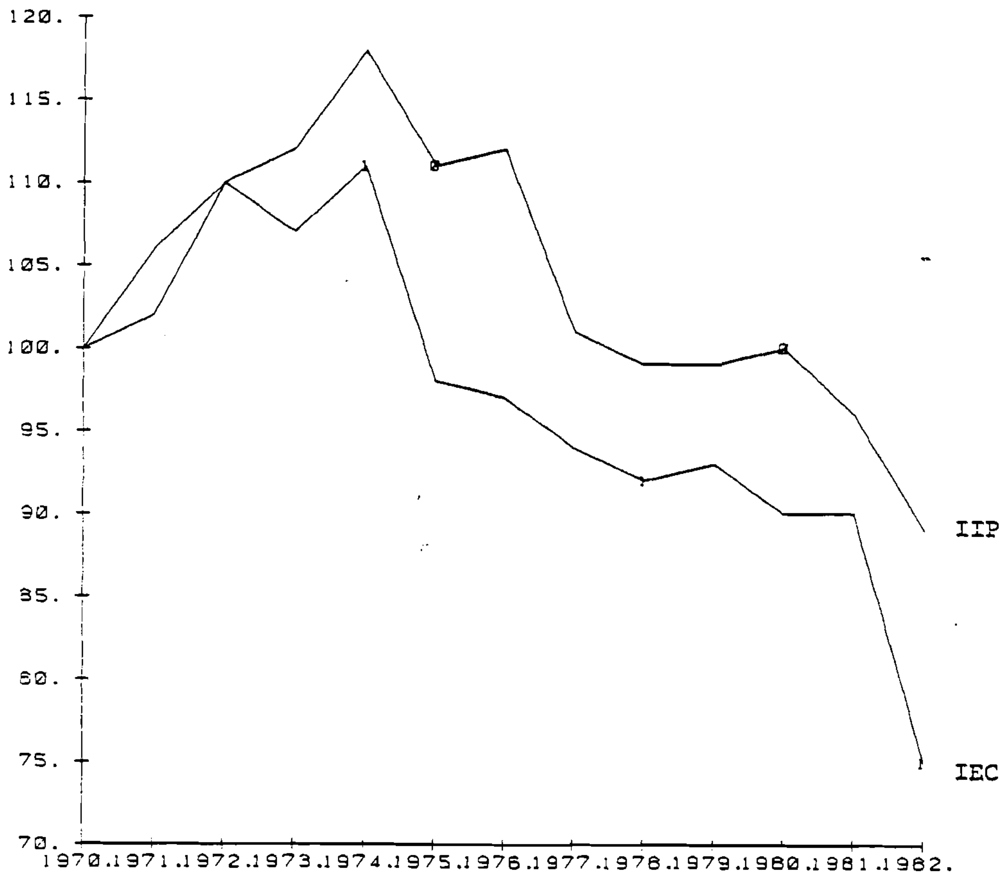


Table 19 shows a decrease of 6% for 1970-1979 (0.7% per annum) and 11% for 1979-1982 (3.7% per annum), compared with 23% and 15%, respectively, for *E/VA* over the total period. The gap between *E/IIP* and *E/IVA* is explained by the increase of the value added content of the production

Table 19. Energy coefficients for cement, plaster, and lime.

	1970	1974	1979	1982
E/IIP	1.00	0.94	0.94	0.84
ESVA	6.46	-	-	-

Table 20. Economic indicators for cement, plaster, and lime.

	1970	1979	1982
IVA	100	122	115
IIP	100	99	89

(Table 20). Unfortunately, the inaccurate method for calculating the value added of this sector [17] partly explains the difference between *E/VA* and *E/IIP*, since the value added of the cement sector is certainly overestimated. This is why *ESVA* is not given after 1970 (Table 19). The decrease of the energy coefficient is thus less important than that shown in Table 19, and must be between 11 and 30%. The *E/IIP* is then more reliable. The evolution of *IEC* and *IIP* are shown in Figure 6.

It is certain though, that the value added content of the sector has increased. The subbranch "plaster" has grown much faster than cement, which has had an effect on energy consumption, plaster being much less an energy-intensive product than cement.

In the technical field, the evolution of energy efficiency is uncertain. It seems [18] that it has ***decreased*** as a consequence of changes in the structure of the energy carriers. The industry has changed to a coal dominated energy-carrier structure since 1979, a consequence of the prices of oil. Oil was dominant before 1979 (68.3% of total energy consumption in 1973), but has seen its share much reduced since (25.3% of total energy consumption in 1982). The technical evolution is contradictory to the economic evolution.

3.4. Nonferrous Metals

The difference in the respective evolutions of *IIP* and *IVA* is particularly large for the industries based on nonferrous metals (Table 21). Because of the lack of disaggregated data, it was necessary to aggregate three types of industries: metal processings,

nonferrous metals, and electrometallurgy, this last one being by far the most energy-intensive activity of the industry as a whole, with an *E/VA* of 4.05 in 1970 as against 0.27 on average. This means that this sector is 15 times more energy intensive than the average of industry. In all three sectors together, the decrease of *E/VA* between 1970 and 1982 is 48%, and had it been possible to isolate nonferrous metals and electrometallurgy, we may have obtained higher decreases . Most of this tremendous decrease is due to

Figure 7. *IEC* and *IIP* for nonferrous metals.

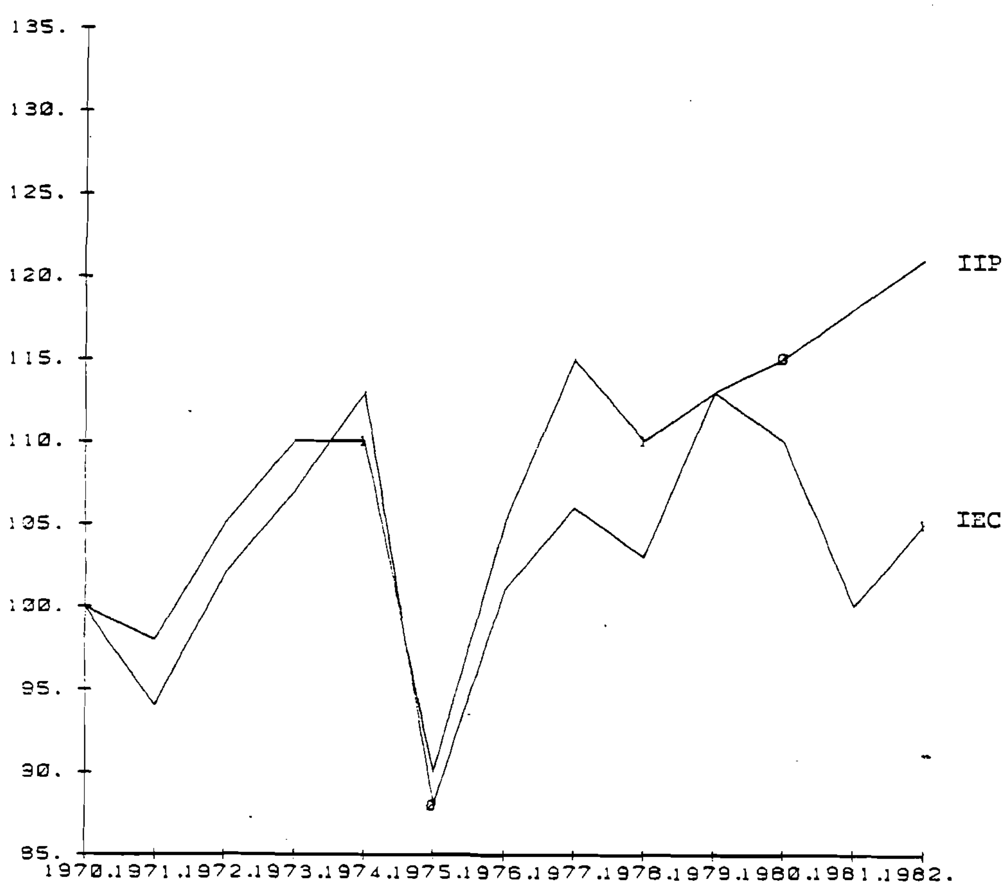


Table 21. Energy coefficients for nonferrous metals.

