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SERIE RESEARCHMEMORANDA

IMPACTS OF ELECTRICITY RATES ON INDUSTRIAL LOCATION

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IMPACTS OF ELECTRICITY RATES
ON INDUSTRIAL LOCATION

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1. INTRODUCTION

As most regions in the developed world exhibited a rapid increase in the use of energy resources, they found themselves confronted with greater external dependency. Furthermore, these regions were faced with mounting levels of waste and pollution arising out of the consumption and production of commodities. Consequently, particularly the technologically advanced regions had to orient their production and consumption activities to a conservation or careful use of energy resources.

The adjustment processes aligned to the new scarcity have not only led to different production and consumption patterns (either through the market system or by public intervention), but also to changes in location, settlement and transportation systems. Thus the rise in energy costs has both technological and geographical impacts. Especially energy-intensive activities may be quite sensitive to the new scarcity, as these may try to achieve a maximum efficiency in energy consumption through technological innovations and locational shifts.

A closer analysis of the impacts of (realized or expected) changes in the energy sector on the spatial distribution of activities is, however, fraught with difficulties. Until now, strikingly little empirical evidence is available regarding the sensitivity of location and settlement patterns and of related transportation and mobility patterns for energy scarcity. The impacts of shifts in land use and in urban space (for example, the design of energy saving cities or transportation networks or the creation of satellite cities) upon energy consumption are fairly unknown as well.

The present paper will address the issue of the impact of energy prices (notably electricity rates) upon spatial activity patterns. Section 2 will provide a brief survey of the literature on location patterns and energy scarcity. In section 3 some more specific methods for analyzing the effect of electricity rates on industrial location will be presented. Section 4 will be devoted to an empirical study of location patterns and electricity costs in the Netherlands, while in section 5 the results of a more in depth investigation into the energy cost sensitivity of industries will be presented. The overall conclusion is somewhat striking: despite significant variations in regional electricity rates, is the sensitivity of the Dutch industries - as far as their (re)locational choices are concerned - almost negligible.

2. ENERGY AND LOCATION PATTERNS

In the geography and regional science literature since the beginning of the seventies, much attention has been paid to the spatial dimensions of energy problems (see also Lakshmanan and Nijkamp, 1982, and Nijkamp, 1983). In the present section, three main issues will briefly be dealt with, viz. spatial structure and energy use, residential location and industrial location.

2.1 Spatial structure and energy use

In recent years, a lot of attention has been directed to the issue of an optimal spatial layout, notably urban forms (from the point of view of saving energy) (see Keyes, 1982; Maier et al., 1981; Sakashita, 1980). Compact arrangements of activities are generally assumed to lead to higher energy efficiencies. It should be noted, however, that this simple assumption is not always valid. Essentially a distinction has to be made between *concentration of individual dwellings and activities* into compact agglomerations of high density and *dispersal of settlements or cities* in a broader spatial framework. Concentration and dispersal as the basis for spatial design do not necessarily imply the highest energy efficiency from a spatial viewpoint.

In essence, the major aim is to find an optimal layout. In this case, at least two side-conditions have to be kept in mind: (1) A compact city will only give rise to energy savings if its whole spatial layout is oriented to an effective use of transportation means. With higher density there is always the risk of more congestion, so that an appropriate use and spatial layout of transportation infrastructure (flexible working hours, e.g.) is a prerequisite. Otherwise the assumption that shorter distances between home and work will lead to energy savings is not warranted. (2) An internally compact city is in general only more energy saving if its external relationships are not extremely strong. In the case of many traffic flows to neighbouring cities, there is a danger that a compact arrangement may increase the total number of miles traveled. In addition, this arrangement would also require an efficient infrastructure network at a regional level.

Thus, it may happen that the energy savings of a compact arrangement may to a certain extent be offset by congestion factors and by external distance factors, and so an integrated energy-location-transportation planning is necessary.

A good illustration of such an integrated approach can be found in the TOPAZ model (Technique for the Optimum Placement of Activities into Zones; see Brotchie et al., 1979). This planning model considers the urban system as a set of mutually linked activities in a number of zones that interact through a transportation network. An efficient allocation of activities depends inter alia on interaction costs and location costs. The interaction costs may be subdivided into various categories such as economic, energy, and pollution costs.

Some conclusions from this model are:
(i) a growth of urban population will cause a higher total energy use and a higher energy use per capita;
(ii) urban sprawl will lead to a higher energy use per capita.
Consequently the suggestion was made in the TOPAZ model that new urban patterns have be constructed on the basis of geographical clusters of dwellings and dense housing patterns near main public transport stations.

