Title

Electricity Consumption and Structural Change in Manufacturing Industry in Developing Countries

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Publication Date

1990-04-01

LBL-28762
UC-350

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

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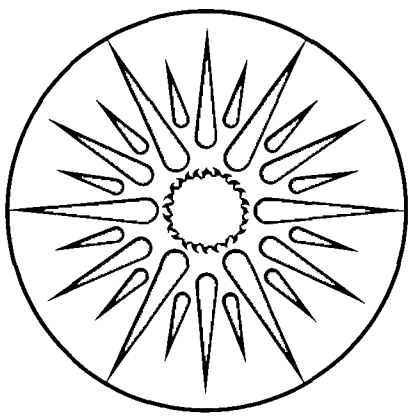

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Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

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LBL-28762

ELECTRICITY CONSUMPTION AND STRUCTURAL CHANGE IN MANUFACTURING INDUSTRY IN DEVELOPING COUNTRIES

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April 1990

This work was supported by the Office of the Assistant Secretary for Environment, Safety, and Health of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

ABSTRACT

This report presents data and analysis on historic trends in electricity consumption and economic output in manufacturing industry for a number of newly-industrialized and developing countries. Combining energy and economic data, we show trends in manufacturing electricity intensity, and analyze the causes of change in intensity to the extent possible. For several of the countries we also show trends in electricity intensity at the sub-sectoral level.

Since 1975, there have been large increases in aggregate intensity in Thailand, Brazil, Argentina, Mexico, and Venezuela, large decreases in Taiwan and China, and little net change in South Korea and India. While interpretation of trends is hampered by lack of data, the evidence suggests that the effect of change in the composition of manufacturing output on aggregate electricity intensity was much less important than the effect of change in intensity at the sub-sectoral level. Though we were unable to analyze change in composition within sub-sectors, it is evident that it has affected electricity intensity.

Comparison of aggregate manufacturing electricity use per unit of value-added (converted to U.S. dollars) shows that intensity in the mid-1980s varied by more than a factor of two among six countries. China and India, both of whom have relatively old equipment in their industries, are at the top of the range, while South Korea and Taiwan, both of whom have relatively new equipment, are at the low end. With the exception of India, there is a clear correlation between electricity intensity and the average price of electricity to industry. Comparison of intensity among 2-digit sectors, which gives a better sense of the relative efficiency of countries, also shows a considerable range for most sectors.

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1. INTRODUCTION

This report presents data and analysis on historic trends in electricity use and economic output in the manufacturing sector for a number of newly-industrialized and developing countries. Combining energy and economic data, we show trends in manufacturing electricity intensity, and analyze the causes of change in intensity to the extent possible. For many of the countries we also show trends in electricity intensity at the sub-sectoral level.

1.1. Historic Growth in Industrial Electricity Consumption

The industrial sector accounts for 50-60% of total electricity consumption in most developing countries.[1] The industrial sector consists of four major sub-sectors: manufacturing, mining, agriculture and fishery, and construction. Most of industrial electricity consumption is accounted for by manufacturing. Mining may be an important electricity user in countries with large mining operations, though these often generate electricity for their own needs internally. In some countries, agricultural irrigation is also a significant electricity user. Construction is a minor user of electricity.

We found consistent time-series data on *manufacturing* electricity consumption for only a handful of countries. Thus, for comparing historic trends, we use *industrial* electricity consumption (excluding agriculture in most cases). The rate of growth has varied among countries (Table 1-1). In the 1979-87 period, it has been quite rapid in some countries (Indonesia, Pakistan, South Korea, Thailand), but slow in others (the Philippines, Argentina). Taking together the 12 largest developing countries in Asia and Latin America (excluding China), the increase averaged 9.6% per year in the 1970-1979 period, and 6.8% per year in the 1979-1987 period. The lower growth in the latter period was mainly due to much slower growth in Latin America in 1979-87 (6.0% per year) relative to 1970-79 (10.3% per year). This was due both to the economic recession of the 1980s and the policy of encouraging industrial electricity use that was pursued in Brazil in the 1970s. In Asia, growth in industrial electricity use was on average only slightly lower in 1979-87 than in the 1970s, though there was a marked difference (both increase and decrease) for particular countries.

[1] This includes generation by industries for their own use ("self-production"), which amounts to 10-15% or more of total industrial electricity use in many developing countries. The industrial share of public electricity generation is therefore somewhat less than 50-60%.

Table 1-1
Average Annual Growth in Industrial Electricity Consumption (%)

	1970-79	1979-87
India	4.8	7.0
Indonesia*	11.2	15.7
Malaysia*	8.0	5.7
Pakistan	5.6	9.1
Philippines*	10.1	-1.9
South Korea*	16.9	9.3
Taiwan	12.8	5.7
Thailand	14.4	8.4
Argentina	7.2	2.5
Brazil	12.9	6.8
Mexico	8.4	6.3
Venezuela*	10.1	6.0
Asian-8	8.7	7.5
Latin-4	10.3	6.0
Total-12	9.6	6.8
China	-	7.0**

Includes industrial self-production.
* May include agriculture.
** 1980-87

1.2. Analyzing Trends in Manufacturing Electricity Use

Change in manufacturing electricity use is shaped by two general factors: (1) Change in the level of production or output, and (2) Change in intensity, or electricity use per unit of output.

Output is often measured in terms of *value-added*, which is derived from value of shipments (gross output) minus value of purchases (intermediate inputs). For time-series analysis, it is necessary to correct for price changes using sector-specific indices. Analytical difficulties can be introduced due to fluctuations in relative prices and importance of inputs and output.

An alternative measure of output is the *physical production index*, which reflects change in quantities produced. For interpretation of data on energy intensity, physical production indices are more helpful than value-added statistics, because energy use is more closely related to the production process itself, rather than to changing market conditions which affect prices and value-added. Unfortunately, physical production indices are less available. Interpretation of production indices is fairly straightforward at a very disaggregated level where the products are relatively homogenous. As one moves to higher levels of aggregation, the weighting of production indices for the various sub-sectors becomes an issue, since the relative importance of the sub-sectors may change over time. (Weighting is based on the relative share of each sub-sector in value-added in the base year of the index.) In cases where data on value-added and physical production are available for the same time period, comparison shows that the two measures

sometimes diverge significantly, thereby giving a different picture of relative trends among sectors.

Since manufacturing activities inherently differ in their electricity intensity, the electricity intensity of the manufacturing sector and its sub-sectors is affected by changes in the mix of manufacturing output. We refer to this as *structural change*. Such change occurs in all countries in response to changing domestic and international markets, industrial investment strategies, and competitiveness of industries. Structural change *within* each of the sub-sectors of manufacturing (e.g., basic metals, chemicals, food) may influence the electricity intensity of the sub-sector. For example, within the sub-sector "metal products," there may be shifts in the relative production of goods whose manufacture is inherently more or less electricity-intensive (e.g., ships vs. electronics).

Going to a finer level of disaggregation, the average electricity intensity at a national level with which *particular goods* are produced changes in response to several factors, including: (1) Institution of improved energy management practices in existing facilities; (2) Introduction of new equipment or processes in existing facilities; and (3) Opening of new factories that incorporate equipment or processes that may be more or less energy-intensive than those in existing facilities, or closing of old, inefficient factories. Production capacity (ability to capture efficiencies of scale) and capacity utilization also affect intensity. Energy efficiency tends to improve as a result of innovations in manufacturing technology, though in some cases such changes may increase *electricity* intensity.