	1970	1979	1982
E/IIP	1.00	0.97	0.84
ESVA	2.85	3.24	2.31

an increase of the value added of the three sectors (Table 22).

All the figures in Table 22 show an increase of the share of these sectors in total industry and the growth of their value added does not correspond to a growth in the pseudo-physical indicators. The growth of value added is not observable in current prices until 1979, which means that the evolution of *ESVA* is unfavorable until this date and favorable after; the decrease of *ESVA* after 1979 is tremendous. The energy savings of these three sectors do not have an observable "physical" basis (see Figures 7, 8, and 9). For the three sectors together, the decrease of *E/IIP* is modest. In fact, there is no savings for metal processings according to this criterion,

Figure 8. *IEC* and *IIP* for electrometallurgy.

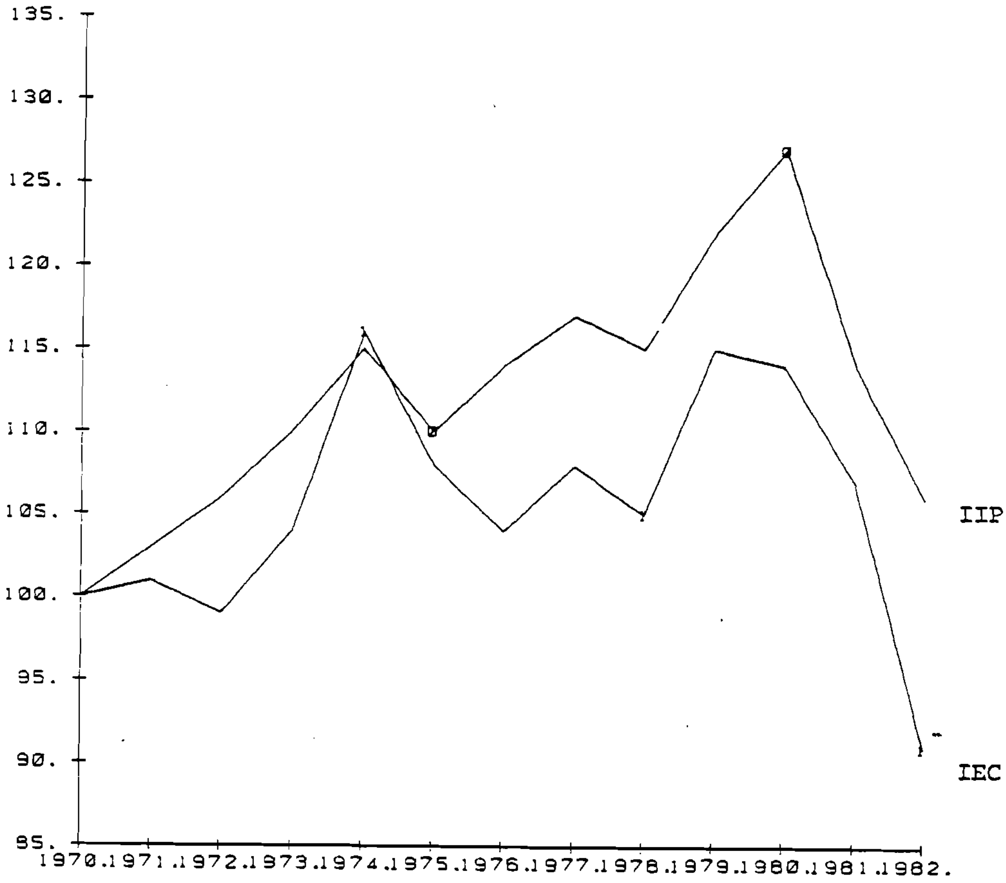


Table 22. Economic indicators for nonferrous metals.

	1970	1979	1982
Share in industry's value added at constant prices (%)	2.94	3.17	3.82
Share in industry's value added at current prices (%)	2.94	2.69	3.72
IVA	100	156	189
IIP	100	121	116
IVA/IIP	1.00	1.29	1.63

Figure 9. *IEC* and *IIP* for metal processings.

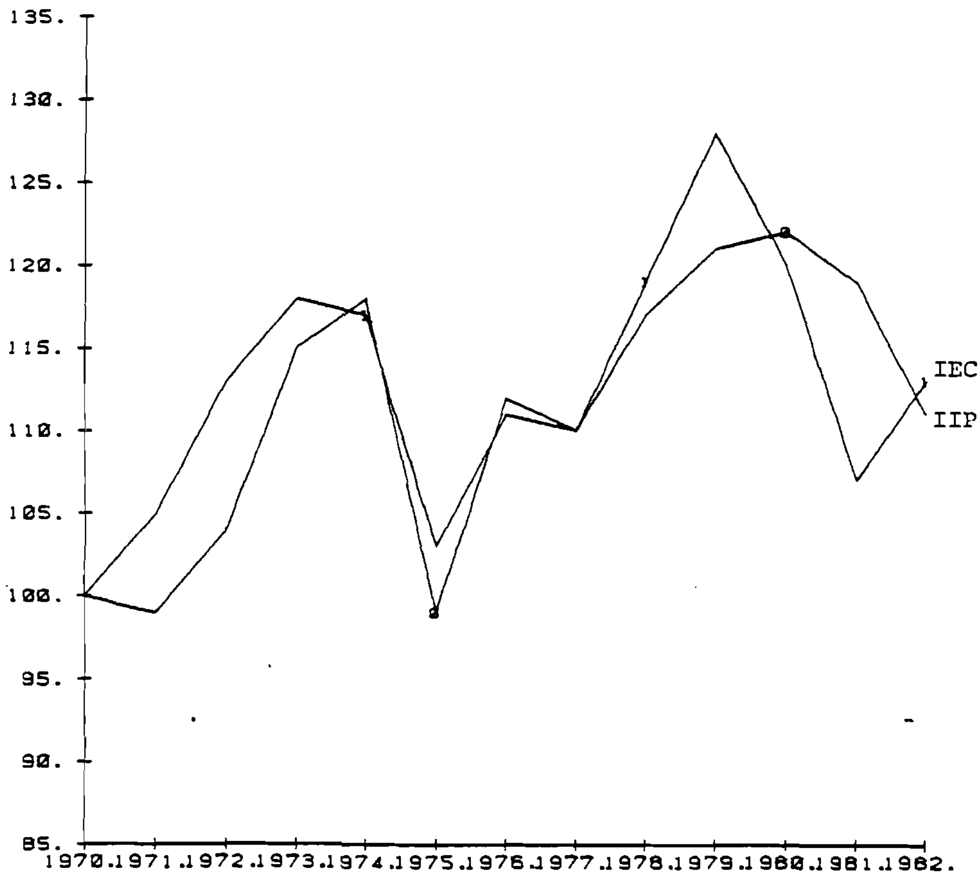


Table 23. Growth of value added for nonferrous metals.