It should be added that in the case of construction of new cities a much more efficient spatial layout can be realized. Integrated urban designs for new cities have demonstrated that in such cases energy savings in transportation may amount to more than 50 %.

2. Residential location

An increase in energy saving with regard to residential locations can be realized in three ways:
(i) by carrying out adjustments in the energy efficiency of existing dwellings (for example, by better insulation, by improvements of central heating systems);
(ii) by orienting the architectural design and shape of new dwellings to the saving of energy (for example, by constructing houses with more windows in a southern direction in order to capture solar energy, by protecting houses against strong winds, by constructing district heating in new residential areas); and

(iii) by locating new residential areas at more energy efficient places (for example, locations near public transportation centers, compact cities).

The last two aspects have also been studied in the framework of analyzing the impact of rising energy prices on residential choices (see Romanos, 1978). In this respect, dwelling costs may be separated into energy and non-energy costs. The general conclusion from Romanos's analysis was that - given the elasticity of demand for houses and assuming a spatial equilibrium - a rise in energy prices will induce a movement of households toward the place of work. It is worth noting, however, that this phenomenon does not necessarily lead to a higher density of population, as the resulting residential location pattern depends very much on the dispersal of the places of work. It may even be that a deconcentration of residential sites will occur.

2.3 Industrial and office location

Several studies (for example, Blom, 1982) have shown that travelers are usually less sensitive to the distance between home and public transportation center (pretransportation distance) than to the distance between public transportation center and place of work (posttransportation distance). An obvious explanation for this phenomenon is that the freedom of choice of a transport mode for pretransportation distance is larger than for posttransportation distance. This indicates that an appropriate physical planning strategy would be to locate new entrepreneurial activities near major terminals of public transport. An additional advantage is that the number of persons to be located in entrepreneurial activities is much higher per square meter than in household activities, so that entrepreneurial concentrations at favourable locations may be rather effective tools for saving energy.

In addition to empirical studies, various theoretical analyses have been made with regard to the energy efficiency of entrepreneurial locations (for example, Mills, 1972; Miller and Jensen, 1978). Mills's (1972) model takes for granted a centralized location of entrepreneurs within a central business district (CBD) and a dispersal of dwellings around a CBD. Mills then arrives at the conclusion that it may be more efficient to relocate factories to suburban areas if the average freight rate is lower than the average transportation costs for travelers. Otherwise, a more centralized location of entrepreneurs in a CBD may be more efficient. This conclusion, however, has to be adjusted if the land-use efficiency of households differs from that of entrepreneurs.

Miller and Jensen (1978) have used a production function for an individual firm that includes transportation. They concluded that a centralized location of firms is more efficient if the gross marginal non-energy revenues exceed the marginal costs; otherwise, a decentralized location is more efficient. They also noted, however, the relevance of congestion factors in a centralization strategy for industries and offices.

The conclusion can be drawn that the question whether or not centralization of entrepreneurs is - from a social point of view - more energy efficient depends on the share of energy costs, the presence of congestion phenomena, and the location of employees and markets. This means also that an optimal spatial layout from the point of view of energy efficiency cannot be determined in an unambiguous way, but can only be carried out in an integrated way by examining a whole spatial system in a real-world situation.

A related question concerns the behaviour of the individual firm (see Miernyk et al., 1978, and Sakashita, 1980). Rise of energy prices may have an impact on the following cost items of a firm: the price of production factors (raw material, intermediate goods, energy, investments, labour), the transport rate for production factors, the price of intermediate and final goods to be shipped by the firm, and the transport rate of these goods. Depending on the relative share of these cost items, the entrepreneur may be induced to choose a location toward the place of origin of production factors or of the commodity market (according to Weberian principles, e.g.).

If the issue of energy prices is only limited to electricity rates, a simpler situation emerges. Transportation costs are in general not dependent on electricity rates, so that mainly the input costs of electricity remain to be considered. Thus in this case it has to be examined whether the relative share of electricity costs in a firm's total cost function is large enough to warrant a relocation of activities to other regions with lower electricity rates. This issue will be further discussed in the next section.

3. LOCATIONAL PROFILES OF INDUSTRY

If a country has variations in regional electricity rates, the impacts on industrial location patterns can be studied in two ways:

(i) in a macro sense by analyzing average (sectoral) energy intensities and electricity costs at a regional scale;

(ii) in a micro sense by investigating the individual behaviour or attitude of energy- (or electricity-) intensive firms.

Both approaches will be described sequentially in this paper; the first stage will essentially be used to derive testable hypotheses for the second stage.

