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AN INPUT OUTPUT APPROACH TO THE ANALYSIS OF INTERCOUNTRY DIFFERENCES IN PER CAPITA ENERGY CONSUMPTION

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ABSTRACT

Comparisons of energy consumption patterns in different countries can serve as a tool for identifying ineffieciencies in the use of energy in individual countries. However, differences in terms of relations such as the use of energy per capita or per unit of GDP are not usually very good indicators of intercountry differences in the efficiency of energy use. Factors such as climatic conditions, the sectoral structure of the production system etc. often hide more basic differences in production methods and consumption patterns. Moreover, differences in production methods with similar output may not only be due to differences in the efficiency of energy utilization, but can be the result of intercountry differences in relative prices.

In this study, input-output data for the Federal Republic of Germany, France and the Netherlands is used to identify intercountry differences in per capita consumption patterns which can be assigned to differences in production methods and domestic consumption patterns. It appears that such differences do exist. In particular the technologies used in the three countries differed significantly in terms of energy intensity. However, when these results were combined with data on relative prices, the observed differences in energy intensities in most cases were quite consistent with intercountry differences in relative prices. Thus, the observed differences between the sample countries do not seem to reflect intercountry differences in the efficiency of energy utilization.

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1. Introduction

Increasing interest in energy conservation policies in many countries has stimulated a great deal of research on interactions between the energy sectors and the rest of the national economy. A simple and obvious reason for this is that the merits of an energy conservation program cannot be judged solely on the basis of the resulting changes in energy production and consumption patterns. Its impact on the economy as a whole, and the possibility of conflicts between the energy conservation goals and goals related to economic variables, also have to be considered. Therefore, research on "energy-economy interactions" aims basically at identifying such goal conflicts. 1/

One line of research in this field is the development and utilization of econometric and other models for simulation of various "scenarios" for the development of energy consumption and the economy. Using such models, the economic and political feasiblity of contemplated energy conservation policies can be evaluated.

Another approach, the one on which we focus in this study, is intercountry comparisons of per capita energy consumption based on the following notion: If countries with equal, or at least comparable, material standards of living differ substantially in terms of per capita energy consumption, this might indicate that "energy intensive" countries can reduce their energy consumption without significant costs in terms of the material standard of living.

As there are many countries with approximately the same GDP per capita but quite different levels of energy consumption per capita, the second approach has some appeal. After all, real-world observations tend to be more convincing than results obtained from more or less esoteric mathematical models. However, observed intercountry differences in the use of energy per unit of GDP do not only, or may not at all, reflect intercountry differences in the efficiency of energy utilization.

One reason for this is that generally there are many "structural" differences between the countries which are usually due either to the natural setting of the country (e.g., climate, size) or to man-made conditions which cannot be altered on short notice. 2/ Obvious examples of structural factors affecting the amount of energy used per unit of GDP are intercountry differences in climate and travel distances. Different degrees of self-sufficiency in energy supply lead to different amounts of transformation losses in the energy sector, and thus are factors which, ceteris paribus, lead to intercountry differences in the use of primary energy per unit of GDP.

A somewhat less obvious factor is the trade between countries. Two countries with approximately the same level and composition of domestic consumption might not have the same production systems in terms of sectoral composition. Thus it is possible that the use of energy per unit of GDP differs between two countries primarily because one of them exports energy intensive products whilst the other imports such products.

From an energy conservation policy point of view, most of these structural factors have to be taken as given. This is certainly the case for climatic factors and intracountry travel distances. But it also holds for differences in the sectoral composition of the economy due to international trade. All countries cannot simultaneously substitute imported energy intensive products for domestically produced ones. A single country can - but since prevailing international trade patterns are likely to reflect the international pattern of comparative advantages, it would probably not be an energy conservation strategy without costs in economic terms.

The conclusion of this discussion is that intercountry differences in per capita energy consumption are interesting, from an energy policy point of view, only to the extent that they reflect differences in the technology utilized by the energy consuming production sectors or differences in the domestic consumption patterns. A corollary to this conclusion is that there might be significant differences in the efficiency of energy utilization between two countries, even if the use of primary energy per unit of GDP is approximately the same in the two countries. Thus, from an energy policy point of view, intercountry comparisons of per capita energy consumption should be carried out in such a way that differences due to technology and domestic consumption patterns, or "life-style", can be isolated. Moreover, there is no *a priori* reason to confine the comparisons to countries with widely different energy/GDP ratios. [3] "Structurally" dissimilar countries can differ significantly in terms of energy intensity of technology and "life-style" in spite of a high degree of similarity in terms of energy use per unit of GDP.

However, even if intercountry differences in per capita energy consumption due to technology and "life-style" exist and can be measured, they provide a useful basis for conclusions about the economic impact of energy conservation programs only in special cases. In order to draw such conclusions we need to know how well the input of energy is integrated with the input of other factors of production [4] and how reductions in the use of energy affect the use of these other factors of production. [5] In other words, we need information about the actual use of all factors of production, factor prices and production functions. [6] But if such information were available, which is rare, the efficiency of energy utilization in a particular country could be determined without comparisons with other countries. On the other hand, observations on intercountry energy consumption differences would not be of much value in an energy policy context in the opposite case where we know nothing about factor prices and the use of other factors of production in the different countries. However, observations on intercountry energy consumption differences are potentially useful where we have information on factor inputs and prices, but only scanty evidence on production functions. For instance, if two countries, chosen on the assumption that they have almost identical production functions, are compared in terms of factor inputs and factor prices, the comparison can either indicate inefficiencies in the use of energy in one of the countries or give a rough estimate of the long run elasticity of substitution between the factors of production. The former case appears when differences in factor inputs are inconsistent with relative factor prices, the latter when differences are consistent. [7]

2. The purpose and scope of the study

In accordance with the discussion above, analyses of intercountry energy consumption dissimilarities should first focus on identifying those due to differences between the countries in terms of the technologies utilized in the production system or to the composition of domestic consumption of goods and services. The next step is to investigate to what extent intercountry differences are reflected by differences in production functions or relative factor prices. If these factors cannot explain the observed differences in per capita energy consumption, it is reasonable to interpret the residual as a measure of intercountry differences in the efficiency of energy utilization.

The purpose of this study is simply to apply this scheme of analysis in pairwise comparisons of the energy consumption patterns in three countries: the Federal Republic of Germany (FRG), France and the Netherlands. [8] Our study differs from most others in this field primarily in that it is based on input-output statistics. With few exceptions [9] international comparisons of energy consumption patterns have been based on engineering data about individual processes and activities.

The use of relatively aggregated input-output data, as opposed to various kinds of microdata, has its advantages and its disadvantages. The basic advantage is that the i/o model yields a more comprehensive measure of the "energy intensity" of a given activity than simple observations on the input of energy per unit of output; using the i/o model it is possible to incorporate the indirect use of energy (i.e., the energy used in the production of non-energy inputs) in the estimation of the energy intensity of a given process. [10]

The main disadvantage with available input-output statistics is the high level of aggregation, which tends to reduce the usefulness of the i/o model for characterization of the technology used in various processes. Given this state of affairs, we do not claim that the i/o approach is superior to other approaches; we adopt it here because we think that our way of using the i/o data can throw some additional light on international differences in energy consumption patterns.

3. The model and the data

In this section we present our methodological approach and the data used in this study. At this stage we want to eliminate the impact of one "structural" factor, the degree of self-sufficiency in energy supply in the different countries. Thus our analysis is carried out in terms of per capita final energy consumption.

The methodological approach is very simple. Using the static Leontief model, the observed differences in per capita final energy consumption between two countries are decomposed into a number of components. These components are then grouped so that energy consumption differences due to technological, consumption pattern or "life-style", and foreign trade factors can be distinguished.

To our knowledge, decomposition of observed energy consumption differences using input-output data was done initially by Strout in an unpublished work cited by Reardon (1973). A similar approach was later adopted by Reardon himself. Bergman (1977) carried the decomposition further, particularly by decomposing the final demand effects into a volume component and a composition component. In all these studies, the object was the change in energy consumption over time in one country (U.S. and Sweden, respectively).