	1970	1979	1982
IVA	100	198	262
index of production	100	166	186

and very limited ones for the two other sectors. The usual representation of energy savings is in the form of a "technical progress", which lowers the energy requirements per unit of product. Here, we have savings which take the form of an increase of the value added of the product; the technical progress in these sectors is toward the use of lighter materials, so production in tons may not be the best indicator of activity. Moreover, there are new uses of those materials, again with a limited "weight requirement", but with a high value. This phenomenon is especially true of the nonferrous metals sector of National Accounting [19], from which the nonferrous metals and electrometallurgy figures are issued (Table 23). The index of

Table 24. Growth of value added for total industry.

	1970	1979	1982
IVA	100	145	145
Index of production	100	141	141

production refers to production in monetary terms, not to *IIP*. This can be compared to that of total industry (Table 24). For the three sectors considered, and especially for nonferrous metals and electrometallurgy, there is a decrease of the share of intermediary consumption in the value of production (76% in 1979, 66% in 1982). From an economic point of view, these sectors have achieved the most important energy savings.

The technical basis for the energy savings may be the development of secondary smelting metals, especially aluminum. The growth of remelted aluminum was particularly obvious after 1973-1975. But the same phenomenon is not true for all metals; secondary copper and zinc have had a much slower growth than refined metals. In any case, the technical achievements of these activities are not remarkable, and the decrease of the energy coefficient is a purely economic phenomenon.

3.5. Glass

The case of glass is exactly the inverse, with the valorization of the activity of the sector occurring under poor conditions over the period, Table 24. Not only is the value added (constant prices) content of the production becoming lower, but the relative price evolution is itself unfavorable . This explains the relatively low achievements of the sector in the decrease of *E/VA* and *ESVA*, compared to the outstanding result obtained with *E/IIP* (-36% over 1970-1982 againt -26% for total industry).

The rapid decrease of *E/IIP* starts after 1973. Before that date the IEJE figures show a slower, but real, improvement of the energy efficiency, 2% per annum on average, except for some ups and downs in 1967 and 1971. This evolution is different from that of *E/VA*, which decreased from 1970 to 1973 at the rate of 1.8% per annum, decreased very little until 1979, and finally then decreased at an average annual rate of 4.2% until 1982. For *E/VA* the first shock does not correspond to a breakdown. For *E/IIP*, 1973-1975 is a breakdown period, with the growth of industrial production not linked to that of energy consumption as before (see Figure 10).

There are, within this sector, products that have a much higher growth than others, such as flat glass and glass fiber, and others that are regressing, such as hand-made glass and optical glass. For this reason, the calculation of the *IIP* and value added at constant prices, which use fixed 1970 weights, may not represent the real activity of the sector. Only disaggregated data concerning energy consumption and activity would solve the mystery of the gap between different coefficients. Thus one may prefer to look at *ESVA* (Table 26). For every period, the energy efficiency evolves in a less favorable way than the average of industry.

Figure 10. *IEC* and *IIP* for glass.

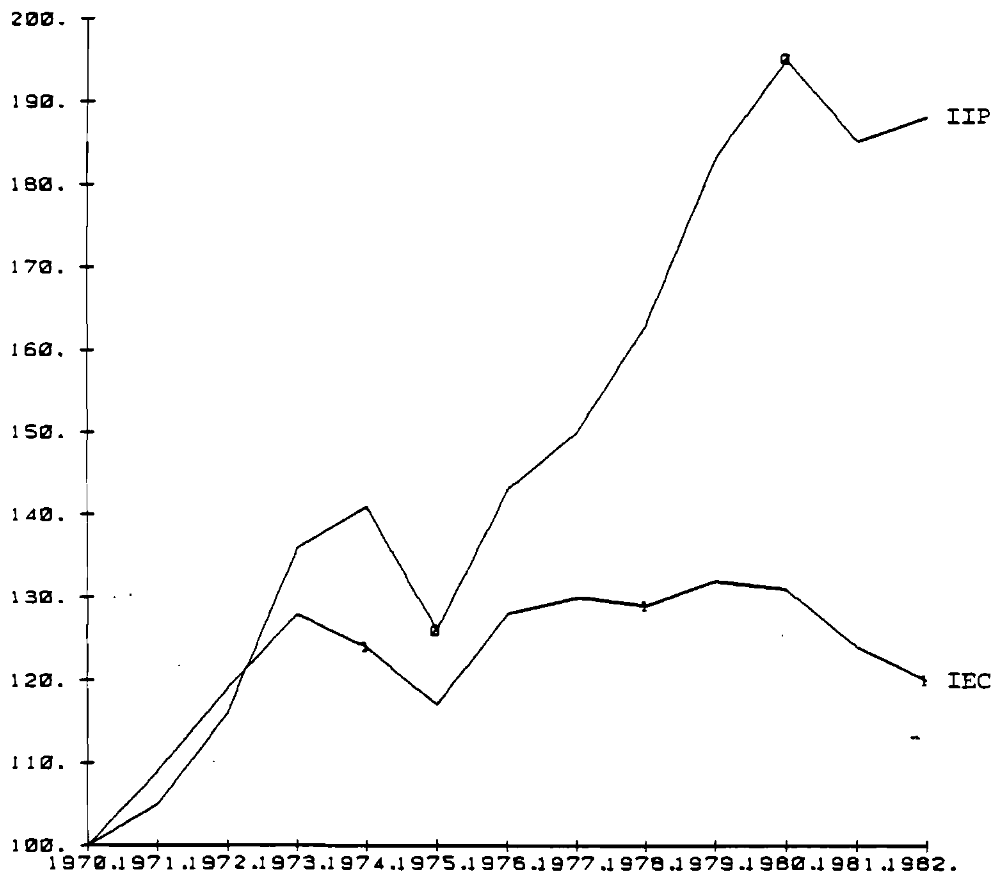


Table 25. Economic indicators for glass.

	1970	1979	1982
Share in industry's value added at constant prices (%)	1.48	1.48	1.55
Share in industry's value added at current prices (%)	1.48	1.35	1.44
IVA	100	145	150
IIP	100	183	188
IVA/IIP	1.00	0.79	0.80

Table 26. Energy coefficients for glass.

	1965	1970	1979	1982
E/IIP	1.04	1.00	0.72	0.64
ESVA	-	1.77	2.25	2.30

3.6. Rubber

Table 27. Economic indicators for rubber.