As mentioned before, energy and electricity prices are only a minor part of total input costs of firms. The locational behaviour of firms is constrained by various factors, for example, historical conditions (orientation toward raw materials, e.g.), physical conditions (presence of harbour facilities, e.g.), socio-economic conditions (need for specialized labour, e.g.), transportation conditions (need for accessibility, e.g.) or public regulations (areas designated for industrial purposes, e.g.).

In the Netherlands the cost share of electricity in most industrial sectors does not exceed 7 percent. Thus altogether one may assume that electricity costs will not exert a dominant influence on a firm's location, unless all input costs except electricity rates are equal in all regions. Then spatial discrepancies in electricity rates will entirely determine the locational pattern of footloose firms. In all other cases energy costs will only have a relative impact.

Therefore, a reasonable approach at a macro scale is to identify the electricity intensity (the share of electricity input relative to the production value; see later on) of industrial sectors in all regions and to confront these results with the variation in regional electricity rates in order to identify the link between industrial location patterns and electricity costs. In this framework the location quotient method will be applied.

In order to select a specific set of industries for a closer investigation, these industries should at least have a certain threshold level for electricity cost shares, as otherwise the impact of electricity rates will be negligible. In our study it is assumed that only sectors with a cost share of higher than <u>one</u> percent are meaningful candidates for further research.

A second exclusion principle emerges from mandatory locational requirements of specific industries (such as oil refinery or basic steel activities) whose location is <u>inter alia</u> determined by the need for sea port accessibility.

Next, the location quotient method is applied to the remaining sectors. The location quotient represents the extent to which a certain sector is over- or underrepresented in a given region. This quotient L_{ir} $(i=1,..,I;\ r=1,...,R)$ is defined here as follows:

$$L_{ir} = \frac{P_{ir}}{\sum_i P_{ir}} \qquad (1)$$

where P_{ir} indicates the gross production value of sector i in region r.[1] Clearly, instead of production values one could also use sectoral investments, but these figures are usually less stable. The results for all sectors and all regions can be included in a matrix M of location quotients:

$$M = \begin{bmatrix} L_{11} & \cdots\cdots & L_{1R} \\ \vdots & & \vdots \\ L_{I1} & \cdots\cdots & L_{IR} \end{bmatrix}$$

In addition, one may also calculate the average <u>regional</u> location quotient $\overline{L}_r$ as follows:

$$\overline{L}_r = \sum_{i=1}^{I} L_{ir}/I \qquad (2)$$

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1) In our study only plants with more than 10 employees are included. From the total production value of the whole industry $(\sum_i P_{ir})$ the oil and natural gas industry has been excluded.

Analogously, one may calculate the average <u>sectoral</u> quotient $\bar{L}_i$ as:

$$\bar{L}_i = \frac{\sum_r P_{ir}}{\sum_i \sum_r P_{ir}} \qquad (3)$$

All these figures provide us with relevant information regarding the presence or dominance of activities in certain areas. If one also calculates the average national-sectoral quotient $\bar{L}$, one may derive the following condition for the <u>regional attractiveness</u> A_r:

$$A_r = \frac{\bar{L}_r}{\bar{L}} \qquad (4)$$

If $A_r > 1$, then region r is more attractive than the national average.

Furthermore, one may also study the <u>industrial size effect</u> B_i:

$$B_i = \frac{\bar{L}_i}{\bar{L}} \qquad (5)$$

If $B_i > 1$, the industry concerned is large compared to the average industrial size in the country.

Next, one may also define a <u>combined sector-region specific attractiveness effect</u> C_{ir} defined as[1]:

$$C_{ir} = \frac{L_{ir} \cdot \bar{L}}{\bar{L}_r \cdot \bar{L}_i} \qquad (6)$$

By substituting (4)-(6) into (1), one obtains the following decomposition for a certain location quotient L_{ir}:

$$L_{ir} = A_r \, B_i \, C_{ir} \, \bar{L} \quad , \qquad (7)$$

which is essentially a gravity-type of expression (viz., a power function).

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[1] The original location quotient can be obtained by multiplying A_r by C_{ir}.

In this way, an over- or underrepresentation of sectors in a region can be more properly ascribed to one of the above-mentioned effects. The analysis can also be extended toward a multi-period analysis, so that ratios of (7) can be analyzed. In principle, such a model can also be tested by means of log-linear analysis (see Bahrenberg et al., 1984, and Nijkamp et al., 1984).