Changes in electricity prices may promote improved energy management practices and/or introduction of new equipment or processes in existing facilities, but the latter are usually done for purposes not directly related to saving energy. Historic levels of electricity prices relative to other countries may shape the mix of industries. Countries with relatively low electricity prices (generally due to inexpensive hydro production) tend to have a higher proportion of electricity-intensive industries such as aluminum and steel. Less well substantiated but probable is the tendency for such countries to also have relatively high electricity intensity across many industries (because there is low incentive for electricity conservation). In part this is because low electricity prices foster use of processes that rely more on electricity than on fuels (e.g., mechanical or thermo-mechanical pulping unstead of chemical pulping, or electro-steel in place of blast furnaces).

In a country where rate of investment in industrial capital is high (such as in much of Asia), the aggregate electricity intensity at the national level of producing a particular good may change rapidly as well. While introduction of new equipment or processes and new factories often acts to decrease aggregate electricity intensity, this is not necessarily the case. For example, a new process may be more electricity-intensive than the average practice if it replaces human labor with machinery. Electricity intensity may also increase if electricity substitutes for other fuels, as occured to a considerable extent in Brazilian industry in the 1970s due to government subsidization of electricity prices. Introduction of new equipment or processes and new factories in developing countries can result in either increased or decreased electricity intensity. In practice, it is exceedingly difficult to sort out the effects of the many factors that shape aggregate electricity intensity at the sub-sectoral level, though it is possible to gain a qualitative feel for the relative importance of different factors if one is very familiar with the industry of a given country.

1.3. Classification of Manufacturing Sectors

The International Standard Industrial Classification code divides manufacturing activities into nine groups, each of which has a 2-digit number. Within each of these there are further subdivisions. The 2-digit sectors and the main activities that they include (some of which include two 3-digit sectors) are shown in Table 1-2. While most countries make use of this classification for reporting economic data, electricity consumption data are not always reported according to the ISIC code.

1.4. Data on Trends in Manufacturing Electricity Intensity in LDCs

We have found very little data that allows description of change in manufacturing electricity intensity at the 2-digit level in LDCs. Without such data, it is difficult to separate the impacts of (1) structural change, and (2) change in intensity at the 2-digit level on aggregate electricity intensity. The problem is one or both of the following: (1) Lack of time-series data on electricity consumption at the sub-sectoral level; and (2) Lack of time-series data on economic output in constant prices at the sub-sectoral level. For some countries, we have found one but not the other. For only two countries have we found both over a lengthy time period: South Korea and Taiwan. For China, we have data on electricity intensity at the sub-sectoral level for the 1980-1985 period. For India and Brazil, we have data for some sectors for some years.

In the absence of time-series data on sectoral electricity intensity, one can examine the trends in aggregate manufacturing electricity intensity and in the mix of manufacturing production, and attempt to assess qualitatively the likely effect of structural change on electricity intensity. The reasoning behind this approach is that certain sectors are inherently more electricity-intensive than others, and that increase in their relative share of total output tends to increase aggregate manufacturing electricity intensity. This approach has definite problems, as discussed below, but can provide some insights in the absence of better data.

A general problem with manufacturing electricity use data is uncertainty over inclusion of self-production of electricity. In many cases, it is uncertain whether the sub-sectoral consumption data that we have used in this study include self-production. Where we have data on total industrial self-production, it is difficult to assess the reliability of the estimates that have been made in various countries without knowing the situation in each case. In some cases, self-production is embedded in the published data on consumption, and its magnitude is unknown to us. There is also uncertainty about whether the data on industrial self-production include mining operations.

We discuss data issues and sources relating to each country in Appendix 1.

Table 1-2
International Standard Industrial Classification
Manufacturing

Code	Activity
31	Food
	Food products
	Beverages
	Tobacco
32	Textiles
	Textiles
	Wearing apparel
	Footwear
33	Wood
	Wood products
	Furniture
34	Paper
	Paper
	Printing and publishing
35	Chemicals
	Chemicals
	Petroleum refining
	Rubber products
	Plastic products
36	Non-metallic minerals
	Cement
	Glass
37	Basic metals
	Iron and steel
	Non-ferrous metals
38	Metal products
	Metal products
	Machinery
	Transport equipment
	Other equipment
39	Other

1.5. Analytical Problems

It can be difficult to make sense of changes in aggregate manufacturing electricity intensity by examining shifts in relative output among 2-digit sectors. Each sector covers a wide range of activities that often differ significantly in their electricity intensity. Each has within it both "upstream" and "downstream" activities distinguished by the degree to which raw materials are processed. A general rule of thumb is that upstream activities are more energy-intensive than

downstream activities. Over time the relative importance of upstream and downstream activities within a sector may change. The aggregate share of the sector in total manufacturing output may change only slightly, but within the sector downstream activities may become more important, a shift that contributes to declining energy intensity.

The above difficulty also applies when analyzing change in electricity intensity at the 2-digit (or even 3-digit) level, though the problem is usually less severe. Within Iron and steel (ISIC 371), for example, integrated production of steel from ore is in the same 4-digit sector as production of steel from scrap. The effect of a shift toward the scrap-based process will show up as a decline in energy intensity, since the energy embodied in scrap enables lower-energy steel production.[2]

In the absence of a detailed analysis, it is difficult to draw firm conclusions regarding the causes of change in electricity intensity. *In particular, one must take care not to conclude that changes in intensity at an aggregate level reflect similar changes in efficiency*. For all but a few developing countries, the data of which we are aware do not allow analysis of trends at a sufficient level of depth. Data unknown to us may exist within countries that would facilitate analysis of trends in manufacturing electricity consumption. In some cases, manipulation of electric utility sales statistics might provide the necessary disaggregation of manufacturing electricity consumption. Better understanding of historical trends will contribute to more reliable forecasting of future electricity consumption by the manufacturing sector, and of the potential impact of shifts in relative production among sub-sectors and changes in end-use efficiency.

1.6. Structure of This Report

In Chapters 2 through 8, we present data and analysis on trends in manufacturing electricity consumption in 10 countries, beginning with those for which the data allow a greater degree of analysis (Taiwan and South Korea). In Chapter 9, we compare manufacturing electricity intensity in several of the countries. In Chapter 10, we compare change in manufacturing electricity intensity with change in fuel intensity.

1.7. Notes

1. Data on manufacturing value-added or output value are in constant prices.
2. We include the manufacturing sector "Wood" (ISIC 33) in "Other" in the tables and figures. For most of the countries, it is a small category.

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[2] The example is taken from G. Boyd and M. Ross, "The role of sectoral shift in trends in electricity use in United States and Swedish manufacturing," *Electricity*, Lund University Press, 1989.

2. TAIWAN

Electricity consumption by manufacturing in Taiwan grew at an average rate of 8.2% per year between 1972 and 1987. There was decline in consumption in the 1980-82 period, which was marked by reduced economic growth due to the second oil shock and the world-wide recession, but growth averaged nearly 9% per year in the 1982-87 period (Figure 2-1).

Manufacturing electricity intensity — electricity consumption per unit of manufacturing value-added (constant prices) — has declined by 25% since 1975. In particular, there was considerable decline in intensity in the 1980-83 period.

2.1. Structural Change

We had constant-price data on output of 2-digit manufacturing sectors only back to 1978. During this period the share of machinery increased from 24% to 30% of value-added (Figure 2-2 and Table 2-1). The shares of food and textiles both declined, as did the share of non-metallic minerals. Other sectors held more or less constant in share, except for the "Other" category, which increased considerably (this category includes various light manufacturing industries). Overall, the share of "light" industry (food, textiles, machinery, and other) increased slightly from 64% to 66%, while the share of "heavy" industry declined slightly from 36% to 34%.[1]

[1] The grouping into "light" and "heavy" obscures the fact that most sectors contains a range of "upstream" industries (i.e., initial processing), which tend to be "heavier," and "downstream" industries (secondary or tertiary processing), which tend to be "lighter."