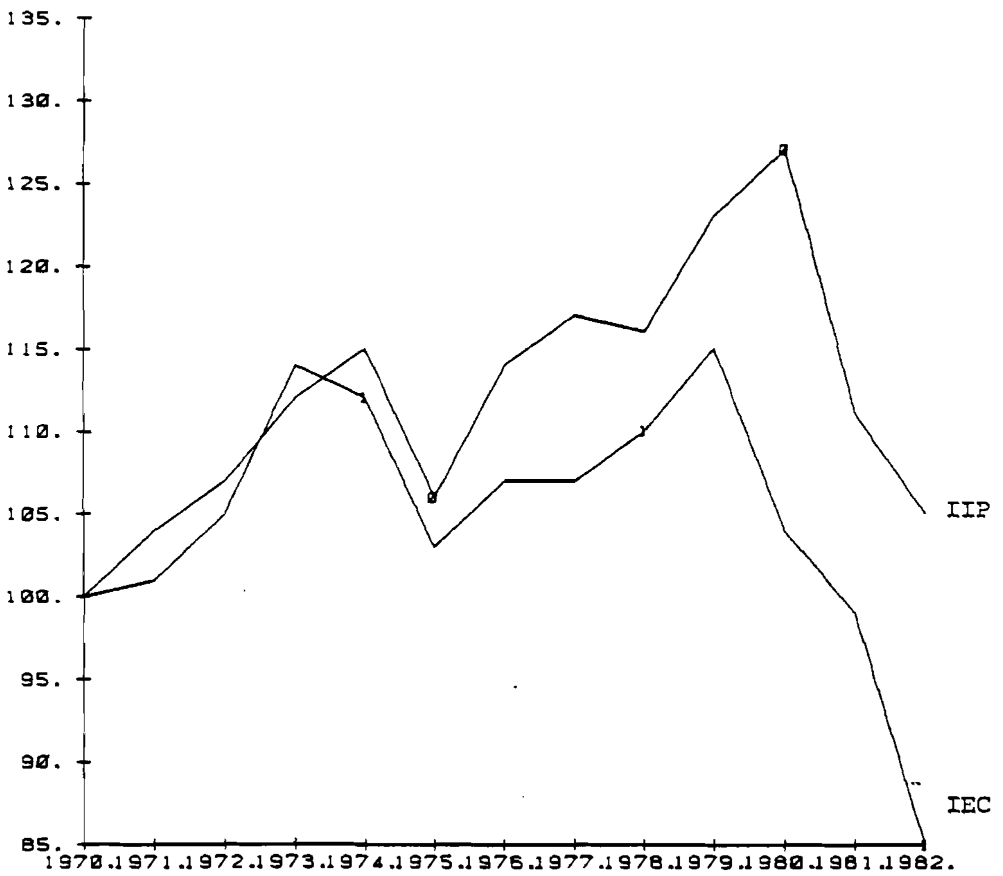
	1970	1979	1982
Share in industry's value added at constant prices (%)	2.35	1.89	1.62
Share in industry's value added at current prices (%)	2.35	2.33	2.08
IVA	100	117	80
IIP	100	123	105
IVA/IIP	1.00	0.95	0.76

Table 28. Energy coefficients for rubber.

	1970	1974	1979	1982
E/IIP	1.00	97	93	81
ESVA	0.64	-	0.66	0.65

Rubber is a regressing sector in terms of value added, this regression being attenuated when one consider industrial production (Table 27). The movement of relative prices is favorable to the sector and softens its regression. The evolution of *ESVA* is a little bit less favorable than average, which is a better result than with *E/IIP* (Table 28). The energy content of industrial production decreases mostly after 1979, when industrial production drops itself, as shown in Figure 11.

Figure 11. *IEC* and *IIP* for rubber.



3.7. Other Building Materials

The energy efficiency of the sector is better with *E/IIP* than with *E/VA* (Figure 12), partly because of the way value added was calculated (see the case of cement, plaster, and lime), and thus the real value added of this sector is presumably larger. Between 1979 and 1982, *E/VA* has decreased faster than *E/IIP*, but this is the case for total industry, since on average value added grows faster than industrial production. The energy savings of this sector remain below the average according to these coefficients. The relative prices evolution is favorable to the sector, and even when the value added is underestimated, *ESVA* is around the average of industry (Tables 29 and 30). With the actual value added, one may assume that the savings of this sector are above the average.

As in other sectors, relatively less energy-intensive products (concrete) have had a higher growth than relatively energy-intensive ones.

Figure 12. *IEC* and *IIP* for other building materials.

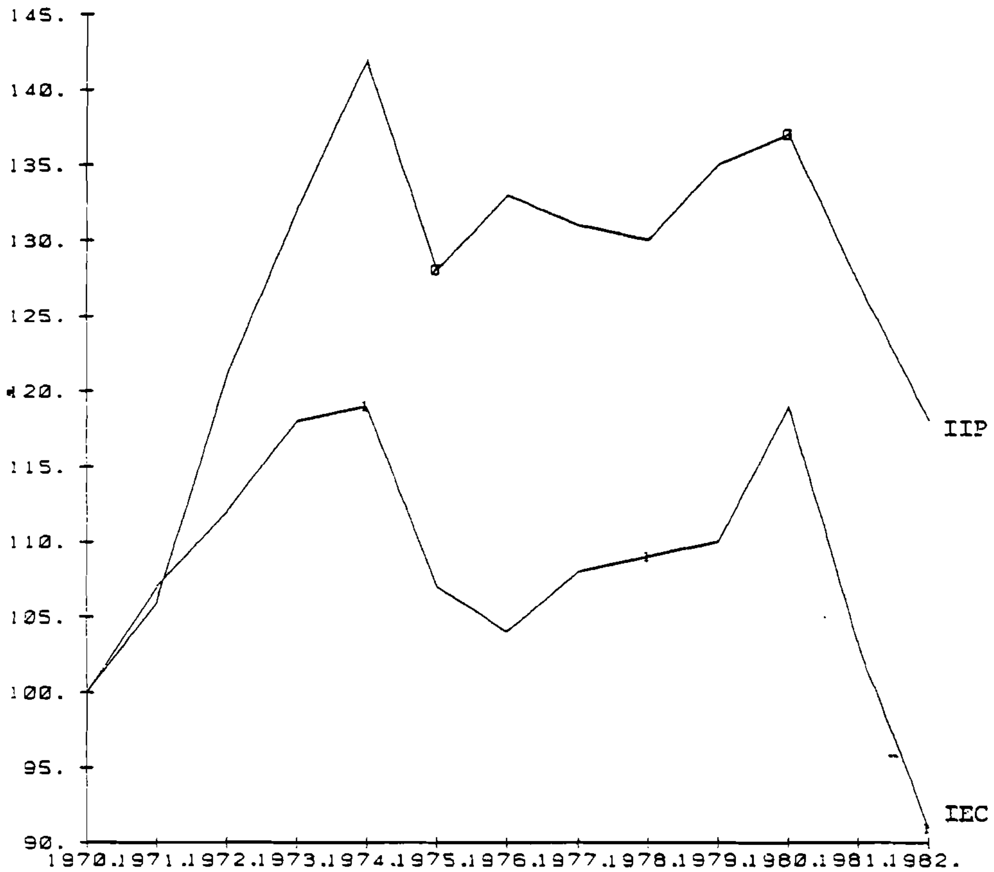


Table 29. Energy coefficients for other building materials.