The basic model is the usual static Leontief model except that the energy sectors are treated as exogenous. That is, the total supply of three kinds of final energy [11/] (domestic production plus imports minus exports) is treated as primary resources and the deliveries of intermediate inputs to the energy sectors are treated as a part of domestic final demand. The energy input coefficients in the energy using production sectors, as well as the energy deliveries to the final demand sectors, are converted to physical units - million tons of oil equivalent (mtoe) - while the remaining intersectoral flows are measured in monetary terms. The basic model can then be written:

$$X = aX + Y_D + Y_Z - M \tag{1}$$

$$E = \epsilon X + E_D \equiv E_I + E_D \tag{2}$$

where

X = a vector of per capita gross production.

Y_D = a vector of per capita domestic [12/] final demand.

Y_Z = a vector of per capita exports.

M = a vector of per capita imports.

a = a matrix of input-output coefficients.

E = total final energy consumption.

E_I = final energy use in the production sectors (except the energy sector).

E_D = final energy use in the household and energy sectors.

ϵ = a vector of direct energy input coefficients ϵ_i.

If (1) is solved and the solution substituted into (2), one obtains:

$$\begin{aligned} E_I &= \epsilon(I - a)^{-1}[Y_D + Y_Z - M] \equiv e[Y_D + Y_Z - M] = \\ &= eY_D + eY_Z - eM, \end{aligned} \tag{3}$$

where

e = a vector of total (direct + indirect) energy input coefficients.

This is the formulation of the model we will use in the following. It implies that we focus on energy use within the country [13/] and that imports are perfect substitutes for domestic production in all sectors. That is certainly an extreme assumption, but lacking information on the substitutability of imports and domestic production, we have chosen the assumption which yields the least cumbersome formulas.

Using (3), the differences in per capita final energy consumption within the production system between two countries, 0 and 1, can be written:

$$\begin{aligned}\Delta E_I &= E_I^1 - E_I^0 = \\ &= (e^1 Y_D^1 - e^0 Y_D^0) + (e^1 Y_Z^1 - e^0 Y_Z^0) - (e^1 M^1 - e^0 M^0). \qquad (4)\end{aligned}$$

We now define a new hypothetical demand vector $\hat{Y}_D$ such that:

$$\sum_i \hat{Y}_{Di} = \sum_i Y_{Di}^1 \quad \text{and} \quad \frac{\hat{Y}_{Dj}}{\sum_i \hat{Y}_{Di}} = \frac{Y_{Dj}^0}{\sum_i Y_{Di}^0}, \; j=1,\ldots,n$$

One can say that $\hat{Y}_D$ has the same volume as Y_D^1 and the same composition as Y_D^0. Similarly, vectors $\hat{Y}_Z$ and $\hat{M}$ are defined for exports and imports.

Using these definitions, eqn.(4), after some manipulations, can be written as follows:

$$\begin{aligned}\Delta E_I &= [(e^1 - e^0)(Y_D^1 + Y_Z^1 - M^1)] + \\ &+ [e^0(Y_D^1 - \hat{Y}_D)] + [e^0(Y_Z^1 - \hat{Y}_Z)] - [e^0(M^1 - \hat{M})] + \\ &+ [e^0(\hat{Y}_D - Y_D^0)] + [e^0(\hat{Y}_Z - Y_Z^0)] - [e^0(\hat{M} - M^0)] \qquad (5)\end{aligned}$$

or

$$\begin{aligned}\Delta E_I &= [(e^1 - e^0)(Y_D^0 + Y_Z^0 - M^0)] + \\ &+ [e^1(Y_D^1 - \hat{Y}_D)] + [e^1(Y_Z^1 - \hat{Y}_Z)] - [e^1(M^1 - \hat{M})] + \\ &+ [e^1(\hat{Y}_D - Y_D^0)] + [e^1(\hat{Y}_Z - Y_Z^0)] - [e^1(\hat{M} - M^0)] \qquad (6)\end{aligned}$$

The difference in final energy consumption in the household and government sectors between the two countries, ΔE_D, can be decomposed in the following way:

$$\Delta E_D = E_D^1 - E_D^0 = d^1 \bar{Y}_D^1 - d^0 \bar{Y}_D^0 \qquad (7)$$

where

$$\bar{Y}_D^k = \sum_i Y_{Di}^k \quad \text{and} \quad d^k = \frac{E_D^k}{\bar{Y}_D^k}; \quad k = 0, 1$$

i.e., d^0 and d^1 represent the final energy consumption per unit of domestic final demand in country 0 and 1, respectively. Similar to eqn.(4), eqn.(7) can be written:

$$\Delta E_D = d^1(\bar{Y}_D^1 - \bar{Y}_D^0) + \bar{Y}_D^0(d^1 - d^0) \qquad (8)$$

or

$$\Delta E_D = (d^1 - d^0)\bar{Y}_D^1 + d^0(\bar{Y}_D^1 - \bar{Y}_D^0) \qquad (9)$$

For computation we use the averages of (5) with (6) and (8) with (9), respectively. Thus we arrive at the following decomposition of the difference in per capita final energy consumption between country 1 and country 0:

$$\underset{TOT}{\Delta E} = \underset{I/O}{(e^1 - e^0)\frac{Y_D^1 + Y_Z^1 - M^1 + Y_D^0 + Y_Z^0 - M^0}{2}} +$$

$$+ \underbrace{\frac{e^1+e^0}{2}(Y_D^1-\hat{Y}_D)}_{DOM.COMP} + \underbrace{\frac{e^1+e^0}{2}(Y_Z^1-\hat{Y}_Z)}_{EXP.COMP} - \underbrace{\frac{e^1+e^0}{2}(M^1-\hat{M})}_{IMP.COMP} +$$

$$+ \underbrace{\frac{e^1+e^0}{2}(\hat{Y}_D-Y_D^0)}_{DOM.VOL} + \underbrace{\frac{e^1+e^0}{2}(\hat{Y}_Z-Y_Z^0)}_{EXP.VOL} - \underbrace{\frac{e^1+e^0}{2}(\hat{M}-M^0)}_{IMP.VOL} +$$

$$+ \underbrace{(d^1-d^0)\frac{\bar{Y}_D^1+\bar{Y}_D^0}{2}}_{DIR.INP} + \underbrace{\frac{d^1+d^0}{2}(\bar{Y}_D^1-\bar{Y}_D^0)}_{DIR.VOL} \; ; \quad (10)$$

where

TOT = Total difference in final energy consumption (DFEC).

I/O = DFEC due to different input-output coefficients.

DOM.COMP = DFEC due to different composition of domestic final consumption.

EXP.COMP = DFEC due to different composition of exports.

IMP.COMP = DFEC due to different composition of total imports.

DOM.VOL[*] *DIR.VOL* = DFEC due to different volume of domestic final consumption.

EXP.VOL = DFEC due to different volume of total exports.

IMP.VOL = DFEC due to different volume of total imports.

DIR.INP = DFEC due to different levels of direct final energy consumption per unit of domestic final consumption.

Eqn.(10) contains more components than are necessary for our purposes, therefore some aggregation can be done. In the following we focus on three components, of which two are aggregated. The *I/O component* is kept as it stands in eqn.(10) and taken as a measure of the difference in final energy consumption due to technological factors. More specifically, the I/O component answers the question: "If the net final demand in country 1 and country 0 were aggregated, and each of the countries supplied half of the resulting demand for each commodity group, what would be the difference in energy consumption between the two countries?" Using this approach different processes get different relative weights in the aggregate description of the technology, but the weights are the same for both countries.