Electricity and Manufacturing
Taiwan

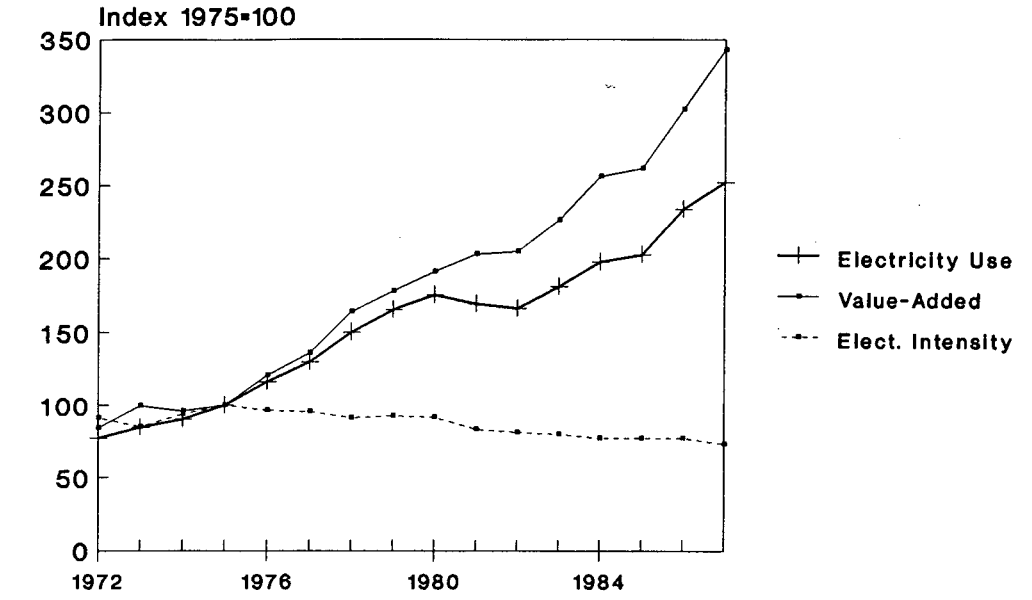

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Figure 2-1

Manufacturing Composition
Taiwan

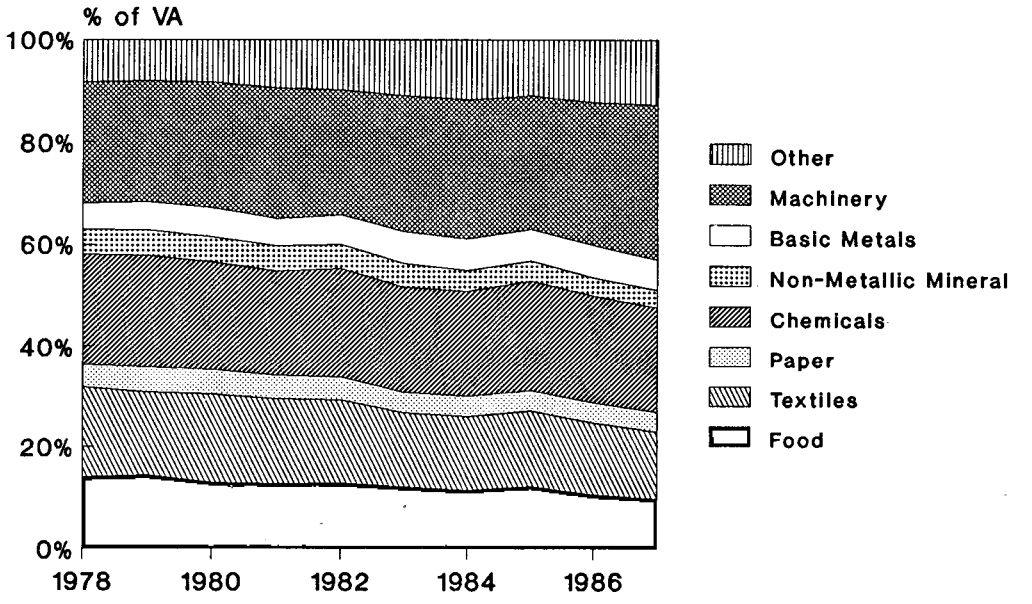

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Figure 2-2

Table 2-1
Value-Added in Manufacturing
Taiwan
(10^9 1981 NT$)

Sub-sector	1978	1987
Food	76	109
(%)	14	10
Textiles	97	146
(%)	18	13
Paper	24	42
(%)	4	4
Chemicals	119	231
(%)	22	21
Non-metallic minerals	26	37
(%)	5	3
Basic metals	28	66
(%)	5	6
Machinery	128	333
(%)	24	30
Other	45	142
(%)	8	13
TOTAL	543	1108
(%)	100	100

2.2. Analysis of Change in Manufacturing Electricity Intensity

In the case of Taiwan, we had time-series data on electricity consumption at the 2-digit ISIC level beginning in 1972, but did not have comparable data on value-added in constant prices. We approximated a time series for value-added using current-price data on value-added and production indices, which we had beginning in 1978. This allowed us to separately analyze the impacts of *structural change* and *change in electricity intensity* at the 2-digit level on aggregate manufacturing electricity intensity. The analysis is based on a Laspeyres index calculation, as described in Appendix 2.

Figure 2-3 shows three indices for aggregate manufacturing electricity intensity: (1) Actual electricity intensity; (2) Electricity intensity if there had been no structural change at the 2-digit level (labelled "Intensity Effect" in the figure); (3) Electricity intensity if there had been no change in electricity intensity at the 2-digit level (labelled "Structure Effect" in the figure). The analysis shows that change in intensity has mainly been responsible for the reduction in aggregate electricity intensity since 1980. We discuss these changes below.

Manufacturing Electricity Intensity
Taiwan

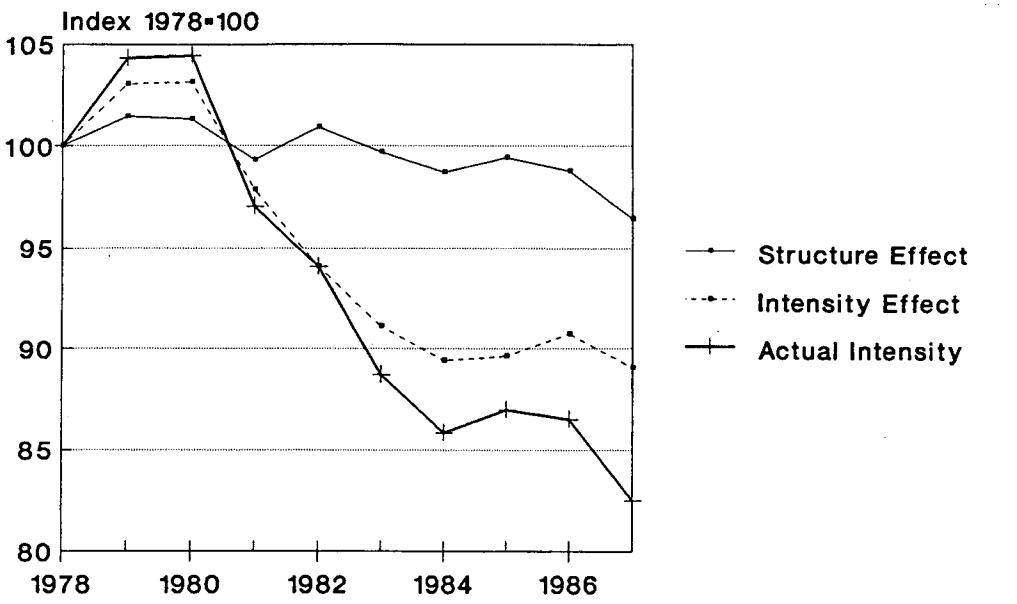

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Figure 2-3

The net effect of structural change was not large. The increasing share of metal products, which pulled aggregate intensity downward due to the relatively low electricity intensity of this sector, was largely balanced by the declining share of food, which also has low electricity intensity. Among high-electricity-intensity industries, the increase in the share of basic metals was balanced by decline in the share of non-metallic minerals.