	1970	1974	1979	1982
E/IIP	1.00	0.84	0.81	0.77
ESVA	1.31	-	1.27	1.33

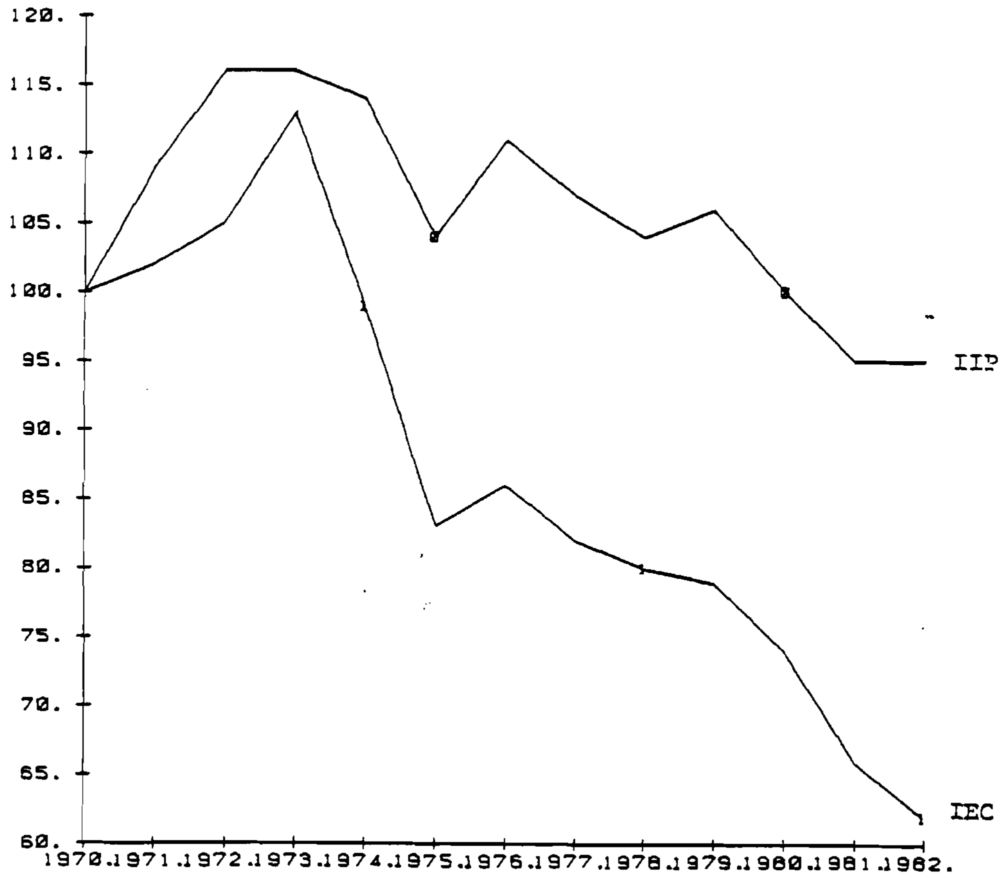
3.8. Textiles, Leather, and Clothing

This sector shows important energy savings with every indicator (Figure 13). The decrease of *E/VA* started only after 1973 and accelerated after 1979 (-4.5% per annum for 1973-1979, -5.2% for 1979-1982). The relative prices evolution is favorable to the sector, especially between 1970 and 1979. This brings an outstanding achievement for energy savings with *ESVA*, although there is a slight regression after 1979 (Tables 31 and 32).

Table 30. Economic indicators for other building materials.

	1970	1979	1982
Share in industry's value added at constant prices (%)	2.16	1.91	1.84
Share in industry's value added at current prices (%)	2.16	2.16	2.06
IVA	100	127	121
IIP	100	135	118

Figure 13. Textiles, leather, and clothing.



The value added content (at constant prices) of the production is stable. The evolution of relative prices after 1979 explains this regression, while the other coefficients show important savings after the second oil shock. The sector, despite being energy extensive, always has better than average results. The treatment of fibers to make finished products grew faster than the basic operations on fibers, but there is no apparent

Table 31. Energy coefficients for textiles, leather, and clothing.

	1970	1974	1979	1982
E/IIP	1.00	87	75	66
ESVA	0.50	-	0.43	0.45

Table 32. Economic indicators for textiles, leather, and clothing.

	1970	1979	1982
Share in industry's value added at constant prices (%)	11.89	8.33	7.97
Share in industry's value added at current prices (%)	11.89	9.66	8.66
IVA	100	104	96
IIP	100	106	94
IVA/IIP	1.00	0.98	1.02

increase in the value added content of production.

3.9. Machinery and Electric Equipment

This sector represents half of French industry's value added (Table 34), but only 13% of its energy consumption. The evolution of the energy coefficient is roughly the same using *E/VA* and *E/IIP*, except that the shocks did not accelerate the decrease of *E/VA* (the average annual decrease being 4.3% for 1970-1973, 3.3% for 1973-1979, and 2.2% for 1979-1982). Figure 14 shows the effects of the two oil shocks; the shapes of these curves are very close to those of total industry. Before 1973, the *E/IIP* decreased at an annual rate of 2%, the same decrease as for the 1970-1982 period. But the *E/IIP* remained approximately constant between 1975 and 1979 (0.84) (see Table 33), and decreased by 4% per annum on average for 1979-1982.

When one takes value added at current prices, the energy savings of this sector are close to average. Being a large sector, it includes subsectors whose relations to energy are very different from one to another. In economic terms, the components of the sectors are diverse too. There are recessive activities, such as foundries, and modern fast growing ones, such as electronics. The combination of the two gives a trend in which there is a decrease of the most energy intensive industries and the rapid growth of the modern activities that have very few energy requirements and a high value added content. The traditional machinery activities are decreasing or stagnating (agricultural and professional machinery, precision materials), but every activity based on office materials (and especially computers) and

Figure 14. *IEC* and *IIP* for machinery and electric equipment.

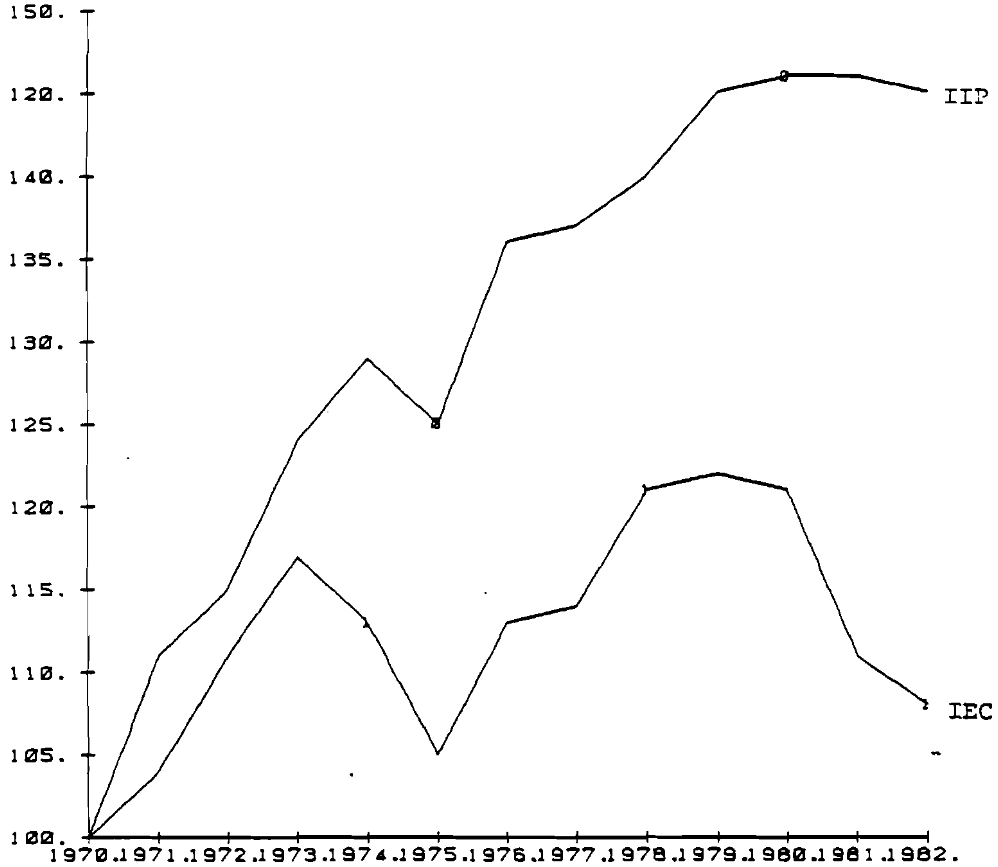


Table 33. Energy coefficients for machinery and electric equipment.

	1965	1970	1974	1979	1982
E/IIP	1.09	1.00	0.88	0.84	0.74
ESVA	-	0.25	0.24	0.24	0.25

professional or domestic electronics are growing very strongly (Table 35).

But an unfavorable relative prices evolution prevents these activities from greatly increasing their share in value added at current prices (9.87% in 1970, 10.44% in 1982). The index of production gives a better idea of the important changes in the production structure, as shown in Table 36.