4. A CASE STUDY FOR THE NETHERLANDS

4.1 Introduction

The method explained in section 3 has been applied in a research project on the possible impacts of interregional differences in electricity prices.[1] The Association of Electricity Distributors in the Netherlands (the so-called V.E.E.N.) was interested in the question whether a significant relationship between the interregional differences in electricity prices and the locational structure of the Dutch industry could be identified. It should be noted that the research concentrated mainly on a national level. Additional international comparisons were only carried out superficially. This does not mean that the impacts at an international scale may be regarded as insignificant.

For a restricted set of industries, the above-mentioned relationship has been tested in a macro sense by means of the location quotient method. An additional qualitative analysis has been carried out for those industries for which the method was not applicable. In addition to the location quotient method and the qualitative analysis, a micro-oriented analysis based on nine interviews with firms belonging to relevant[2] industrial branches has been pursued.

Reliability of the public electricity network was kept outside the analysis. It was assumed that interregional differences of reliability levels were negligible.

Before presenting the results of the study, the way of operating of electric utilities in the Netherlands will be described in the next subsection.

4.2 The organization of electric utilities in the Netherlands

Eleven Dutch companies take care of the generation of electric power. Ten of them are provincial companies, one is a municipal company. One provincial company is essentially a production pool of municipal companies. The service areas of the eleven companies are shown on map 1.

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1) For an extensive explanation of the method and the results, see Perrels (1984).

2) Relevant in the sense of probably sensitive to electricity rates, given the results of the macro analysis.

Map 1. Service areas of electric power generating companies.

Apart from generating electric power, these companies also distribute electricity both directly to consumers and to municipal distribution companies. Usually in rural areas the generation company takes care of the distribution, while most towns of any size have their own distribution company.

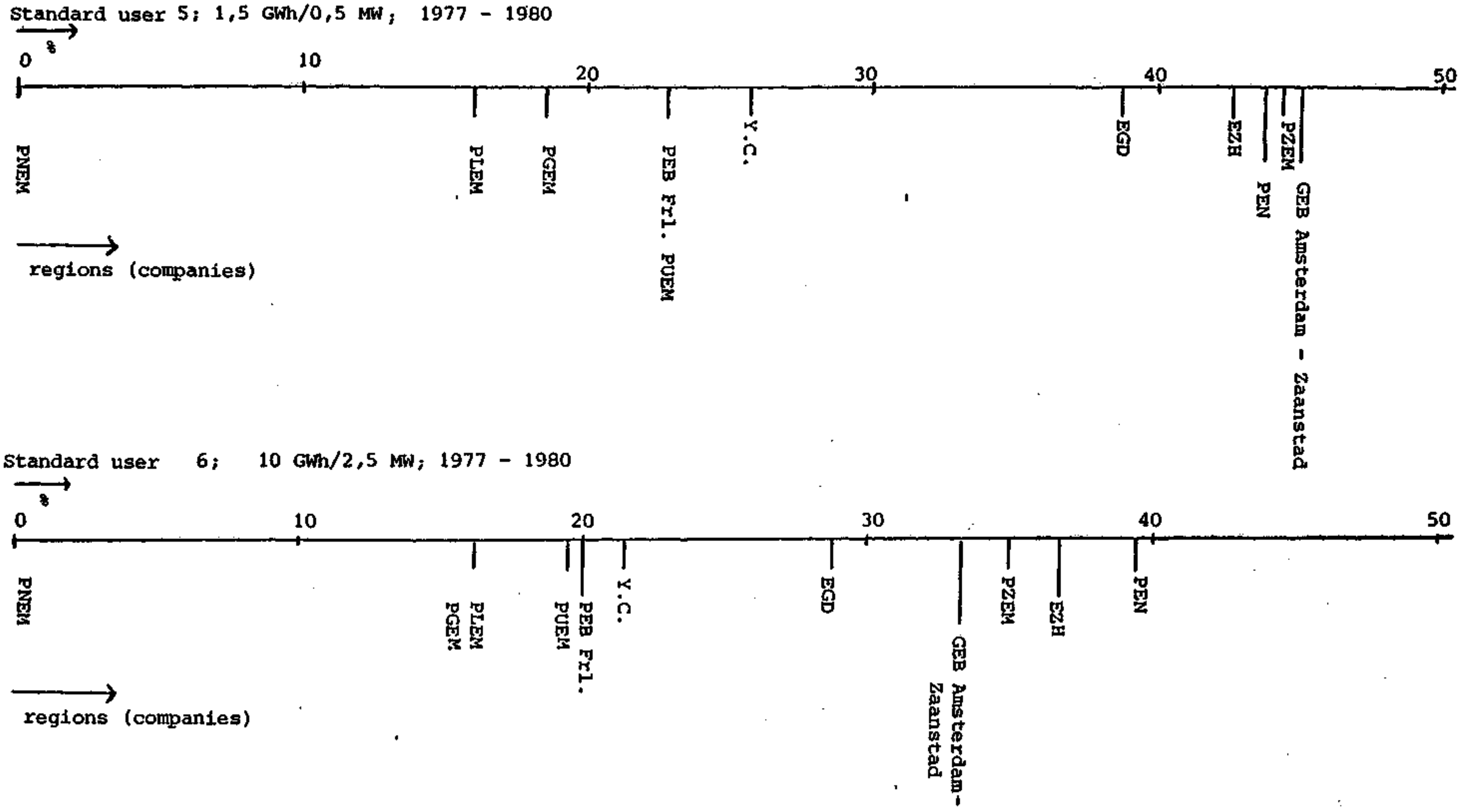
For the various classes of electricity-users considered the rates differ among regions. The price differences became more important after the energy crisis of 1973/1974. These price differences are due to the following reasons.