The Intensity Effect was mainly due to decline in the electricity intensity in the two most electricity-intensive industries, non-metallic minerals and basic metals (Figure 2-4). The decline has been most marked in basic metals, especially in the early 1980s. In this case, the reason for the sharp decline is structural change within the sector, namely decrease in aluminum production, which is highly electricity-intensive. There has also been a decline of intensity in chemicals. Together, the decline in intensity in these industries had a greater effect than the increase in the relatively less electricity-intensive sectors. The only sector which experienced significant increase in electricity intensity is textiles.

As the example of basic metals shows, change in electricity intensity at the 2-digit level may result from structural change *within* the sector, as well as from changes in processes, introduction of new equipment and processes, introduction of new facilities, and energy management.

Electricity Intensities By Mfg Subsector
Taiwan

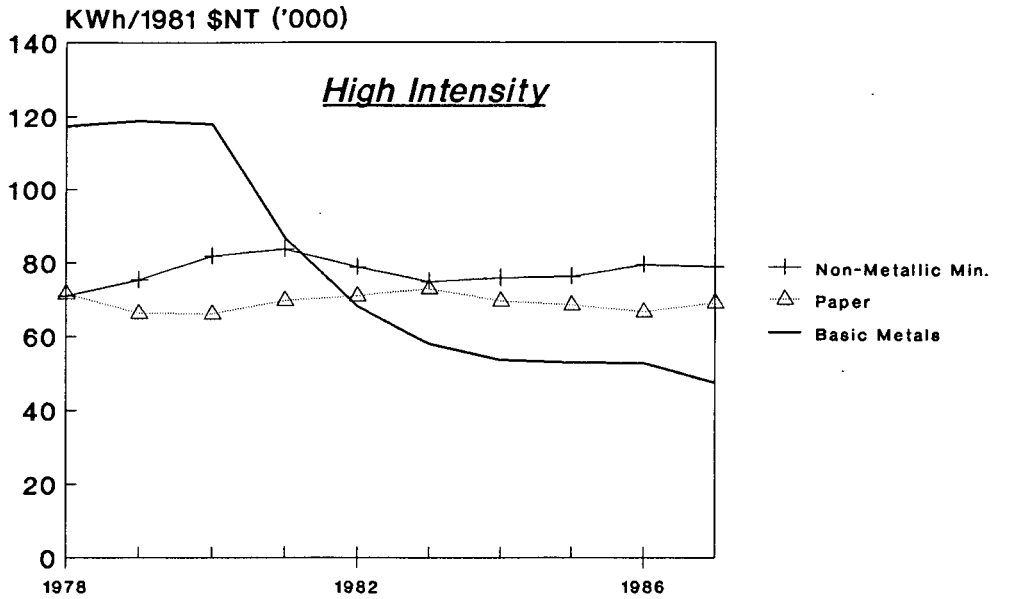

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Figure 2-4a

Electricity Intensities By Mfg Subsector
Taiwan

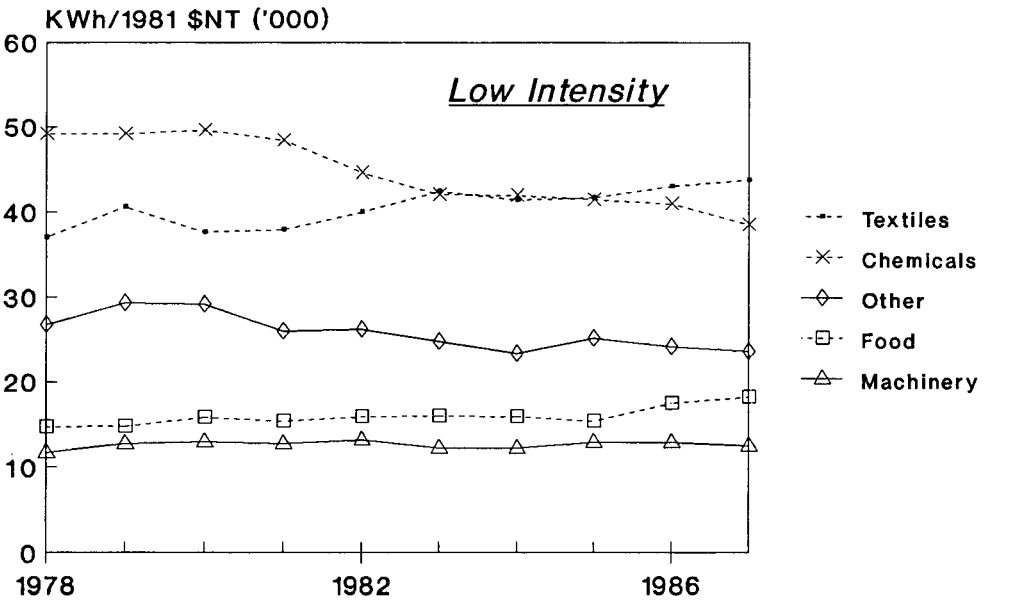

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Figure 2-4b

2.3. Composition of Manufacturing Electricity Consumption

The composition of Taiwan's manufacturing electricity consumption has changed somewhat since the the early 1970s. Relative shares have declined for chemicals, food (slightly), and basic metals, while the shares have increased for metal products and "other" manufacturing (Table 2-2). The share of basic metals actually increased between 1973 and 1980, but has declined substantially since then.

Table 2-2
Composition of Manufacturing Electricity Consumption
Taiwan
(10^9 kWh)

Sub-sector	1973	1980	1987
Food	0.7	1.2	2.0
(%)	7	5	6
Textiles	2.1	4.0	6.4
(%)	18	17	19
Paper	1.1	2.0	2.9
(%)	10	8	9
Chemicals	3.5	6.4	8.9
(%)	31	27	26
Non-metallic minerals	0.9	2.5	2.9
(%)	8	10	9
Basic metals	1.5	4.0	3.1
(%)	13	17	9
Machinery	0.9	1.5	3.4
(%)	8	8	12
Other	0.7	1.5	3.4
(%)	6	6	10
TOTAL	11.4	23.5	33.7
(%)	100	100	100

3. REPUBLIC OF KOREA

Electricity consumption by manufacturing in the Republic of Korea (South Korea) grew at an extremely rapid pace (17% per year) during the 1970s (Figure 3-1). During this period, the government put special emphasis on industrialization of the economy, particularly focusing on expansion of heavy industries such as steel and petro-chemicals. There was much slower increase in the 1980-82 period, which was marked by reduced economic growth due to the second oil shock and the world-wide recession, but growth averaged nearly 11% per year in the 1982-87 period.

Manufacturing electricity intensity — electricity consumption per unit of manufacturing value-added — has fluctuated moderately since 1971. There was a general trend of increase in the 1970s, with a peaking during the recession year of 1980, when value-added grew slower than electricity use. Electricity intensity has declined since then to the same level as in the early 1970s.

3.1. Structural Change

The lack of major change in aggregate electricity intensity obscures the fact that the Korean manufacturing sector in 1987 bore little resemblance to that which existed in the early 1970s. Real output (value-added) increased by seven-fold in this period. The largest changes in the structure of manufacturing are that the share of food declined considerably from 32% to 15% of total manufacturing output and the share of machinery increased greatly from 10% to 36% (Figure 3-2 and Table 3-1). Increase in the share of basic metals in the 1970s was also significant because of the high electricity intensity of this sector. If we group the sectors in a crude fashion, the share of "light" industry (food, textiles, machinery, and other) increased slightly from 61% to 68%, while the share of "heavy" industry declined slightly from 39% to 32%.[1]

[1] See note in Taiwan chapter.