All these activities give a part of their productivity gains to other sectors by the means of decreasing prices.

Table 34. Economic indicators for machinery and electric equipment.

	1970	1979	1982
Share in industry's value added constant prices (%)	45.34	51.81	49.96
Share in industry's value added current prices (%)	45.34	52.03	52.41
IVA	100	161	161
IIP	100	145	145
IVA/IIP	1.00	1.11	1.11

Table 35. *IVA* of electric materials and professional electronics.

	1970	1973	1977	1979	1982
IVA	100	135	182	210	197

Table 36. *IIP* of some fast growing activities.

Sectors	1970	1975	1979	1982
Automatisation materials	100	155	156	201
Telecommunication materials	100	243	297	342
Electronics components	100	157	228	262
Electronic tubes	100	133	244	319

Among the "machinery and electric equipment" sector, the fastest growing activities are the ones where energy plays a very small role as a cost (1.8% for electric and electronic materials, 1.2% for shipbuiding and aircraft industries).

3.10. Chemicals

Figure 15. *IEC* and *IIP* for chemicals.

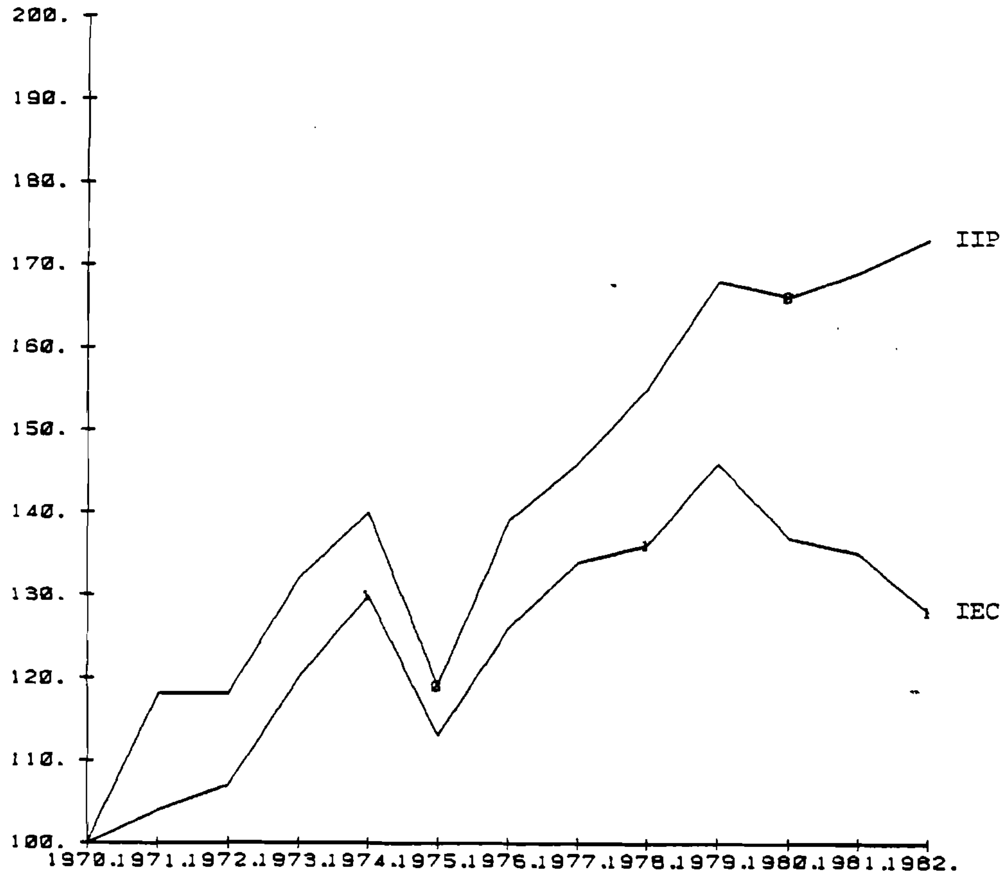


Table 37. Energy coefficients for chemicals.

	1970	1974	1979	1982
E/IIP	1.00	0.93	0.87	0.74
ESVA	1.84	1.88	2.22	2.40

This sector is the second contributor (after iron and steel) to the decrease of industry's energy consumption between 1979 and 1982. Chemicals have a bigger decrease of *E/IIP* than *E/VA* (26% against 22% for 1979-1982) and are a little above average with *E/IIP*, Table 37. It is surprising to see that *E/IIP* had a faster decrease before 1973 (4% per annum on average) than after (2% per annum). This movement is more obvious with *E/VA* (see the evolution of *IVA/IIP*), whose annual decrase is 1.2% for 1970-1973, 0.01% for 1973-1979 and 5.6% for 1979-1982. As for other sectors, it is only since 1979 that the *E/IIP* has quickened its decrease (5%). This is obvious from Figure 15. This sector has very different products: all organic chemicals products are very energy intensive and all pharmaceuticals products are energy extensive.

The growth of products is very different from one to another, and this makes any indicator calculated on the basis of fixed weights (*IIP* and value added at constant prices) rather questionable. For instance, the growth of polypropylene and calcium carbide are (*IIP*) given in Table 38.

Table 38. *IIP* for calcium carbide and polypropylene.

	Weights	1970	1982
Calcium carbide	3.6	100	23
Polypropylene	1.4	100	1555

The production of polypropylene has multiplied by 15 and that of calcium carbide has been reduced to one fifth, but the importance of each sector remains the same in the calculation of *IIP* over the whole period. For this reason, it seems preferable to examine *ESVA* (Table 37). With this indicator, the sector achieves less than average energy savings; indeed, this only reinforces the trend observed with *E/VA*.

Table 39. Economic indicators for chemicals.

	1970	1979	1982
Share in industry's value added constant prices (%)	10.30	11.28	11.96
Share in industry's value added current prices (%)	10.30	11.00	10.70
IVA	100	145	162
IIP	100	168	173
IVA/IIP	1.00	0.86	0.94

A very simple separation can be made in the structure of the sector, between basic chemicals on the one hand and parachemicals and pharmaceuticals on the other. The latter have had a faster growth than the former in terms of *IIP* and value added (the *IVA* of basic chemicals was 150 in 1982, that of pharmaceuticals and parachemicals was 183), especially after 1979. Between 1979 and 1982, the value added at constant prices of pharmaceuticals increased by 25%. For the total chemical sector and especially for pharmaceuticals and parachemicals, the relative prices evolution is unfavorable (Table 39).

The future development of the sector will be based on products with relatively more value added and less energy requirements (i.e., a relative decline of intermediary products).