The components *DIR.INP* and *DOM.COMP* both reflect differences in final energy consumption due to the composition of domestic final consumption (*DIR.INP* for energy, *DOM.COMP* for other goods and services). The other two components associated with domestic final consumption, *DOM.VOL* and *DIR.VOL*, represent a pure scaling of the use of energy. In other words, both price and income factors affecting the composition of domestic final demand are reflected in the components *DOM.COMP* and *DIR.INP*. In the following, we refer to the

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[*] Because $\hat{Y}_D$ has the same volume as Y_D^1 but the same composition as Y_D^0, *DOM.VOL* can be written:

$$DOM.VOL = \frac{e^1+e^0}{2}(\hat{Y}_D-Y_D^0) = \frac{e^1+e^0}{2}\,\frac{Y_D^0}{\bar{Y}_D^0}(\bar{Y}_D^1-\bar{Y}_D^0),$$

i.e., it reflects the difference in the volume of domestic final demand. A similar transformation of *EXP.VOL* and *IMP.VOL* can be made to see that these components reflect the difference in the volume of exports and imports, respectively.

sum of these components as differences due to "life-style". The *Life-style component* ($DIR.INP + DOM.COMP$) answers the question: "If the volume of domestic final demand were the same in both countries, and both countries produced equal shares of the supply of all commodity groups, what would be the difference in energy consumption, resulting from the different composition of domestic final demand?" This component reflects differences in the consumption patterns due to relative prices and income levels as well as differences in the preferences.

The third component we focus on is defined by the four components in eqn.(10) related to foreign trade. In the following this aggregated component is denoted "Trade". The *Trade component* ($EXP.COMP + EXP.VOL - IMP.COMP - IMP.VOL$) can be characterized in almost the same way as the Life-style component: "If the net foreign trade were the same in both countries, and both countries produced equal shares of the supply of all commodity groups, what would be the difference in energy consumption resulting from net foreign trade?" This component reflects differences in the pattern of comparative advantages, resulting from differences in resource endowments and other factors, between the countries.

In order to estimate these components we need i/o tables and energy consumption statistics for a given year for the studied countries. The i/o tables were taken from a collection of standardized input-output tables of ECE countries for years around 1965 (Economic Commission for Europe, 1977). There are two versions available, namely a 22 sector and a 45 sector version. We have chosen the aggregated version for this study. Table 1 lists the sectors distinguished in this version. The tables were normalized for population and converted to a common currency unit (DM) using the hypothetical exchange rates in terms of purchasing power parity, as shown in Table 2.

Table 1. The production sectors in the i/o statistics

1. Agriculture, Forestry, Fishing
2. Mining and Quarrying (excl. Coal, Oil, Gas)
3. Food, Beverages and Tobacco
4. Textiles
5. Clothes
6. Wood Products, Paper and Printing
7. Rubber
8. Chemicals
9. Non-metallic Mineral Products
10. Ferrous and Non-Ferrous Metals
11. Transport Equipment
12. Machinery and Other Manufactured Goods
13. Buildings and Other Construction
14. Trade
15. Transport and Communication
16. Other Services (Material Sphere)
17. Dwelling
18. Other Services (Non-Material Sphere)
19. Government and Community Services
20. Scrap and Waste Products
21. Unallocated Items and Statistical Adjustment
22. Coal, Crude Oil, Natural Gas
23. Petroleum and Coal Products
24. Electricity, Gas and Water

Table 2. Population, GDP, and monetary conversion factors

	Population (1000 people)		GDP at 1965 prices (10^9 nat. curr. units)		Factor increase in real GDP per cap. between 1965 and 1970
	1965	1970	1965	1970	
France	48.76	50.77	573.8	761.4	1.275
FRG	59.04	60.65	462.0	581.7	1.226
Netherlands	12.29	13.02	68.7	90.9	1.249

	GDP per capita (in terms of PPP, FRG=100)		Monet. conv. factors, 1965 (relative to DM)	
	1970 (I.Kravis)	1965 (extrapolated)	actual	hypothetical (in terms of PPP)
France	96.2	(92.4)	1.22	(1.63)
FRG	100.0	(100.0)	1.00	(1.00)
Netherlands	83.6	(82.1)	0.90	(0.87)

Sources:
For population: UN (1975), Demographic Yearbook 1974.
For GDP: UN (1978), Yearbook of National Accounts Statistics 1976.
For purchasing power parity (1970): I.Kravis et al. (1978).

The final energy consumption data was taken from OECD statistics (1976). Final consumption of coal and natural gas was allocated to sector 22 (coal, crude oil, natural gas), final consumption of liquid fuels and feedstocks to sector 23 (petroleum and coal products) and final consumption of electricity to sector 24 (electricity/gas/water). Table 3 summarizes the final energy consumption per capita in France, FRG and the Netherlands in 1965.

Table 3
Final energy consumption per capita
in France, FRG, and the Netherlands, 1965
(in kilogramm of oil equivalent, kgoe)

	France	FRG	Netherlands
Coal	625	899	412
Natural Gas	94	60	111
	719	959	523
Liquid Fuels	803	975	1098
Feedstocks	73	144	141
	876	1119	1238
Electricity	155	205	143

Sources:
For energy consumption: OECD (1976), Energy balances for OECD countries 1960-74.
For population: see Table 2.

4. Some comparisons between FRG, France and the Netherlands

In order to select countries for our analysis we basically apply three criteria. First, the selected countries should have approximately the same level of GDP per capita, simply because we want to identify cases where countries with approximately the same material standard of living differ significantly in terms of energy consumption patterns. Therefore, FRG, France and the Netherlands are reasonably good choices (see Table 4).

Secondly, in order to apply the approach described in the preceding section, comparable input-output tables should be available for at least one year. This is the case for FRG, France and the Netherlands (for 1965), but this criterion rules out U.S. and Sweden, on which several studies in this field have been focused.

Whether the third criterion, namely that the countries should have approximately identical production functions, holds for the three countries, is not easy to verify. However, we think that our choice can be justified also from this point of view. It is reasonable to assume that labor skills and the stock of technological knowledge is about the same in countries like FRG, France and the Netherlands. Moreover,information on new technologies should be available at about the same time in these countries. Thus, the range of potential techniques facing investors should be approximately the same in the FRG, France and the Netherlands. However, due to different rates of economic growth, the share of relatively new capital in the total capital stock can be expected to be somewhat different in the three countries. The importance of this factor is difficult to evaluate, but we have assumed that it is relatively minor.

Other factors affecting the production functions are the climate and intracountry travel distances. The importance of these factors can be discussed in connection with the following two tables:

Table 4
GDP and final energy consumption indices 1965
for FRG, France and the Netherlands

	Per capita final energy consumption	GDP per capita (in terms of PPP)	Final energy consumption per unit of GDP
FRG	100	100	100
France	76	92	83
Netherlands	83	82	101

Sources:
See Tables 2 and 3.

Table 5
Climate and travel distance indicators and adjusted* per capita energy consumption indices for FRG, France and the Netherlands

	Average no. of degree days	Area	Population density	Adjusted* per capita energy cons.
FRG	100	100	100	100
France	85	222	37	78
Netherlands	105	13	155	80

* Final energy consumption minus energy use in the transportation sector and the use of fuels in the household and public service sectors, as given in the OECD energy balance sheets.

Sources:
For degree days: J. Darmstadter et al. (1977), How industrial societies use energy.
For area: International Road Federation (1970), World Road Statistics 1965-69.
For population and energy consumption: see Tables 2 and 3.

Table 4 contains some basic economic and energy consumption data. It reveals non-negligible differences between the countries in terms of final energy consumption per capita. To some extent these differences coincide with the differences in terms of GDP per capita. Thus, on the basis of Table 4 and adopting a popular way of reasoning, FRG and Netherlands are equally "inefficient" in their utilization of energy, and both countries should learn from the more "energy efficient" France. However, in accordance with the discussion in Sections 1 and 2, structural factors can hide differences more relevant for energy conservation policy. Thus, on the basis of Table 4 no "energy efficiency" ranking can be made. Neither can it be ruled out that FRG and the Netherlands differ significantly in terms of their efficiency of energy utilization, in spite of their similarity in terms of final energy consumption per unit of GDP.