Electricity and Manufacturing
South Korea

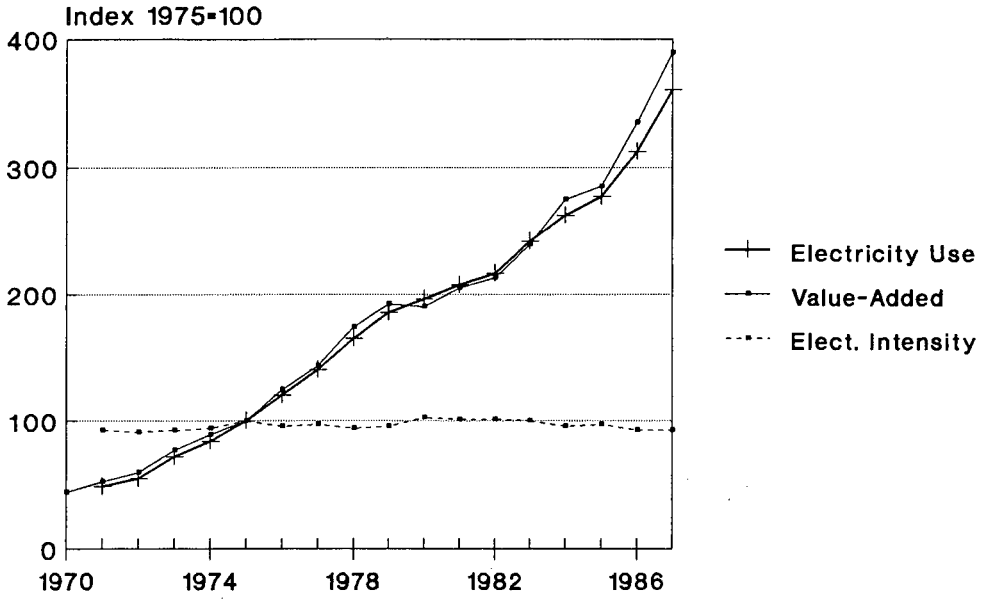

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Figure 3-1

Manufacturing Composition
South Korea

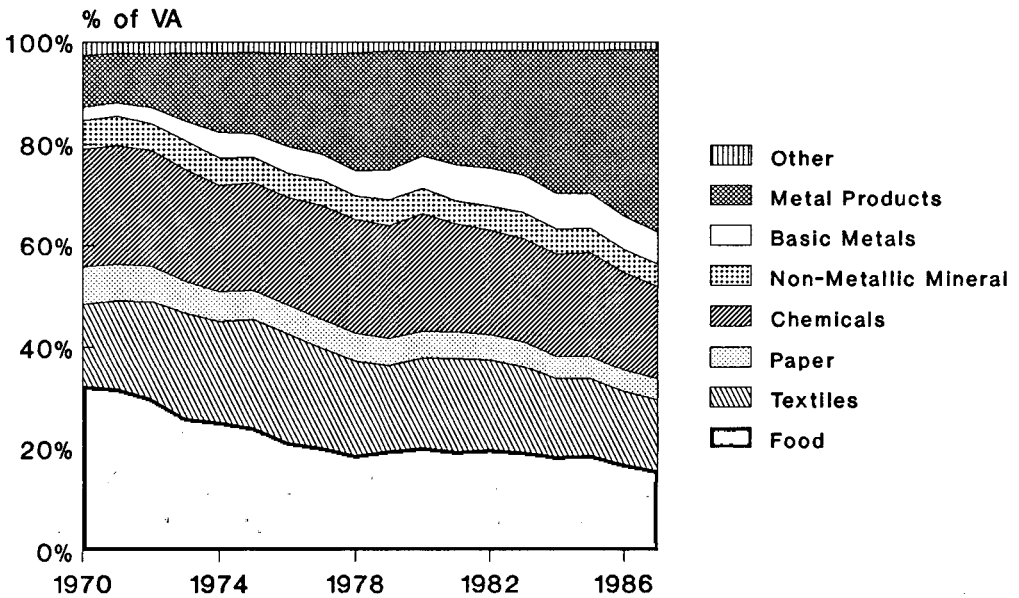

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Figure 3-2

Table 3-1
Value-Added in Manufacturing
Republic of Korea
(10^9 1980 won)

Sub-sector	1971	1979	1987
Food	987	2225	3601
(%)	32	20	16
Textiles	531	1905	3176
(%)	17	17	14
Paper	220	591	969
(%)	7	5	4
Chemicals	734	2511	4141
(%)	24	22	18
Non-metallic minerals	178	583	1003
(%)	6	5	4
Basic metals	84	666	1471
(%)	3	6	6
Metal products	294	2647	8238
(%)	10	23	36
Other	69	211	366
(%)	2	2	2
TOTAL	3097	11340	22964
(%)	100	100	100

3.2. Analysis of Change in Manufacturing Electricity Intensity

In the case of South Korea, there are compatible time-series data on electricity consumption and value-added at the 2-digit ISIC level that allow us to separately analyze the impacts of *(1) structural change* and *(2) change in electricity intensity* at the 2-digit level on aggregate manufacturing electricity intensity. The analysis is based on a Laspeyres index calculation, as described in Appendix 2.

Figure 3-3 shows three indices for aggregate manufacturing electricity intensity: (1) Actual electricity intensity; (2) Electricity intensity if there had been no structural change at the 2-digit level (labelled "Intensity Effect" in the Figure); (3) Electricity intensity if there had been no change in electricity intensity at the 2-digit level (labelled "Structure Effect" in the Figure). The analysis shows that structural change pushed upward on aggregate electricity intensity from 1975 through 1983, but since then it has pushed in the opposite direction. Particularly important in the 1970s was growth in output of basic metals; although it was not large on a percentage basis (from 2.7% of total value-added in 1971 to 7.6% in 1982), it had a substantial effect due to the very high electricity-intensity of this sector.

Manufacturing Electricity Intensity
South Korea

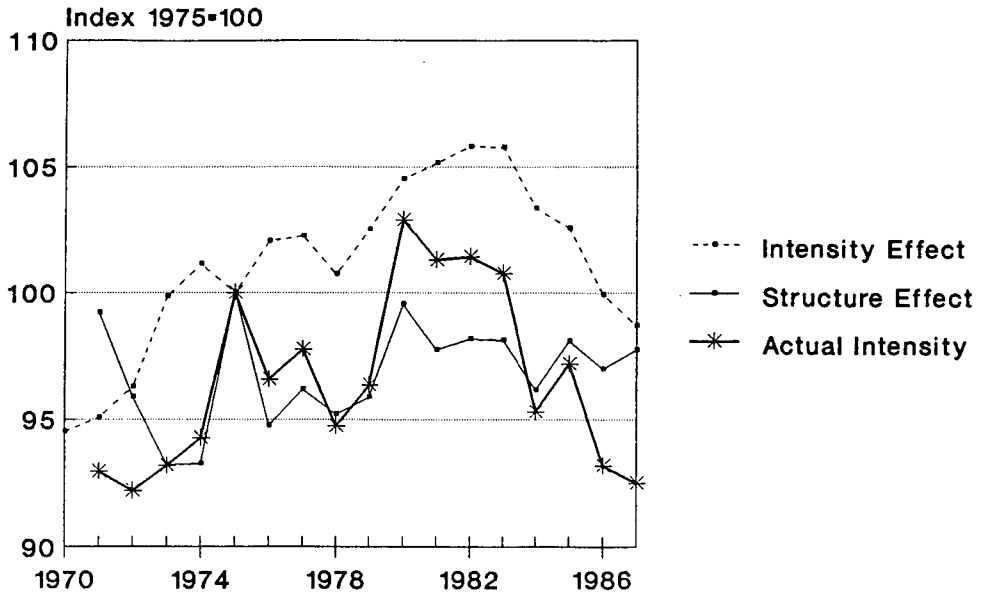

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Figure 3-3

Changes in electricity intensity at the 2-digit level have contributed more strongly than structural change to change in aggregate electricity intensity. This is true of both the increase in aggregate intensity in the 1970s and the decrease since 1983. As shown in Figure 3-4, electricity intensity has **decreased** since the early 1970s in the two most electricity-intensive industries, non-metallic minerals and basic metals. The decline has been most marked in basic metals, especially in the early 1970s when new facilities were being brought into production. There has also been a decline of intensity in chemicals, which is a moderately electricity-intensive industry. Together, the decline in intensity in these industries had a greater effect than the increase in food and metal products, the least electricity-intensive sectors, and textiles, which is a moderately electricity-intensive industry. In the cases of food and textiles, increased mechanization of production probably played an important role in raising intensity. The same may be true in metal products, though in the latter there has been rather large shift in structure at the 3-digit level which has probably affected intensity.