3.11. Mining

Figure 16. *IEC* and *IIP* for mining

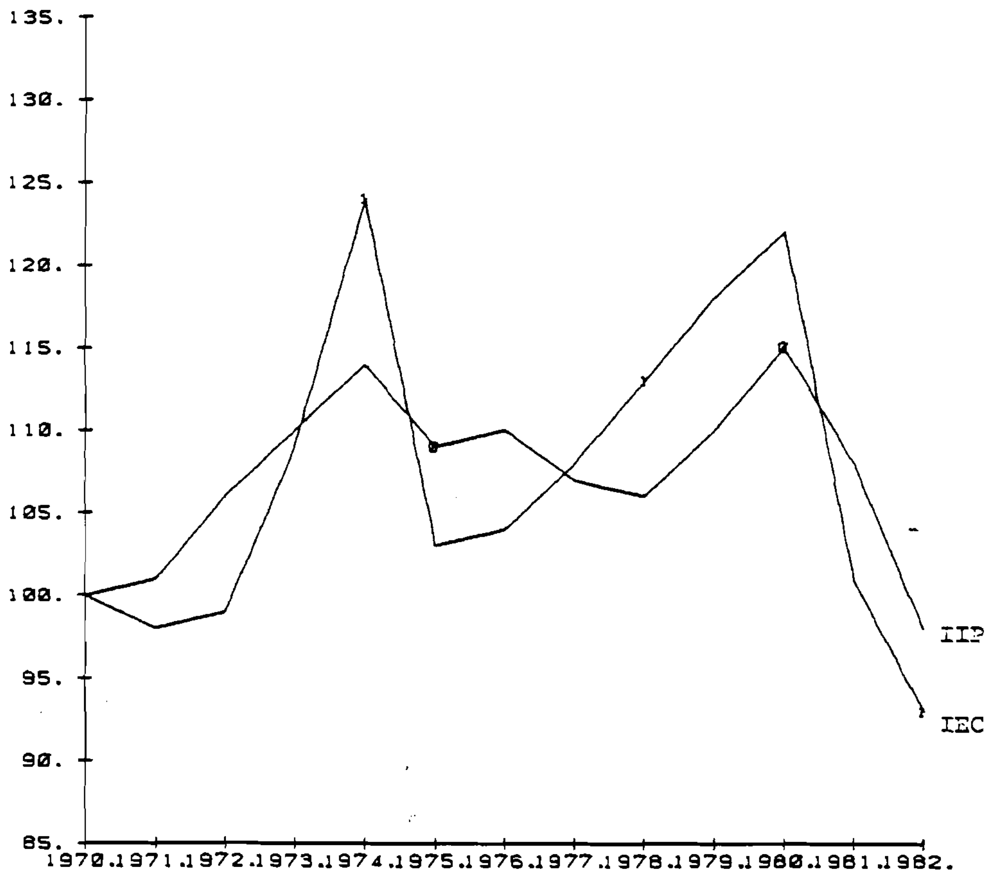


Table 40. Energy coefficients for mining.

	1970	1974	1979	1982
E/IIP	1.00	1.09	1.08	95
ESVA	0.92	-	1.45	1.41

For mining, *E/IIP* shows a stagnation of energy efficiency (figure 16), with the degradation of *E/VA* due to a drop in the value added content of production (Table 41).

The relative prices evolution attenuates the decline of the sector, but *ESVA* makes obvious the nonexistence of energy savings, especially between 1970 and 1979, although the situation improves after 1979 (Tables 40 and 41).

Table 41. Economic indicators for mining.

	1970	1979	1982
Share in industry's value added at constant prices (%)	2.00	1.18	0.99
Share in industry's value added at current prices (%)	2.00	1.31	1.28
IVA	100	86	71
IIP	100	110	98
IVA/IIP	1.00	0.78	0.72

3.12. Miscellaneous

Among the two sectors that have seen an increase of *E/VA* , one is miscellaneous, by definition a heterogeneous sector, with activities having low energy requirements. Energy is not a major constraint of these activities, and the move towards less energy-intensive techniques or products is not a characteristic of their evolution; the comparison with *ESVA* shows the same results (Tables 42 and 43).

Table 42. Energy coefficients for miscellaneous.

	1970	1974	1979	1982
E/IIP	1.00	1.16	1.25	135
ESVA	0.21	-	0.36	0.45

Table 43. Economic indicators for miscellaneous.

	1970	1979	1982
Share in industry's value added at constant prices (%)	12.16	10.36	11.00
Share in industry's value added at current prices (%)	12.16	9.22	9.99
IVA	100	124	129
IIP	100	132	137
IVA/IIP	1.00	0.94	0.94

CONCLUSION

At this point, one may have the feeling that the questions raised are only partly answered. It has been seen that the pattern of energy consumption in the French industry altered in the 1970s, but mostly in 1979. After the first oil shock, there are two ways of viewing the energy consumption: either one considers that the decreasing trend of the energy coefficient has not accelerated, or one considers that the decrease in the energy coefficients with the deceleration in growth is a change relative to the previous period. But after 1979, the evolution of energy consumption is different from that before. A part of this change, but not the major part, can be simply explained by the changes in the structure of the French industry, a change observable at the level of disaggregation used here, especially the decline of heavy, energy-intensive activities such as iron and steel. This phenomenon is not new, it can be observed in other countries as well and it did not start in the 1970s, although it was boosted by the crisis. But it has been shown too, that the bulk of change in the level of energy consumption related to activity could not be simply reduced to the decline of the industries mentioned [20]. The main part of the decrease of energy demand is due to a smaller input of energy for the same amount of output. For each branch (except miscellaneous), there is a "content effect", but its level varies greatly according to each branch.

More than simply a change in the relative importance of each sector in the total industry, ***at least at the chosen level of disaggregation,*** the reality of the decrease of industry's energy consumption is a decrease of the energy content. This content effect must not be mistaken for an "efficiency" or "energy conservation" effect. It is only an economic effect and does not deal with the technical evolution of the sector. Indeed, for at least one sector (cement), there is an increase of the technical energy coefficient and a decrease of the energy content of value added. There is not one energy coefficient, but many, each one reflecting a different reality. Economic coefficients, such as E/VA, must not be mistaken for the energy content of one unit of a definite product. The content effect is associated with the level of disaggregation, a more disaggregated structure of the industry would have given a larger structure effect. The estimation of what is this decrease in content is extremely difficult at the level of a macroeconomic study like this one.

There are several energy coefficients, each one with a different meaning, so one must not mistake the index of production for value added or physical indicators in order to estimate an energy coefficient whose decrease would give information on the energy conservation (or lack of) in some sectors. Most of the energy coefficients have only an economic meaning, and cannot therefore be used to estimate the "energy conservation".

There are some "objective" technical explanations concerning the better efficiency of production equipment, or the shift toward less "energy-intensive" products, but the estimation of these effects on energy consumption requires a technical study. The main explanation of the decrease of the demand lies in the economic growth dynamics. The products and branches that have the larger growth potential do not require large amounts of energy, and the content of growth is much lighter than before, partly because of a new pattern of accumulation around new technologies, and partly because there is a slowdown of activities that were favored by the particular conditions of post-World War II growth (reconstruction in the 1950s, cheap energy in the 1960s, etc.). The effect of these changes on economic structures are, nevertheless, limited. When one examines the shares in value added at current prices, there is no tremendous change, except in a few sectors. One must bear in mind that the period considered here is short, many of the most promising activities are not fully developed yet, and the level of disaggregation is inadequate to appreciate the changes and to give a clear image of the economic weight of some new activities.

Physical indicators are only available for a few sectors and are not useful for a *structure* study. At the level of total industry, it is evident that there are energy savings, but the contribution of each sector to these savings cannot be accurately identified (see the case of nonferrous metals). The decrease of the energy content of growth cannot be denied, but it has many aspects. The study of energy coefficients, such as *E/VA* or *E/IIP*, is limited by the fact that they represent a certain structure of production (products, technology, prices, etc.), and the decrease of the energy content of growth is an alteration of these structures. The physical indicators, such as t.o.e. per ton of steel, are only valid to a certain extent, since the products change qualitatively over time (steel gets thinner and stronger,etc), and do not have the same use either. It is then difficult to compare one unit of product at different periods from the point of view of growth and development, since their role alters. The energy content of an automobile of 1970 is not the same as that of 1982, but the automobile is not the same either. We may resort to the function "individual means of transportation" and look at direct and indirect energy inputs necessary to individual transportation. One could take examples for all types of industries, in particular those where the products are changing fast. Instead of considering the final product itself, and obtaining a pseudo-engeenering ratio, it may be possible to go further and consider the "functions" themselves (individual or collective transportation, communication, etc.). Ayres (quoted in [21]) proposes a "substitution ladder" that distinguishes several levels of technological change, Figure 17.