In the first place, the electric power companies do not use the same fuels (or the same mix of fuels). This implies that among regions there are differences in the cost structure of a unit of electricity, so that the electricity can be more expensive in some regions than in others. In practice this means that, compared with oil- and gas-fired plants, coal-fired generation plants allow for a greater digression in the rate structure and <u>on average</u> produce electric power against lower total costs per unit of electricity.

In the second place, the local distribution companies are allowed to put an extra margin on the price in order to generate some profit for the municipality. In addition to this local profit generation some regions show a complicated distribution structure, which causes additional administrative overhead costs. For instance, in the province of Zuid-Holland the electricity generated by an electric power company can pass through four organizational stages before reaching the consumer.

The interregional differences are not the same for all consumer classes. Especially after the introduction of several kinds of rebates in 1982, small and medium-size industrial consumers experience larger percentage differences than the large industrial consumers. Large consumers receive several types of rebates, which have a strong converging influence on the regional prices. While medium-size consumers can be confronted with price variations up to 40 %, large consumers experience variations only up to 13 %. Figure 1 shows the extent of variations. Apart from the regular rebates some branches of industry have negociated special prices. These branches only consist of industries consuming vast amounts of electricity.

Figure 1. Percentage differences compared to the region (company) with the lowest price. (The respective companies account a price x% higher than PNEM does).



The division in four areas is based on these standard users for the period 1977-1980.
1,5 GWh/0,5 MW means a yearly consumption of 1,5 GWh (= $1{,}5 \cdot 10^6$ kWh) and an amount of claimed power of 0,5 MW (= 500 kW).
10 GWh/2,5 MW means a yearly consumption of 10 GWh (= 10^7 kWh) and an amount of claimed power of 2,5 MW (= 2500 kW).
Both so-called standard users are taken from the VDEN[1]-survey of standard users. Standard user no. 5 and no. 6 were until 1982 the largest types of standard users included in the survey.

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[1] The VDEN is an associated institute of the VEEN.

In connection with the analysis of the results presented in the next sections, it is convenient to make the following classification in accordance with prices and their interregional differences.

	plant size	magnitude of the variations
A.	small and medium-size consumers (1 GWh to ± 40 GWh)	- large interregional differences
B.	large consumers (± 40 GWh to ± 150 GWh)	- small interregional differences (rebates decreased the differences)
C.	vast consumers (> ± 150 GWh)	- possible differences depending on individual contracts (privileges)