Change in electricity intensity at the 2-digit level may result from structural change *within* the sector, as well as from changes in processes, introduction of new equipment and processes, introduction of new facilities, and energy management. We do not have the information necessary to assess these components.

Rise in the electricity price may have exerted downward pressure on electricity intensity. The real price of electricity for industrial users (measured as average revenues per kWh sold in the "Large Power" category) increased by 50% in 1975 and then rose again by 75% in the 1978-82 period. Since then it has declined slightly. The average price in 1987 was equivalent to $0.06/kWh. Government programs to encourage electricity conservation have probably also had an impact on electricity intensity.

Electricity Intensities By Mfg Subsector
South Korea

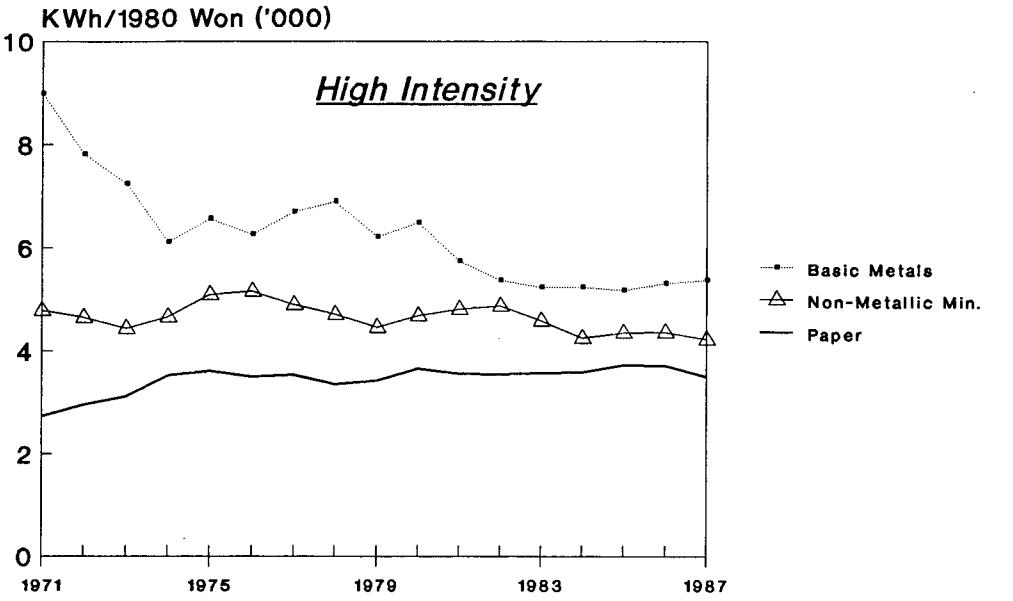

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Figure 3-4a

Electricity Intensities By Mfg Subsector
South Korea

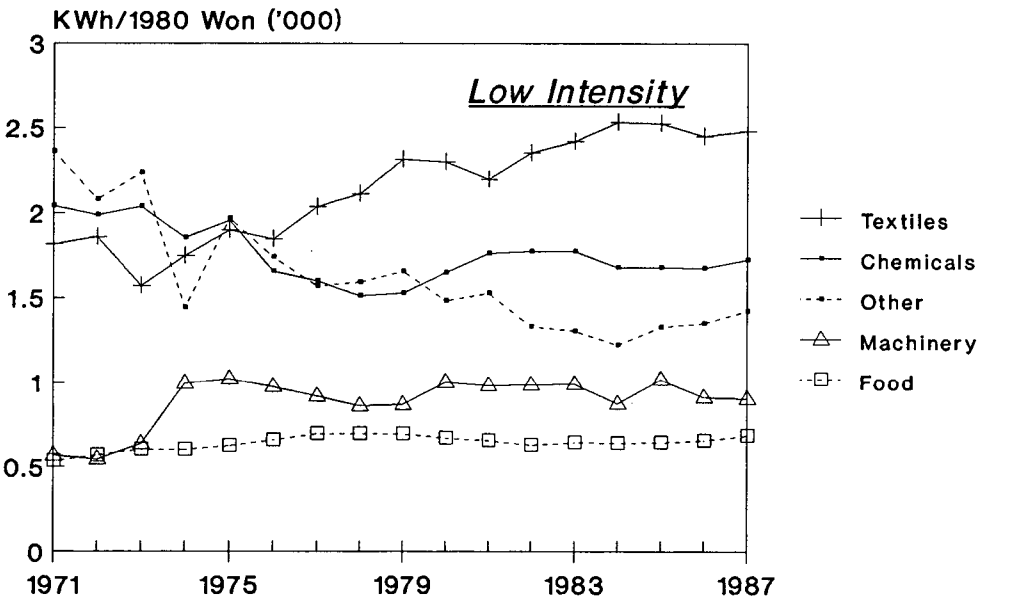

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Figure 3-4b

3.3. Composition of Manufacturing Electricity Consumption

As a result of structural change and change in intensity, the composition of manufacturing electricity consumption has changed since the the early 1970s. Relative shares have declined for food, chemicals, and non-metallic minerals, while the shares have increased for basic metals and metal products (Table 3-2). The share of basic metals actually declined between 1979 and 1987, while that of metal products continued to increase substantially.

Table 3-2
Composition of Manufacturing Electricity Consumption
Republic of Korea
(10^9 kWh)

Sub-sector	1971	1979	1987
Food	0.5	1.6	2.5
(%)	10	7	6
Textiles	1.0	4.4	7.9
(%)	18	21	19
Paper	0.6	1.7	3.1
(%)	11	8	8
Chemicals	1.5	3.8	7.1
(%)	27	18	18
Non-metallic minerals	0.9	2.6	4.2
(%)	16	13	10
Basic metals	0.7	4.1	7.9
(%)	14	20	19
Metal products	0.2	2.3	7.5
(%)	3	11	18
Other	0.1	0.2	0.4
(%)	1	1	1
TOTAL	5.5	20.8	40.5
(%)	100	100	100

4. INDIA

Electricity consumption by manufacturing industry in India has grown rapidly since 1979 (Figure 4-1). (Consumption data nominally include self-generation.) The growth in consumption has been faster than that of value-added, with the result that *manufacturing electricity intensity* has increased by about 15% since 1979. Intensity had increased between 1974 and 1976, and then declined for several years.

4.1. Structural Change

There was relatively little change in the composition of Indian manufacturing value-added between 1970 and 1985 (Figure 4-2 and Table 4-1). The share of chemicals increased somewhat in the 1970s, while the shares of non-metallic minerals and machinery both increased between 1978 and 1985. The share of basic metals decreased over the 1970-1985 period.