Table 5 contains some data about climate and intracountry travel distances. The climatic factors can be reasonably well represented by the average number of degree days. Intracountry travel distances should depend on both the area of the country and the population density, but it is difficult to know exactly how. One could perhaps infer from Table 5 that the intercountry differences in final energy consumption per unit of GDP can be entirely explained by the differences in the average number of degree days. That, of course, is not the case. If final energy consumption is reduced by the amount of energy used in the transportation sector and all fuels used by the household and public service sectors, the remaining differences should be approximately net of energy used for transportation and heating purposes. As can be seen in Table 5 (the column "Adjusted per capita energy consumption"), such an operation leaves the intercountry differences in final energy consumption almost unaffected. Thus one can conclude that climatic factors and intracountry travel distances do not explain a substantial share of per capita final energy consumption differences between FRG, France and the Netherlands.

Next we turn to the application of our decomposition formula. The main results are summarized in Tables 6, 7 and 8. The first column contains estimates of the total difference in per capita final energy consumption (the component TOT in eqn.(10)). In the second, the difference in per capita final energy consumption is expressed as the ratio to the average level of per capita final energy consumption (for each energy form separately and for all forms together) in the two countries. According to this measure, it can be seen that the countries differ more in the consumption of individual kinds of energy than in terms of total per capita final energy consumption.

In the columns (3)-(6) the results obtained from the application of eqn.(10) in Section 3 are presented. The differences due to each of the components "Technology", "Life-style" and "Trade" (as defined on p. 10) as well as the sum of the first two, are expressed as ratios to the total difference in per capita final energy consumption. If the value for "Technology" or "Life-style" is close to or greater than one, it is reasonable to conclude that important differences in the energy consumption pattern are hidden by various "structural" factors.

As can be seen in the tables, there are a few cases where the absolute value of an individual component is considerably greater than the total difference. In particular, the Netherlands seem to have a technology which uses liquid fuels much more intensively than the technologies used in France and FRG. It is interesting to note that although FRG and Netherlands are quite similar in terms of final energy consumption per unit of GDP, the energy intensities of the technologies used in the two countries are quite different.

Using the product of the figures in column (2) and the figures in one of columns (3), (4), (5) or (6) as a measure of the relative "importance" of the various components, it turns out that the "Trade" component in none of the comparisons is as big as 7.5% of the average level of consumption of the fuel in question in the two countries under comparison. France seems to have the most energy intensive "life-style" of the three countries, although the Netherlands is the most electricity intensive country from this point of view. However, the differences between the countries in terms of the "Life-style" component are in most cases quite small.

Generally the "Technology" component appears to be the quantitatively most important one, and in the following we primarily focus on that component. In terms of the technology component FRG and France are rather similar, but both countries use technologies which, from an energy point of view, differ significantly from the technology used in the Netherlands. However, it should be noted that the ranking of the three countries on the basis of the aggregated "Technology" component is the same as the ranking based on final energy consumption per unit of GDP; Netherlands is the most energy intensive country followed by FRG and France. In terms of final energy consumption per capita, however, FRG is the most energy intensive country in the sample, followed by the Netherlands and then France (see Table 4).

TABLE 6. A decomposition of the difference in per capita final energy consumption 1965 between FRG and the Netherlands.

	1) ΔE	$\frac{2\Delta E}{E^0 + E^1}$	2) $\frac{\text{Technology + Life-style}}{\Delta E}$	2) $\frac{\text{Technology}}{\Delta E}$	2) $\frac{\text{Life-style}}{\Delta E}$	2) $\frac{\text{Trade}}{\Delta E}$
	(1)	(2)	(3)=(4)+(5)	(4)	(5)	(6)
Gas and Solid Fuels	435.8	.583	$\underline{.626}$ *	$\underline{.556}$ *	.070	.044
Liquid Fuels	-118.5	.101	$\underset{---}{-2.894}$ *	$\underline{-2.965}$ *	.071	-.089
Electricity	61.9	.355	$\underset{\cdots}{.228}$ *	$\underset{---}{.743}$ *	$\underset{---}{-.515}$ *	.208
Total	379.2	.181	-.146	-.167	.021	.057

1) $\Delta E = E_{FRG} - E_{NETH}$.

2) See Equations (10) and p. 9 in Section III for the definition of the components

*$\underline{\quad}$ = (2) × (absolute value in col. (3),(4),(5) or (6)) $\geq$ .300

*$\underset{---}{\quad}$ = (2) × (absolute value in col. (3),(4),(5) or (6) $\geq$ .150 but < .300

* ... = (2) × (absolute value in col. (3),(4),(5) or (6) $\geq$ .075 but < .150

TABLE 7. A decomposition of the differences in per capita final energy consumption 1965 between the Netherlands and France.

	1) ΔE	$\frac{2\Delta E}{E^0 + E^F}$	2) $\frac{\text{Technology + Life-style}}{\Delta E}$	2) $\frac{\text{Technology}}{\Delta E}$	2) $\frac{\text{Life-style}}{\Delta E}$	2) $\frac{\text{Trade}}{\Delta E}$
	(1)	(2)	(3)=(4)+(5)	(4)	(5)	(6)
Gas and Solid Fuels	-195.4	.315	-1.038 *	-.777 *	-.261 *	-.136
Liquid Fuels	362.3	.343	.839 *	.970 *	-.131	.022
Electricity	-12.3	.082	1.000 *	-1.789 *	.789	-.650
Total	154.6	.085	.574	1.148	-.574	-.171

1) $\Delta E = E_{NETH} - E_{FRANCE}$

2) See Table 6

* See Table 6

TABLE 8. A decomposition of the difference in per capita final energy consumption 1965 between FRG and France.

	1) ΔE	$\frac{2\Delta E}{E^0 + E^1}$	2) $\frac{\text{Technology + Life-style}}{\Delta E}$	2) $\frac{\text{Technology}}{\Delta E}$	2) $\frac{\text{Life-style}}{\Delta E}$	2) $\frac{\text{Trade}}{\Delta E}$
	(1)	(2)	(3)=(4)+(5)	(4)	(5)	(6)
Gas and Solid Fuels	240.4	.287	.100	.204	-.104	.035
Liquid Fuels	243.8	.490	-.061	.114	-.175 *	.045
Electricity	49.7	.276	.035	.435 *	-.400 *	.058
Total	533.8	.265	.021	.185	-.164	.042

1) $\Delta E = E_{FRG} - E_{FRANCE}$

2) See Table 6

* See Table 6

The differences between the countries can also be analyzed on a sectoral basis, making use of the information provided by the i/o table. Thus it is possible to identify the relative contribution of different sectors to the total difference in energy consumption, in both the "Technology" and "Life-style" components. Looking first at the "Technology" component given in eqn.(10) in Section 3,

$$I/O = Technology = (e^1 - e^0)\frac{Y_D^1 + Y_Z^1 - M^1 + Y_D^0 + Y_Z^0 - M^0}{2}$$

where

$$e = \epsilon(I - a)^{-1},$$

one can distinguish two subcomponents. The first, $(e^1 - e^0)$, reflects the direct and indirect energy content of a unit of output in each of the 20 sectors of the i/o table. The second part is the average net final demand in both countries and serves as the weight given to different processes. As mentioned above in Section 3, the technology component is supposed to reflect the difference in energy consumption between two countries if each were to supply half the resulting aggregate demand of both countries.