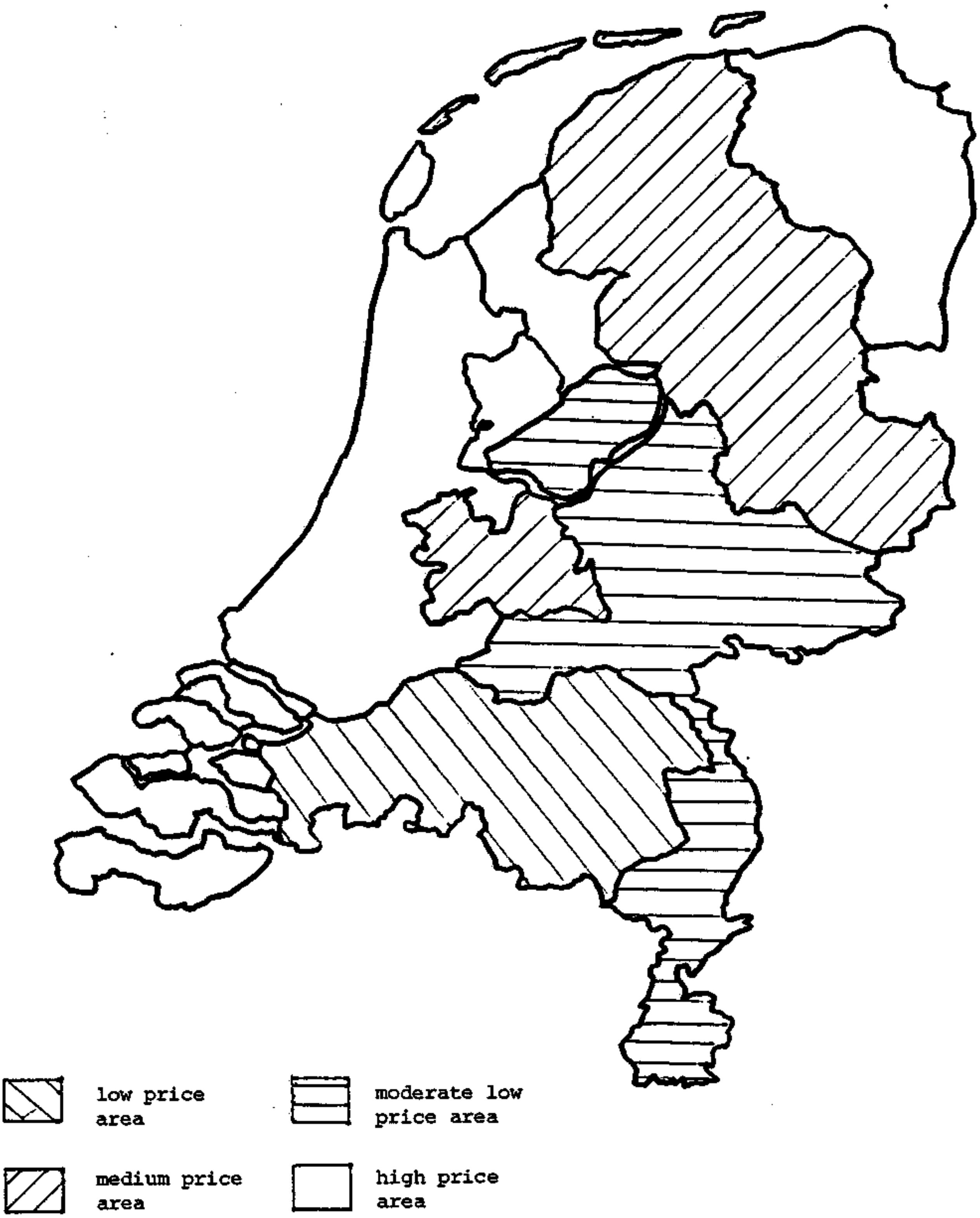
Based on this analysis of prices the Netherlands has been subdivided into four areas, which are defined as: low price area, moderate low price area and medium price area, high price area. The areas are shown on map 2. The references to regions in the next sections relate to the above defined areas.

4.3 Results of the analysis by means of location quotients

The Association of Electricity Distributors in the Netherlands (the V.E.E.N.) was concerned about the locational impacts of interregional price variations on industrial consumers. The location quotient method may be regarded as a suitable instrument to analyze the possible impacts. The method was thought to be applicable to industries that fulfilled the two prerequisites mentioned in section 3, viz.,

1. a minimum cost share of electricity of 1 %;
2. no mandatory locational requirements.

Map 2. Division of the Netherlands in four areas.



In relation with the classification presented in the foregoing section (4.2), the following classification scheme for the industry could be constructed:

<u>Scheme 1.</u> Classification by cost share and size of consumption.

class → of firms / size of yearly consumption	footloose		non-footloose	
	1	2	3	4
	share ≤ 1%	share > 1%	share ≤ 1%	share > 1%
A. small/medium-size, large price differences (1 GWh – ± 40 GWh)	A1 . food, clothing . metal processing . machinery . electrotechnics	x A2 . textile . paper . plastic . foundries . rubber . chemicals . building materials	A3 . means of transport	A4 -
B. large size, small price differences (rebates) (± 40 GWh – ± 150 GWh)	B1 . food . machinery . electrotechnics . means of transport . chemicals	x B2 . paper . chemicals . building materials	B3 . chemicals . means of transport	B4 . chemicals . building materials . basic steel works
C. vast size, no systematic differences (privileges) (> 150 GWh)	C1 -	C2 -	C3 -	C4 . chemicals . building materials . basic steel works

x – suitable for location quotient method.