The changes that occured after the oil shocks and the crisis make reference to every level of this ladder, which does not necessarily mean that there are causal links, but there are consequences for energy demand.

Another problem is the diffusion of energy savings. If one takes again the example of an automobile, the energy needed for the fabrication and use of a product necessary for individual transportation has decreased, partly because of the weight of the automobile. This loss of weight is made possible by the replacement of steel with other materials, such as plastic and alloys, and by the fact that steel sheets are becoming lighter [22]. The car industry is the primary user of steel, and thus its evolution will have consequences on that of the steel sector. This results in a smaller production (in physical terms, at least) and a relative decline of steel and as a consequence a reduction of the total energy consumption of the industry. At the start of the causal chain of the decrease of consumption was the decrease of the input of energy for a product (a decrease that is wanted). The usual

Figure 17. (Taken from [21]).

The Substitution Ladder

Level (Rung)	Brief Description	Examples
VII	Shift in social or personal values or goals resulting in shift in demand	More consumer goods versus quality of life
VI	Shift in strategy to achieve goals	Telecommunication versus personal travel
V	Shift in technical means (i.e., systems) to implement strategy	Individual personal transport versus mass transport
IV	Shift of subsystems, within a system (design change)	Internal combustion engine versus battery powered vehicle
III	Shift in components (design change)	Piston engine versus turbine engine
II	Shift in materials for specified component	Aluminium versus cast iron for engine blocks
I	Shift in materials processing technology	Ingot casting versus continuous strip casting of metals

Source: Robert U. Ayres (partly modified)

links between energy consumption and structural change have been reversed.

This is to point out that structural change must be related to changes in the development pattern. The 1970s have witnessed two major breakdowns: the conditions of energy supply have been radically altered (price, security, etc.); the development pattern of the past decades is in crisis, a crisis that is not confined to the industrial sector . The conjunction of these two breakdowns has led to a change in the relations between energy and development. The crisis implies changes in technologies, products, industries, and "functions" as well, i.e., the components of the development pattern. To reestimate the relations between energy and development, and thus make a more accurate estimation of the "energy savings" of each sector or subsector, it is necessary to take into account all the elements mentioned. For these reasons, the study of the structural change in the French industry related to industry's energy consumption cannot answer all the questions that may come to mind when one looks at the tremendous decrease of the "energy content of growth", and, what is more, the changes in the energy consumption pattern of the industry are important only since 1979. Since data is available only up to 1982, it is not possible to make definitive statements on the basis of such a small period.

APPENDIX

Description of the sectors studied.

The disaggregation adopted in this paper is the one taken in [23] to give the energy consumptions. It consists of 14 branches, brief descriptions of which are given below.

Mining: includes all mining activities for iron ore, lead, zinc, copper, and other metallic ores, and minerals used in construction, such as sand, clay, etc.

Nonferrous metals: production of nonferrous metals, such as lead, zinc, and cadmium, and the metallurgy of those metals.

Electrometallurgy: metallurgy of aluminum (first and secondary smelting) and iron alloys.

Metal Processings: all steel processings, aluminum semi-finished products,and other nonferrous semi-finished products.

Machinery and electric equipment: smelting works, all machineries, electric and electronic equipments, aircrafts, cars, naval construction.

Cement, plaster, and lime: production of cement, plaster, and lime.

Other building materials: production of concrete, bricks, tile, china, etc.

Glass: all glass products.

Chemicals: mineral, organic and parachemicals, pharmaceuticals, synthetic rubber.

Textile, leather, and clothing: all textile and clothing activities, including synthetic fibers.

Rubber: all rubber production and processings, except synthetic rubber.

Paper and paperboard: production of pulp, paper, and paperboard.

Miscellaneous: printing and publishing, plastic, wood products, toys, jewellery, etc.

Iron and steel: production of steel and first stages of steel processing.

Notes

[1] B. Chateau (1985), La prévision énergétique en mutation, *Revue de l'Energie*, n. 371, pp. 1-11.

[2] And especially what the CEPII considers to be one of the three major breakdowns of the crisis: the industrial breakdown (the other two being, respectively, energy and monetary breakdowns). CEPII (1983), La montée des tensions, *Economica*, p. 19.

[3] Les Collections de l'INSEE C 120. Les Comptes de l'Industrie, édition 1983, INSEE, Paris.

[4] INSEE, Annuaire Statistique de la France, editions for relevant years, INSEE, Paris.

[5] Le mouvement économique en France 1949-1979, Séries Longues macro-économiques, INSEE, Paris Mai 1981.

[6] Martin, Chateau, Criqui, Lapillonne (1984), La diminution de la consommation d'énergie en France, réaction conjoncturelle ou inflection de longue période, *Revue de l'Energie*, n. 363, pp. 181-191.

[7] Comité National Français de la Conférence Mondiale de l'Energie. Synthèse des Bilans Energétiques Français 1962-1981.

[8] Ministère de l'Industrie, Energie la voie Française, Paris, 1980

[9] As seen before, the elasticity coefficient of the 1968-1974 period is larger than that of the 1962-1968 period; its use would increase the difference between forecasts and actual figures.

[10] What is more, we deal only with economic indicators, which cannot be related simply to "technical progress", a technical concept by definition.

[11] Partly because the necessary data are not available.

[12] For more details about this method see [6].

[13] Metal processings are included here because it is not possible to separate them from nonferrous metals and electrometallurgy data for 1979 and 1982.

[14] Value added at constant prices is calculated as the difference between production at constant prices (deflator of the sector considered) and intermediary consumption at constant prices.

[15] The Index of Industrial Production (*IIP*) is an indicator of activity published by INSEE and based on representative series of the evolution of activities for each branch. The series reflect either the evolution in physical terms, or the value of shipments with application of a deflator, or, more rarely, the evolution of production hours. The weight system is based on the proportional value of production for each branch in 1970, and for large branches on the proportional value added in 1970.

This index is used in this paper as a pseudo-physical indicator, considering that the weights are fixed, and its calculation is, as much as possible, based on real physical values. Difficulties arise with industries with heterogeneous products (chemicals, machinery and electric equipment) or that have had important changes in the product mix.

The *IIP* is different from the index of production, which refers to the value of shipments, and is published by National Accounting.

[16] Centre de Recherche en Economie Industrielle, L'industrie en France, Flammarion, 1983

[17] Since cement cannot be isolated at level 90 of National Accounting, weights of 1970 were used.

[18] As stated by Dr B. Chateau (IEJE).

[19] Different from the one referred to before.

[20] The structure of the industry when one takes value added at current prices gives the following share for energy intensive-industries: 26.3% in 1970, 25.5% in 1979, 25.6% in 1982. There is a larger decrease than with constant prices structure (which was the basis of our analysis), but not a collapse.

[21] D. Altenpohl, Materials in World Perspective, Springer Verlag, Berlin Heidelberg New York, 1980.

[22] This loss of weight does not mean that the sheets are more fragile. Research in steel industry aims at obtaining more resistant steel with less weight. This does not mean a loss of quality because fragility of the materials in the front part of the car is useful in order to absorb the possible shock. For the French industry, the following figures are given in [16]:

Share of each material in total weight of the automobile (%):

	1965	1980
Steel	62.9	60.1
Pig iron	12.5	11.8
Aluminum	1.8	3.6
Plastic	1.0	5.9

[23] Ministère de l'Industrie et de la Recherche. L'Energie dans les Secteurs Economiques, édition 1984, La Documentation Française, Paris 1984.