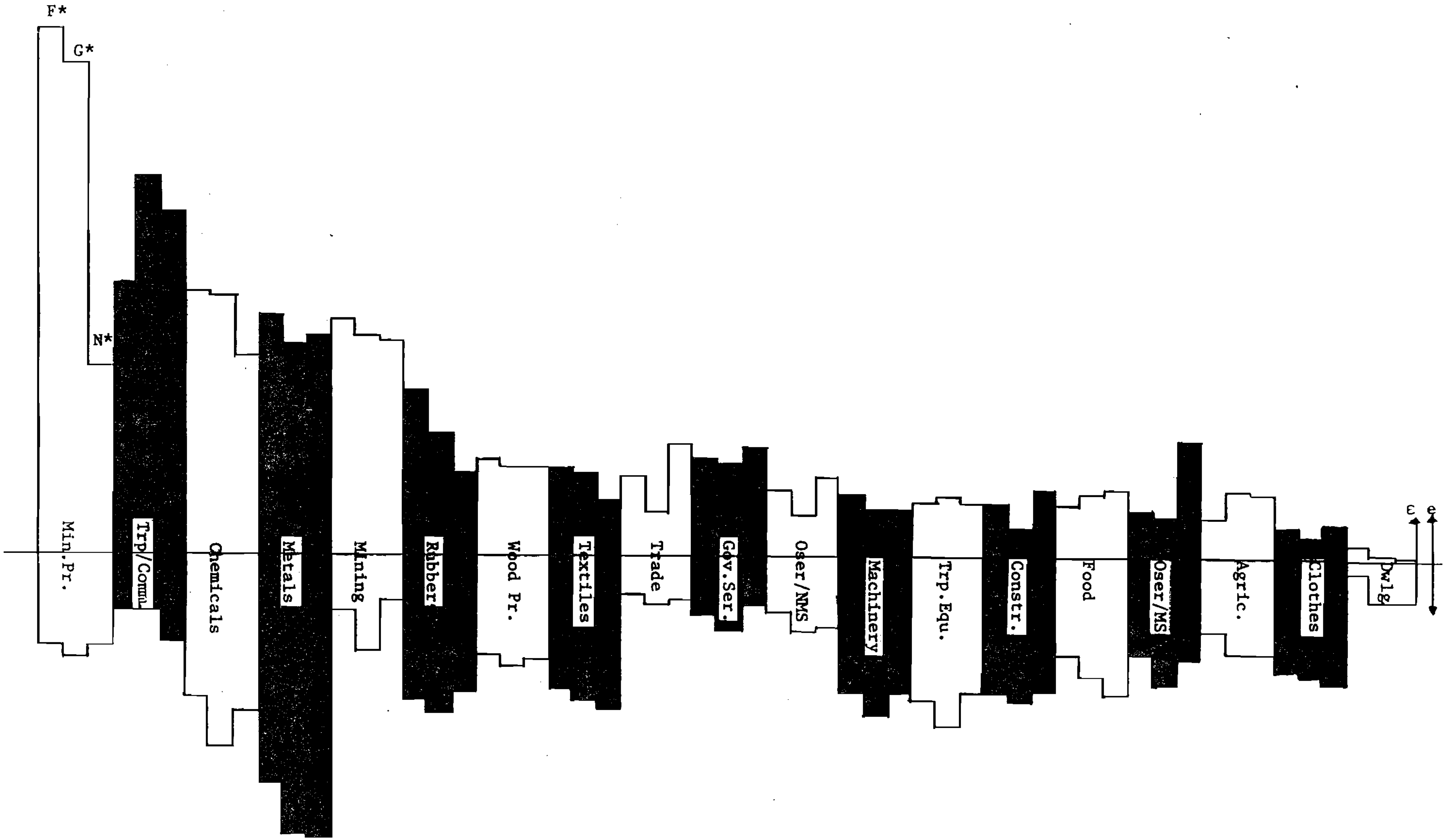
In Chart 1, one finds the direct energy coefficients (ϵ) and the total energy coefficients (e) for the 20 sectors of the three countries under consideration. It is obvious that the energy intensity ordering within the various commodity groups differs substantially from the overall ordering in the technology component where the Netherlands is the most "energy intensive" country (see Tables 6, 7, 8) followed by Germany and then by France. For example, in the energy intensive sectors (high ϵ and e) like Mining, Chemicals, Mineral Products, Metals, and Transport/Communication, the Netherlands leads in one sector only -- Metals. In all others, Germany (Mining, Chemicals, Transport/Communication) or France (Rubber, Mineral Products) are more energy intensive. Hence, one is led to seek the explanation for the overall ranking in the "Technology" factor elsewhere, namely in the weighting factor of net final demand.

To test for the sensitivity of this weighting factor, we can substitute net final demand (FD + Exports - Imports) in the expression defining the Technology component, by domestic final demand (FD), but this does not change the ranking of the three countries nor the absolute differences to any substantial extent.

As expected, the ratio ϵ_i/e_i differs substantially within sectors, with low figures in Food, Construction, Clothes, Textiles, Machinery and Transport Equipment, and high figures in Mining, Mineral Products and Transport/Communication. In many cases, however, France has higher sectoral ϵ_i/e_i ratios as compared to the other two countries. The conservation implication of such an observation is that it is possible to save energy not only by cutting down direct energy input coefficients, but also by reducing the use of intermediate goods. The case of France with higher direct (ϵ_i) but lower total (e_i) energy input coefficients than the other countries seems to point in this direction.

It was also found that in all pairwise country comparisons only a few sectors accounted for a large part of the difference in energy consumption in the Technology component. These were in the Food, Construction, Trade, Transport/Communication, Government Services and Other Services/Material Sphere sectors. (Note that in the Food and Construction sectors the ratio ϵ_i/e_i is low while in the other sectors the share of direct to total energy is high, especially in the Transport/Communication sector.) Of these commodity groups only Transport/Communication had a high difference in energy coefficients $\Delta e = (e^1 - e^0)$. The importance of the contribution of these sectors to the Technology component lies more often than not in the size of the weighting factor. In Table 9 the percentage share of these six sectors in the domestic final demand shows that they constitute around 60% of the total in all three countries. Hence a small Δe in these sectors can nevertheless lead to a large difference in the Technology component.

CHART 1



F* = France - G* = Germany N* = Netherlands

It is interesting to note that the structure of domestic final demand is remarkably similar in all three countries although the total value of final demand differs with Germany being the highest and France being the lowest (see Table 9, footnote 1). This fact becomes important in explaining the low differences in the *DOM.COMP* part of the "Life-style" component (see below).

The sectoral contribution to the Technology component results in some cases from a high FD and a low Δe (Food, Construction, Trade) or from a high Δe and a low FD (Machinery, Transport/Communication, Other Services/Material Sphere and Government Services). One thing to note is that the Netherlands and Germany have nearly identical Transport/Communication sectors, both being more energy intensive than France.

Another point to note is that the overall ranking between the countries in terms of the Technology component does not hold in these seven sectors. The FRG is the most energy intensive in Transport/Communication and Government Services, while France leads in Construction and Trade. To conclude, the above analysis serves to focus attention on a few sectors which contribute most to the pairwise difference in the Technology component, and this paves the way for a closer look at processes within these sectors which could explain these differences. It also serves to isolate differences that are due to direct energy input coefficients and other input coefficients, from those due to the volume and composition of final demand in the different countries.

The above analysis of total energy differences can be extended in the same way to the sectoral differences in final energy consumption of different energy products, namely, of primary energy products (coal and natural gas), refined energy products (liquid fuels), and electricity (electricity and manufactured gas). This further disaggregation allows a closer view of which types of energy are used more intensively, by which sectors, and in which countries.

Tables 10, 11 and 12 present the main sectors responsible for the pairwise country differences of the "Technology" factor for the consumption of the three energy forms.

By looking at Table 10, one finds that for the consumption of refined energy products a greater number of sectors seem to be influential in explaining the total difference in the consumption of liquid fuels. Thus for the difference (Netherlands-FRG) sectors 3, 13, 14 and 15 are of importance, but for the difference (Netherlands-France) sectors 8, 13, 14, and 19 are more significant, etc. Thus there is no uniformity, as was found for the overall aggregated results in Table 9. However, it is interesting to note that the Netherlands is uniformly more energy intensive than FRG or France in all sectors [positive signs of $(e^N - e^G)$ and $(e^N - e^F)$] except for Transport Equipment, where FRG uses more liquid fuels per unit of output. But in all other 19 sectors it holds true that the Netherlands uses more liquid fuels per unit of output. This may be due to uniformly lower prices and availability of refined liquid fuels in the Netherlands. Despite the fact that energy prices are not uniform across different sectors, they may be uniformly lower in the Netherlands for all sectors as compared to FRG and France. Comparing the latter two countries, one finds that this does not hold true. There are as many sectors where FRG uses liquid fuels more intensively than France and vice versa.