The above scheme shows that for the majority of the industry the cost share is not high enough to assume any relevant sensitivity for large price variations. On the other hand, a great many industries which are definitely sensitive for electricity rates turn out to be not footloose. So only a few parts of some branches appear to be suitable for the location quotient method. The selection includes the following industries (sic 3-digit level):

Beer
Wool and Cotton
Paper and Cardboard
Synthetic Resins
Pigments
Synthetic Fibres
Rubber
Plastic Processing
Pottery
Glass
Foundries

Location quotients[1] per industry per region have been calculated for the years 1977 and 1980[2]. By calculating the quotients for two years it was possible to identify a shift from high price areas to low price areas. Such a shift would be an indication that electricity-intensive industries showed a tendency to (re)locate because of interregional differences in electricity rates.

At first sight the low price areas seemed to have a location pattern that confirmed the tendency to locate in low price areas. However, a further analysis revealed that such a conclusion would be invalid.

The historical ties between certain industries and certain regions are an important element. Industries that are nowadays footloose, were not footloose at the time of their foundation. So industrial inertia has a conservating influence on location patterns.

A further consideration on the effects in which the quotients can be decomposed does not give any support to the above-mentioned tendency. The regional attractiveness (A_r) is only of some importance in Gelderland + Limburg (positive) and in Western Holland + Groningen (negative). The specific attractiveness (C_{ir}) varies from region to region for most industries. No systematic support for a (re)locating tendency can be identified. Finally the dynamics in the quotients and various kinds of attractiveness show a relative decline of the regional attractiveness of the low price areas. The specific attractiveness is almost constant for every region.

Apart from location quotients based on production value, quotients based on investments (in land and buildings) have been calculated. These results confirmed the results of the analysis based on the production value.

Although the non-footloose industries are restricted in their choice of location, some further qualitative investigations have been carried out about the backgrounds of the current locations of these industries. With one exception all these industries consist of (very) large scale plants.

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1) As defined in section 3, equation 1.

2) A complete set of data could be only obtained for the period 1977-1980. So of necessity the location quotient method could be only applied to this rather short period.

The scale of operations demands vast amounts of input materials. Therefore, the location is input oriented, which means a settlement nearby the place where either the main input is extracted from (e.g. mines) or the main input is supplied to (e.g. a seaport). Indeed most plants are settled according to the above-mentioned criteria. Rijnmond is the favourite seaport to settle. However, the ports of Vlissingen and Delfzijl have attracted some electricity-intensive industries (e.g. aluminium) by offering electricity rates far below the regular minimum prices. In the areas involved (PZEM, EGD) other consumers (including industry) are confronted with a relatively high price of electricity, in order to offset the low prices for the few privileged industries.

The conclusion remains that within the Netherlands there is no systematic relationship between the electricity price and choice of location for any industry. On an international scale there could be a relationship as far as the hyper-intensive industries[1)] are concerned. However, for some of these hyper-intensive industries natural gas is as important as electricity and in most cases natural gas is cheaper in the Netherlands than in the surrounding European countries.

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1) Aluminium, Zinc, Phosphorus, Steel, Paper, Chlorine/Sodium Hydroxide, Fertilizer.

5. MAIN RESULTS OF INTERVIEWS WITH ENERGY-INTENSIVE FIRMS

5.1 Introduction

Extensive interviews were held with nine different companies. Six companies consisted of more than one production plant. Apart from the rubber- and plastic processing industry, all selected branches have been included. Among them were two hyper-intensive activities (paper and chlorine/sodium hydroxide). By the interviews all participants received a questionnaire in order to be well prepared during the interview. The advantage was that this created more time to highlight some questions and answers or to make some sidesteps. The questionnaire was structured according to a sequence of themes, which were presented in the following sequence: the nature of the appliance of electricity, the magnitude of the electricity consumption, savings on electricity consumption and electricity rates. Concerning the impact of interregional price variations the following conclusions could be drawn from the interviews.

5.2 Location choice

Within the framework of an increasing awareness for energy consumption and energy costs the costs of electricity consumption also received more attention. Since the real prices of electricity provided by the public enterprises increased considerably for the last ten years, the prices and the price structure appeared to be of increasing interest for the industry. However, notwithstanding an increasing share of the costs of electricity, electricity rates are still not of primary importance for the majority of the Dutch industry. It is therefore understandable that both the location quotient method and the interviews did not give any ground to believe there is a systematic relationship between location choice and interregional differences in electricity rates.
Some firms wished to emphasize that normally a firm expects other location factors, like seaport facilities, well educated labour, etc., to be more valid for a longer period than a short-term advantage because of interregional variations in electricity prices.