Table 4-1
Value-Added in Manufacturing
India
(10^9 1970 rupees)

Sub-sector	1970	1978	1985
Food	7.0	9.8	10.5
(%)	13	12	10
Textiles	12.0	18.7	22.8
(%)	23	24	22
Paper	2.2	2.8	3.3
(%)	4	4	3
Chemicals	6.8	11.8	16.3
(%)	13	15	16
Non-metallic minerals	2.3	3.3	5.8
(%)	4	4	6
Basic metals	4.0	5.5	6.5
(%)	8	7	6
Machinery	10.8	16.7	25.8
(%)	21	21	25
Other	7.2	10.5	11.8
(%)	14	13	11
TOTAL	52.2	79.2	102.8
(%)	100	100	100

Electricity and Manufacturing
India

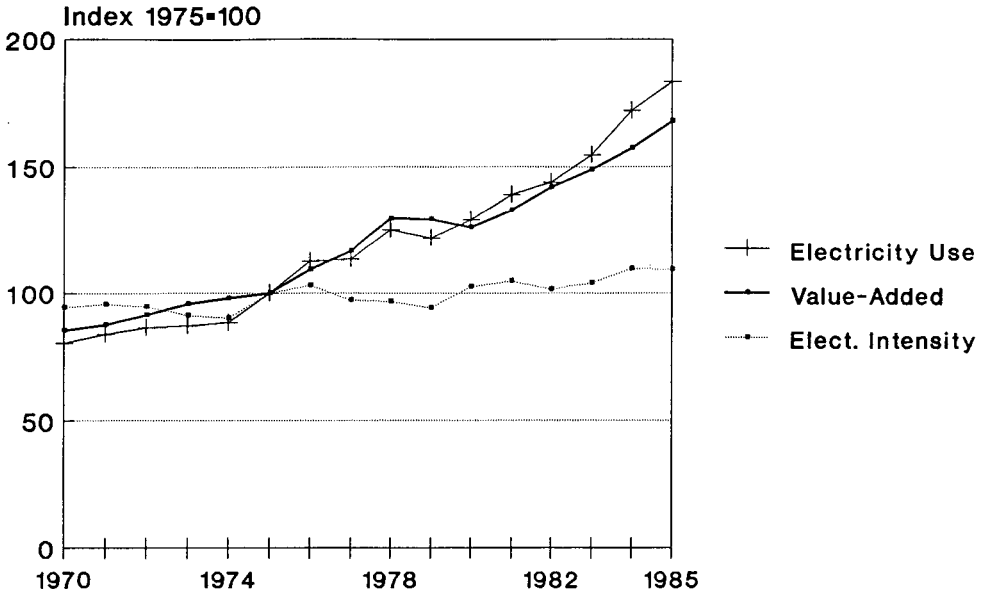

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Figure 4-1

Manufacturing Composition
India

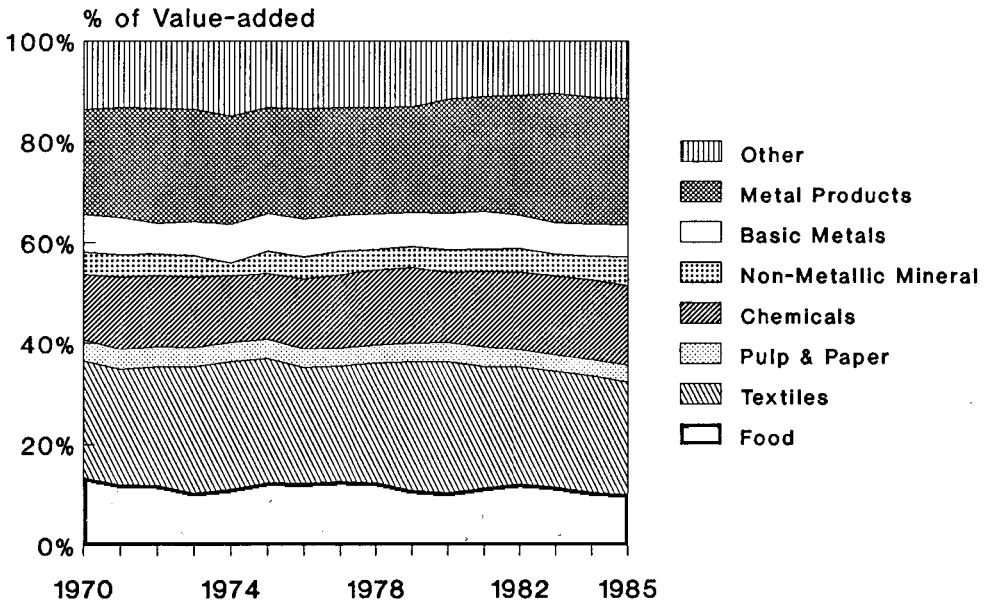

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Figure 4-2

4.2. Analysis of Change in Manufacturing Electricity Intensity

We did not have data on electricity consumption at the 2-digit level for all manufacturing sectors in India, and were thus unable to quantitatively separate the effects of structural change and change in electricity intensity at the 2-digit level on aggregate manufacturing electricity intensity. It would appear that *structural changes* would have had little overall impact. The increase in share of non-metallic minerals could have been balanced by the decline in share of basic metals. The increase in share of metal products, a low intensity sector, was balanced by decline in share of food, also a a low intensity sector.

The data at the 2-digit level show varying trends in *electricity intensity* between 1970 and 1983 (Figure 4-3). They show a decline for basic metals between 1975 and 1980, followed by a sharp increase. For chemicals, there was increase between 1970 and 1975, but gradual decline thereafter. Paper shows a substantial increase in intensity during the period, while textiles remained about the same. (The source did not give data for other sectors.)

The increase in aggregate electricity intensity between 1979 and 1983 may have been primarily caused by the rise in intensity in basic metals and non-metallic minerals. Concerns about the reliability of the 2-digit level consumption data and uncertainty about inclusion of self-generation make us hesitant to draw firm conclusions, however.

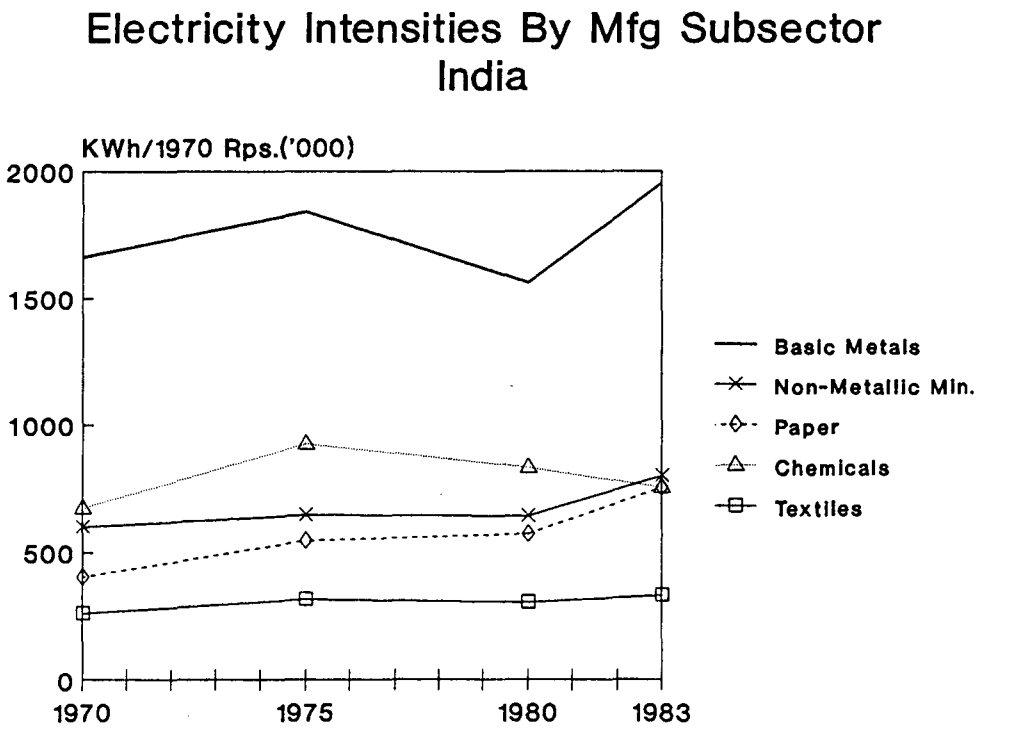

Figure 4-3

4.3. Composition of Manufacturing Electricity Consumption

As a result of structural change and change in intensity, the composition of manufacturing electricity consumption has changed slightly since the early 1970s (Table 4-2). Lack of data precludes us from seeing the whole picture, however, as data on electricity consumption for food and metal products were not presented separately.