From Tables 9 and 10 one sees that the Netherlands, on the other hand, uses less electricity and primary energy products in all sectors than either FRG or France. Hence, it is the least energy intensive consumer of electricity and primary energy products, but the most intensive user of liquid fuels. These results are masked by aggregation. Thus, in Table 9, overall energy intensities $(e^N - e^G)$ show different signs in the various sectors. The ordering according to decreasing intensity of use in the Technology factor is FRG > France > Netherlands for primary energy products and electricity, but Netherlands > FRG > France for refined energy products and aggregated energy use.

Table 9. Pairwise country comparisons of the "Technology" factor in some I/O sectors.

N = Netherland
G = FRG
F = France

$$\text{Technology} = \left[(e^1 - e^0) \ \frac{(Y_D^1 + Y_D^0)}{2} \right]$$

					% of p.c. Domestic Final Consumption			Technology Factor %		
No.	Sector	e^N-e^G	e^N-e^F	e^G-e^F	Netherlands	FRG	France	T^N-T^G	T^N-T^F	T^G-T^F
3.	Food	0.022	0.067	0.045	13.2	12.0	11.3	34	35	35
12.	Machinery	-0.025	-0.020	0.005	11.2	11.1	11.0	-34	-9	4
13.	Construction	0.029	0.011	-0.018	14.6	16.0	15.9	54	7	-19
14.	Trade	0.064	0.040	-0.024	11.8	11.5	12.8	90	21	-19
15.	Transport/ Communication	-0.006	0.106	0.111	2.2	2.2	1.9	2	9	15
16.	Oser/Ms	0.061	0.109	0.048	2.0	3.4	5.0	21	16	13
19.	Gov. Service	-0.007	0.023	0.030	18.6	16.3	16.9	15	17	33
Average[3] $\lvert e^1 - e^0 \rvert$		0.046	0.055	0.028	71.6%	69.1%	69.8%	151[2] %	96%	62%

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[1] p.c. Domestic Final Consumption FRG: 7552.74 DM or 100%; Netherlands: 6218.34 DM or 82.34%; France: 5893.33 DM or 78.04%.

[2] Figure above 100% only means that in the other sectors negative signs are present.

[3] Average for the 20 sectors of the input output table.

Table 10. Pairwise country comparisons of the "Technology" factor for consumption of refined energy products.

N = Netherlands
G = FRG
F = France

$$\text{Technology} = \left[(e_R^1 - e_R^0)\ \frac{(Y_D^1 + Y_D^0)}{2} \right]$$

					% of p.c.Domestic Final Consumption			Technology Factor %		
No.	Sector	$e_R^N-e_R^G$	$e_R^N-e_R^F$	$e_R^G-e_R^F$	Netherlands	FRG	France	T^N-T^G	T^N-T^F	T^G-T^F
1.	Agriculture	0.021	0.060	0.039	2.3	3.1	3.6	1	4	17
3.	Food	0.071	0.103	0.032	13.2	12.0	11.3	19	3	50
4.	Textiles	0.082	0.081	-0.001	2.5	2.5	1.4	4	4	-3
8.	Chemicals	0.136	0.154	0.018	2.1	1.7	2.5	5	9	-
11.	Transport Eq.	-0.015	0.011	0.026	5.0	4.3	4.4	-2	1	15
12.	Machinery	0.018	0.006	-0.012	11.2	11.1	11.0	4	4	-18
13.	Construction	0.069	0.046	-0.023	14.6	16.0	15.9	23	17	-49
14.	Trade	0.078	0.041	-0.037	11.8	11.5	12.8	20	12	-6
15.	Transport/Comm.	0.161	0.201	-0.040	2.2	2.2	1.9	8	10	1
16.	Oser/Ms	0.057	0.096	0.039	2.0	3.4	5.0	3	8	22
19.	Gov. Service	-	0.036	0.036	18.6	16.3	16.9	2	16	80
Average[2] $\lvert e_R^1 - e_R^0 \rvert$		0.055	0.063	0.026	85.5%	84.1%	86.7%	87%	88%	109.00 %[3]

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[1] p.c. Domestic Final Consumption: FRG 7552.74 DM or 100%; Netherlands: 6218.34 DM or 82.34%; France: 5893.33 DM or 78.4%.

[2] Average difference of all 20 sectors.

[3] Figures above 100% only indicate that in the other sectors negative signs are present.

Table 11. Pairwise country comparisons of the "Technology" factor for consumption of primary energy products.

N = Netherlands
G = FRG
F = France

$$\text{Technology} = \left[(e_P^1 - e_P^0) \frac{(Y_D^1 + Y_D^0)}{2} \right]$$

					% of p.c. Domestic Final Consumption			Technology Factor %		
No.	Sector	$e_P^N - e_P^F$	$e_P^N - e_P^F$	$e_R^G - e_R^F$	Netherlands	FRG	France	$T^N - T^G$	$T^N - T^F$	$T^G - T^F$
3.	Food	-0.040	-0.030	0.010	13.2	12.0	11.3	16	2	23
4.	Textiles	-0.090	-0.086	0.004	2.5	2.5	1.4	7	8	2
8.	Chemicals	-0.216	-0.180	0.036	2.1	1.7	2.5	13	20	14
12.	Machinery	-0.026	-0.018	0.008	11.2	11.1	11.0	10	10	17
13.	Construction	-0.035	-0.033	0.002	14.6	16.0	15.9	18	24	6
15.	Transport/Comm.	-0.161	-0.092	0.069	2.2	2.2	1.9	12	9	27
19.	Gov. Service	-0.004	-0.010	-0.006	18.6	16.3	16.9	2	8	-19
Average $\lvert e_P^1 - e_P^0 \rvert$		0.064	0.06	0.018	53.5 %	52.9 %	53.2 %	78 %	81 %	70 %

Table 12. Pairwise country comparisons of the "Technology" factor for consumption of electricity.

N = Netherlands
G = FRG
F = France

$$\text{Technology} = \left[(e_E^1 - e_E^0) \frac{(Y_D^1 + Y_D^0)}{2} \right]$$

No.	Sector	$e_E^N - e_E^G$	$e_E^N - e_E^F$	$e_E^G - e_E^F$	% of p.c. Domestic Final Consumption Netherlands	FRG	France	Technology Factor % $T^N - T^G$	$T^N - T^F$	$T^G - T^F$
3.	Food	-0.009	-0.006	0.003	13.2	12.0	11.3	16	19	11
8.	Chemicals	-0.020	-0.025	-0.005	2.1	1.7	2.5	5	15	-3
11.	Transport Eq.	-0.012	-0.006	0.006	5.0	4.3	4.4	8	7	8
12.	Machinery	-0.017	-0.008	0.009	11.2	11.1	11.0	26	23	31
13.	Construction	-0.005	-0.002	0.003	14.6	16.0	15.9	11	8	15
19.	Gov. Service	-0.002	-0.003	0.001	18.6	16.3	16.9	5	14	5
Average $\lvert e_E^1 - e_E^0 \rvert$		0.011	0.008	0.005	64.7 %	61.4 %	62.0 %	71 %	86 %	67 %

We next turn to an analysis of the "Life-style" component which, as mentioned in Section 3, is defined by the sum of the components *DIR.INP* and *DOM.COMP* in eqn.(10). The results of the calculations are summarized in Table 13.