5.3 An alternative; energy saving

The pattern of location appears to be rigid or, stated otherwise, the main factors determining a location appear to be quite stable over time. This means that increasing energy costs have to be faced within the plants. The possibilities to arrive at lower energy costs consist of energy savings and (private) industrial co-generation. The efforts concerning saving are strongly intensified the last ten years. Seven of the nine interviewed firms had appointed an energy manager.

Savings can be made on existing equipment or incorporated in new equipment. The amount of aggregate energy saving realized is supposed to be correlated with the real price *level*. The amount of additional savings is supposed to correlate with movements (rising) of the real price level.1)

As far as electricity saving devices are incorporated in new equipment, five firms stated that in investment decisions cost saving elements were always taken into account. Two firms stated that it depended on the size of the investment whether it was taken into account or not. Two other firms regarded the incorporated savings not relevant enough to be taken into account in their investment decisions.

The impact of saving can be measured in terms of intensity. Intensity can be defined as follows:

1. in physical terms: $\dfrac{\text{energy use}}{\text{output}} \quad \begin{array}{l}\text{(Joules, kWh's)}\\ \text{(quantities)}\end{array}$

2. in cost terms :a. $\dfrac{\text{energy costs}}{\text{production value}} \quad \left(= \dfrac{\text{energy use x unit price of energy}}{\text{output x unit price of output}}\right)$

b. $\dfrac{\text{energy costs}}{\text{value added}} \quad \left(= \dfrac{\text{energy use x unit price of energy}}{\text{labour costs + rent + gross profit}}\right)$

Intensity in cost terms as defined in 2.a was used in our approach. In case of an analysis at a disaggregated level an intensity related to production value is to be preferred to one related to value added. This can be argued as follows. The intensity related to production value can be described as the energy-output ratio. This ratio is an indication of the factor productivity of energy. The intensity related to value added

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1) One can imagine that potential savings are not equally distributed in relation to increasing real prices. In that case aggregate savings will not increase smoothly over time, but jumpwise.

- with labour costs being the greater part of value added - is closely related to the energy-labour ratio. However, this ratio is not an indication of productivity but of relative factor inputs.
Relative factor inputs do not only change because of energy savings but these relative inputs are also strongly affected by technological development. Especially mechanization means substituting energy (notably electricity) for labour. So mechanization has a much larger impact on the energy-labour ratio than on the energy-output ratio. Consequently, the measurement of the impacts of energy savings by using intensity related to production value will be much less biased due to influences of mechanization, compared to the measurement by means of intensity related to value added. However, if the analysis is carried out at an aggregated level production value related intensity becomes less valuable, because the intersectoral supplies will "blow up" the production value. In this case the intensity related to value added is to be preferred.

The measurement of realized savings is, however, not a very simple task. Besides savings, the utilization rate and technological development (mechanization) influence the intensity. The impact of the utilization rate can either be positive (over-utilization) or negative (under-utilization). In the long run, its impact may be negligible. The rate of mechanization is always important, notably in the long run. The general impression from the interviews was that increasing mechanization and additional savings offset each other during the period 1980-1983. However, the period of easy achievable energy savings is finished, so that future additional savings will be more difficult to realize. On the other hand mechanization is expected to increase steadily. Therefore physical intensity may be expected to increase slightly in the nearby future.
Of course, this assumption (also) depends on the development of electricity prices as well as output prices.

The possibilities to switch to private industrial co-generation are linked to technical restrictions. This is relevant for a small amount of mainly large-scale firms. Due to investments, firms are quite cautious in installing own generating capacity. Since the creation of rebates in 1982, the rate of return on private generation capacity has decreased. The lowest rate of return is achieved in the areas served by coal-fired generation plants. One firm mentioned a rate of return below the expected rate of return and an other firm mentioned the cancellation of an investment in private co-generation capacity. In both cases, the low price level of electricity was the cause. This allows us to conclude that interregional price differences can cause some regional differences in the amount of aggregate savings. Also the decision to install a private co-generation plant can thus be influenced. In other words, interregional differences in electricity prices can possibly cause interregional differences in physical energy intensity.

CONCLUDING REMARKS

A few remarks are in order in light of the conclusions put forward in the previous sections. First, the time period covered was fairly brief, so that it is still possible that some long-term locational shifts may take place, though this is - in view of the current stable energy prices - not very likely.

In the second place, the spatial scale of the Netherlands is very small, so that it is perhaps difficult to observe a significant locational behaviour of industrial firms. There is indeed some evidence that at an international scale firms in West Europe tend to be more energy-sensitive.

Finally, firms which are potential candidates for relocation have already managed to obtained special contracts with reduced electricity rates, so that it is not entirely evident that global statistical data lead to entirely reliable results. More micro-oriented research would by all means be necessary.

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