Table 13
Pairwise country comparisons of
"Life-style" differences in energy consumption

	DIR.INP	+	*DOM.COMP*	=	*Life-style*
France-FRG	84.71		2.33		87.04
France-Netherlands	102.95		-14.15		88.80
FRG-Netherlands	30.30		-22.45		7.85

$$DIR.INP = \frac{Y_D^1+Y_D^0}{2}(d^1-d^0)\,; \quad DOM.COMP = \frac{e^1+e^0}{2}(\hat{Y}-Y_D^1)\,.$$

As can be seen in the above table, it is only in the comparison between FRG and the Netherlands that the component *DOM.COMP* is quantitatively important. The reason for this is that the composition of domestic final consumption is relatively similar in the three countries. It should also be noted that the ranking of the countries in terms of the *DOM.COMP* component differs from the ranking in terms of the *DIR.INP* component.

To conclude, intercountry differences seem to exist in per capita final energy consumption resulting from differences in technology and "life-style". In fact, these differences are in some cases larger than the total difference between the countries in terms of final energy consumption per capita. Thus, although "structural" factors are important, they do not explain the whole, or the major part, of the differences between FRG, France and the Netherlands in this respect. This means that a detailed comparison of the energy consumption pattern in those countries might reveal inefficiencies in the utilization of energy, and thus yield insights into the economic impact of energy conservation programs. Next we investigate to what extent the intercountry comparisons presented so far can be used as a basis for identifying inefficiencies in the utilization of energy in FRG, France or the Netherlands.

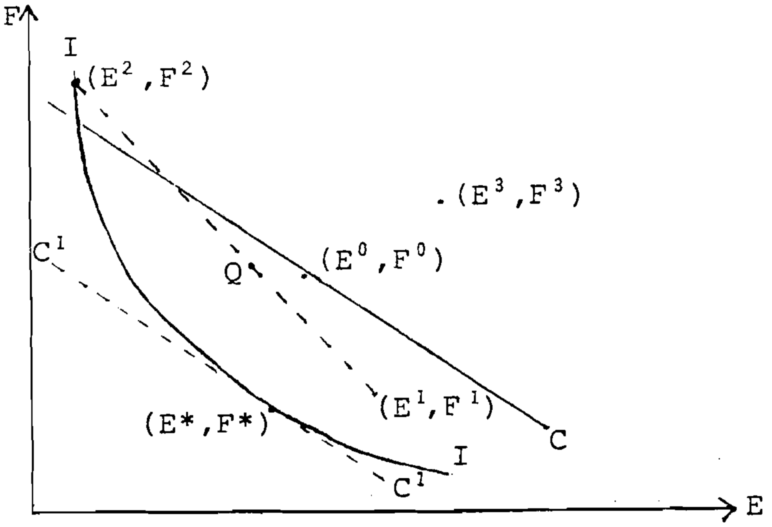
5. Interpretation of the results

So far we have been able to highlight some differences between the patterns of energy consumption in FRG, France and the Netherlands. As previously noted, however, the observed differences in energy use have to be combined with data about the use of other factors of production as well as factor prices before we can draw conclusions about possible differences in the efficiency of energy utilization. Thus, in the next step we combine our results on energy use with similar results on the use of labor as well as the corresponding factor prices for the three countries in our sample. Unfortunately, data about capital use has not been available, and accordingly our results are somewhat partial in nature.

Our basic assumption is that the three sample countries have identical but, fur us, unknown production functions. In accordance whith this assumption the observed factor combinations in the sample are feasible factor combinations for each of the three countries. The null hypothesis is that each of the countries uses energy and labor efficiently in the sense that they use a cost-minimizing factor combination at the prevailing system of relative factor prices. The analytical scheme can be illustrated by Diagram 1. (For simplicity we use a two-dimensional diagram to illustrate our approach although our calculation refers to a case with several factors of production.)

E and F represent the inputs of energy and an aggregate of all other factors of production respectively. The factor prices in country 0, (P_E^0, P_F^0), determine the slope of the isocost line, cc.

DIAGRAM 1.



The curve II represents the set of efficient factor combinations yielding one unit of output. Thus, at the factor prices (P_E^0, P_F^0) the point (E^*, F^*) is the cost minimizing factor combination (the line c'c' is parallel to cc). The difference between the optimal factor combination (E^*, F^*) and the actual factor combination (E^0, F^0) represents the inefficiency in the production system which, using the actual prices (P_E^0, P_F^0), can be expressed as a cost difference.

Our point of departure is that we do not know the curve II, but we assume that all countries in our sample have identical production functions. Thus, all the points (E^j, F^j), $j=0,1,2,3$ are assumed to be feasible factor combinations for all countries. The point (E^3, F^3) is clearly inferior to (E^0, F^0) and (E^1, F^1) at all factor prices. The choice between (E^0, F^0) and (E^1, F^1) or (E^2, F^2), however, depends on the relative factor prices. It turns out that on the basis of the factor prices prevailing in country 0, the factor combination used in country 1 would result in lower production costs while the one used in country 2 would give the opposite result.

Thus, if we assume that the observed factor combinations (E^j, F^j), $j=0,1,2,3$ are the only feasible points in the input space, country 0 cannot reduce its use of energy without decreasing the overall efficiency of resource utilization. However, if the set of feasible factor combinations also contains all convex combinations (that is, we assume that the production functions are quasi-concave) of the observed factor combinations, country 0 can both reduce its use of energy and increase the overall efficiency in the production system. In this case, all points on the line-segment between (E^2, F^2) and (E^1, F^1) would be feasible. Of these the point Q implies a smaller input of energy but the same input of other resources as the point (E^0, F^0).

The existence of a point like Q indicates that energy is not efficiently utilized in country 0. It is obvious that if that country had used the factor combination (E^*, F^*) rather than (E^0, F^0), it would not have been possible to find a factor combination resulting in lower production costs with the factor prices (P_E^0, P_F^0). In the following, we will reject the hypothesis that energy is efficiently utilized in a given country, as a whole or on the sectoral level, if we can find a point like Q as defined in Diagram 1.

The analysis is carried out for four factors of production: three types of energy, and labor. If the null hypothesis is true, i.e., that energy and labor are efficiently utilized in the sample countries, it holds that:

$$P_L^1 L^1 + P_P^1 E_P^1 + P_R^1 E_R^1 + P_E^1 E_E^1 \leq P_L^1 L^0 + P_P^1 E_P^0 + P_R^1 E_R^0 + P_E^1 E_E^0$$

which can be written more compactly as:

$$P_L^1 \Delta L + P_P^1 \Delta E_P + P_R^1 \Delta E_R + P_E^1 \Delta E_E \leq 0$$

where P_i^j represents the price index for factor i in country j, L^j the use of labor in country j and E_P^j, E_R^j and E_E^j represent the use of coal+gas, liquid fuels and electricity, respectively, in country j.

In our analysis the price-variables were represented by the implicit price indices which were obtained when the total use of energy and labor, respectively, expressed in monetary terms, were divided by the same variables expressed in physical terms. The factor use measures were on the aggregated level represented by the Technology component, and on the sectoral level by the total (that is, the sum of direct and indirect) energy and labor input coefficients.

In the comparisons on the macro level, that is, in terms of the Technology component, it turned out that FRG should not change its technology to that of France or the Netherlands. France, on the other hand, would have lower production costs both with FRG's and the Netherlands' technologies. The Netherlands, finally, would be better off with FRG's technology, but would prefer to keep its own rather than switch to the technology utilized in France.

Since the technology used by the Netherlands is more energy intensive than the one utilized by FRG, these results suggest that the Netherlands could both reduce its energy consumption and its overall economic efficiency. That is not, however, the case for France; from the French point of view FRG's technology is more efficient, but it uses more energy than the French technology. In the same way, a switch from the French to the Dutch technology would lead to lower production costs but higher energy consumption in France. Thus, only in the case of the Netherlands can we reject the hypothesis that energy is efficiently utilized.

However, lacking information about capital use, the significance of these results is clearly uncertain. If the capital intensity is higher in FRG than in the other two countries, and higher in the Netherlands than in France, it is quite possible that a calculation including capital costs would yield the result that each of the three countries is better off using its own technology rather than switching to the one utilized by either of the countries. With this reservation in mind, we turn to the results on the sectoral level.

In the comparison between FRG and France, the German technology led to lower production costs in all sectors, both with the German and the French factor prices. In most of the sectors this result was primarily due to a lower input of labor per unit of output. There are, however, also sectors where a switch from French to German factor proportions would entail both reduced energy consumption and reduced product costs. That holds for the sectors Clothes, Rubber, Mineral Products, Construction and Trade.

The comparison between the Netherlands and France gave a somewhat mixed result. Thus, in the Agriculture and Other Services sectors, the French technology led to lower production costs both with French and Dutch factor prices, while the opposite held in all other sectors. In Mining, Textiles, Wood Products, Rubber, Chemicals, Mineral Products, Transport Equipment and Machinery, a switch from the French to the Dutch factor proportions would lead to reduced production costs as well as to lower energy consumption.

The results in the comparison between FRG and the Netherlands were quite mixed. From the Dutch point of view, and using Dutch factor prices, production costs would be lower with the German technology in Food, Textiles, Transport Equipment, Trade, Other Services and Government Services. In Food, Trade and Other Services a switch to German factor proportions would also lead to lower energy consumption. From the German point of view, and using German factor prices, production costs would be lower if Dutch factor proportions were adopted in Agriculture, Chemicals, Machinery and Construction. A switch from German to Dutch technology would lead to both lower production costs and lower energy consumption in only one sector - Chemicals.

Thus, the results on the macro level are not entirely representative for the results on the sectoral level. For instance, in the comparison between FRG and the Netherlands, the macro analysis, where the production sectors appear with different weights, suggested that the Netherlands would get lower production costs and energy consumption by using FRG's technology. In the sector analysis, on the other hand, it turned out that the production costs and the use of energy in some German sectors would be lower if the Dutch factor proportions were adopted.

As such, these results are not surprising. If there are inefficiencies in the utilization of an economy's resources, there is no reason to expect that these inefficiencies are evenly distributed over the production sectors. However, the sector by sector analysis also indicates that in each of our three sample countries there are sectors in which both production costs and energy use would be reduced if the factor proportions were changed to those used in the corresponding sector in one of the other countries. Thus, for each of the three sample countries, we can reject the hypothesis that energy is efficiently utilized.

In terms of the Technology component, the Netherlands turned out to be the most energy intensive country, followed by FRG and France. On the basis of our analysis the difference between FRG and the Netherlands can be explained, to some extent, by a lower efficiency in the utilization of energy in the Netherlands. However, the difference between France and the Netherlands cannot be explained in such terms. In many sectors, the observed differences in energy input coefficients were consistent with the differences in relative factor prices, and in the other sectors a switch from Dutch to French factor proportions would increase both production costs and energy use in the Netherlands.

These observations illustrate that differences in energy intensity should not be confused with differences in the efficiency of energy utilization. In other words, differences in energy intensity do not necessarily indicate costless or profitable energy conservation possibilities. However, one should perhaps expect that observations on differences in energy intensity between the different countries would be a rough but still useful guide for the identification of inefficiencies in the use of energy. Our results reject that hypothesis; the intercountry comparison of energy consumption patterns in Section 4 gave no indication at all about the outcome of the analysis of the efficiency of energy utilization in the three countries.

Concluding remarks

In order to draw precise conclusions about the existence of energy conservation possibilities, compatible with unchanged or improved overall efficiency of resource utilization, the analyst should know both the actual and the potential input-output structure (the production functions) in the economy. At best, he knows the actual input-output structure and has some uncertain estimates of the production functions for aggregated production sectors. A reasonable step in that situation is to compare the actual input-output structure in one country with corresponding data for comparable countries. Of course, the whole analysis becomes considerably less time-consuming if the comparison can be confined to the energy consumption patterns.

The question then is whether intercountry comparisons of energy consumption patterns can be used as a tool for identifying inefficiencies in energy use. The answer to this question cannot be positive unless at least two conditions are satisfied. First, there should be some differences in the energy consumption patterns between the countries, and these differences should not only reflect "structural" factors like the production functions, the income level, the climate, the intracountry travel and transport distances, etc. Second, differences in energy intensities in the production system in different countries should give at least a rough indication of the existence of inefficiencies in the utilization of energy.

We have tried to analyze to what extent these conditions are satisfied in pairwise comparisons of the energy consumption patterns in FRG, France and the Netherlands. Using comparable input-output tables and a decomposition formula, we came to the conclusion that the differences in per capita energy consumption between these three countries cannot be entirely explained by "structural" factors. In particular, it turned out that much of the intercountry differences in per capita consumption were due to differences in the technology utilized in the three countries. Thus, in this case, the first of the above mentioned conditions seems to be satisfied.

In the next step we combined the observations on energy consumption with observations on labor use and relative factor prices. Using a very simple test procedure we came to the conclusion that the observed differences in per capita energy consumption between our three sample countries, due to differences in factor proportions, were not at all related to different degrees of efficiency in the utilization of energy in the three countries. More often than not, the differences in energy intensities were consistent with the differences in relative factor prices. Thus, on the basis of our results, the second of the above mentioned conditions does not seem to be satisfied.

Accordingly, the usefulness of intercountry comparisons of per capita energy consumption patterns as a tool for identifying costless or profitable energy conservation possibilities can be questioned.

However, our results can be questioned both on empirical and conceptual grounds. We have already mentioned that we had to neglect capital costs. Moreover, in order to derive energy and labor input coefficients in physical terms for the input-output sectors, we had to assume that energy prices and wages were the same for all sectors within the economy. If that is not the case, which is quite likely, the resulting "total" energy and labor coefficients might be distorted (see Griffin (1976)). In addition, our test procedure in Section 5 can be questioned. If the technology is such that *ex ante* substitutability between different factors of production differs from the *ex post* substitutability, which is likely, the optimality of actual factor proportions cannot be determined on the basis of the factor prices prevailing in one single year. (See for instance Fuss (1977)). Thus, we do not reach a definite conclusion about the usefulness of intercountry comparisons of per capita energy consumption patterns as a tool for identifying inefficiencies in the utilization of energy. However, it seems to be urgent to explore that issue further, before expanding intercountry energy consumption comparisons as a field of research.

Footnotes

1. See Hitch (1977) where five approaches to the modeling of energy-economy interactions are presented.
2. For further discussion of the notion of "structural" factors see Darmstadter et al. (1977).
3. Most of the studies in this field have dealt with the "energy intensive" U.S. and several less "energy intensive" industrialized countries. See Darmstadter et al. (1977) and Shipper and Lichtenberg (1976).
4. As energy is used together with other factors of production to produce light, heat, mechanical work, etc. in all sectors of the economy, including the household sector, we find it appropriate to regard energy as a factor of production.
5. It should be noted that nothing can be said about the economic efficiency of energy use on the basis of a thermodynamic efficiency concept; if the input of energy in a particular process in one country is closer to the thermodynamic limit than in another country, it does not mean that the former, from an economic viewpoint, uses energy more efficiently.
6. We use the concept "production function" as a summary description of the set of (economically) efficient combinations of inputs and outputs in a process, a sector, or in the economy as a whole.
7. Econometric studies of the substitutability of energy and other factors of production, based on international cross-section data, generally presuppose that energy is efficiently utilized in the sample countries; the observed differences in energy intensities are assumed to represent different points on the prodution function, chosen in response to international differences in relative factor prices.
8. The choice of these countries is discussed in Section 4.
9. See for instance Darmstadter et al. (1977) and OECD (1976).
10. It should be noted that the existence of indirect energy consumption in production processes using various produced inputs has some implications for energy conservation policy: it is not necessarily true that energy conservation efforts should be directed towards reducing direct energy input coefficients. In some cases, it might be more efficient to concentrate on reducing the use of energy intensive non-energy inputs. For instance, it might be better to reduce the use of steel in some processes than to reduce the input of energy in the steel production processes.
11. Electricity, liquid fuels and coal+gas.
12. That is, the sum of private consumption, public consumption, investment and inventory changes.
13. We neglect energy contained in imported non-energy commodities.

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