Table 4-2
Composition of Manufacturing Electricity Consumption
India
(10^9 kWh)

Sub-sector	1970	1975	1983
Food*			
(%)			
Textiles	3.1	4.8	6.9
(%)	9	11	11
Paper	0.9	1.3	2.1
(%)	3	3	3
Chemicals	4.6	7.4	10.8
(%)	14	17	17
Non-metallic minerals	1.4	1.7	3.1
(%)	4	4	5
Basic metals	6.6	8.5	11.2
(%)	20	20	17
Metal products*			
(%)			
Other	17.1	18.9	31.2
(%)	51	44	48
TOTAL	33.6	42.5	65.4
(%)	100	100	100

* Included in "Other"

5. CHINA

Data on total manufacturing electricity consumption in China were available only from 1980 through 1985. (Consumption data nominally include self-generation.) Growth averaged 5.8% per year in this period, which was much slower than growth of output, with the result that *manufacturing electricity intensity*[1] declined by nearly 25% (Figure 5-1).

5.1. Structural Change

There was relatively little change in the composition of Chinese manufacturing value-added between 1980 and 1985 (Figure 5-2 and Table 5-1). The share of machinery increased somewhat after 1983, while that of basic metals declined.

Table 5-1
Manufacturing Production
China
(Gross output value in 10^9 1980 yuan)

Sub-sector	1980	1985
Food	61	95
(%)	14	12
Textiles	73	127
(%)	17	16
Paper	7	11
(%)	2	1
Chemicals	57	93
(%)	13	12
Non-metallic minerals	20	35
(%)	5	5
Basic metals	47	66
(%)	11	9
Machinery	112	224
(%)	25	29
Other	64	130
(%)	15	17
TOTAL	441	781
(%)	100	100

[1] The measure of output is gross output value (constant prices). Data on value-added were not available.

Electricity and Manufacturing
China

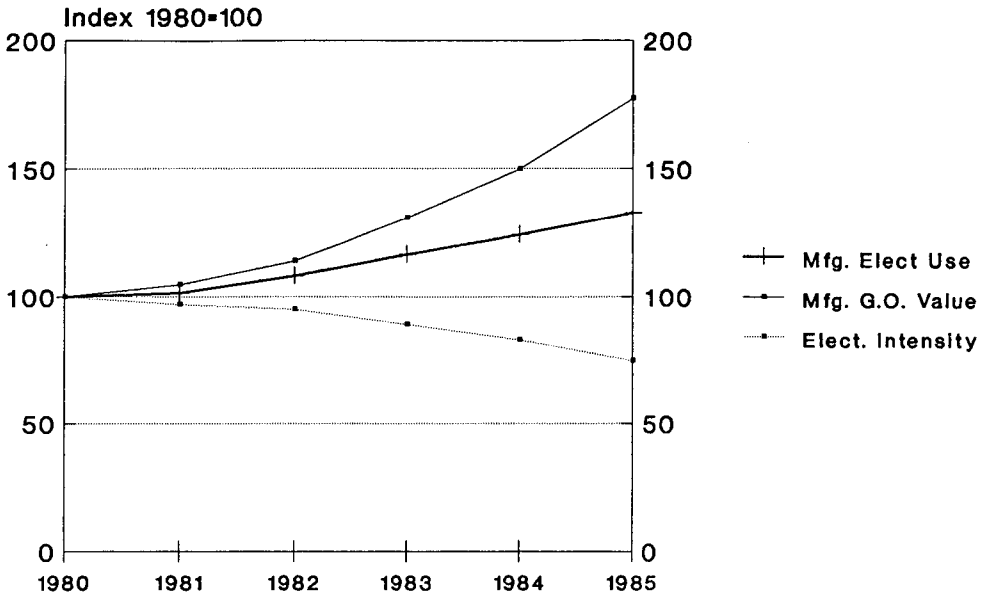

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Figure 5-1

Manufacturing Composition
China

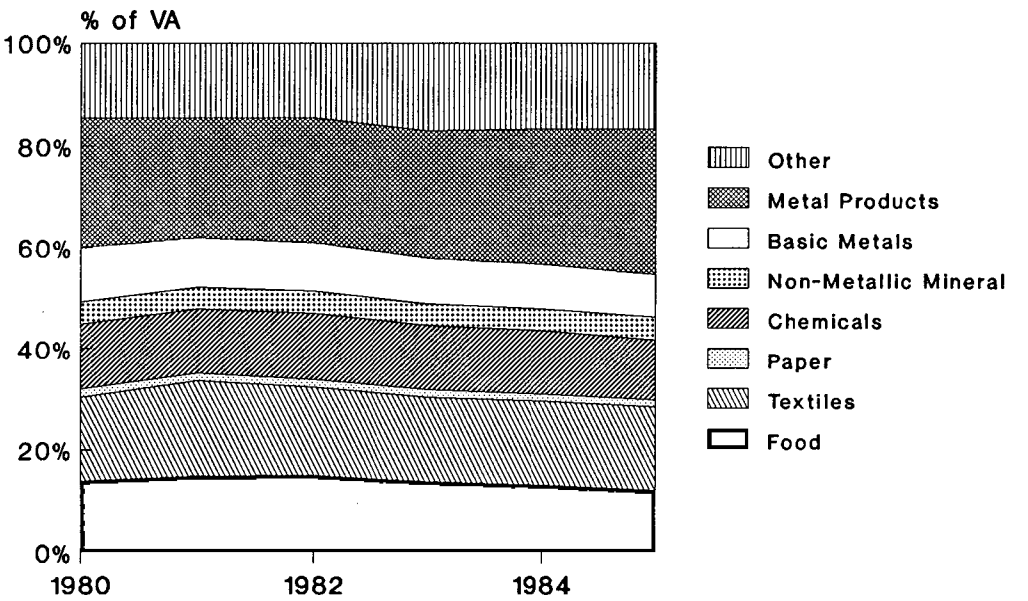

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Figure 5-2

5.2. Analysis of Change in Manufacturing Electricity Intensity

The increase in share of metal products and decline of basic metals contributed to the decline in aggregate manufacturing electricity intensity, but the main cause was change in electricity intensity at the 2-digit level. The data on *electricity intensity* at the 2-digit level show decline in most sectors between 1980 and 1985 (Figure 5-3). The relative decrease was largest for chemicals, and was also considerable for metal products. The declines in intensity at the 2-digit level were due to several factors, including closing of many small, inefficient factories, efforts to conserve electricity, and perhaps structural change within sectors. The efforts to conserve electricity were encouraged by the serious shortage of electricity, which became more severe over the period.

5.3. Composition of Manufacturing Electricity Consumption

Chemicals and basic metals together account for over half of total electricity consumption in manufacturing. As a result of structural change and change in intensity, the composition of manufacturing electricity consumption changed slightly between 1980 and 1985 (Table 5-2).

Table 5-2
Composition of Manufacturing Electricity Consumption
China
(10^9 kWh)

Sub-sector	1980	1985
Food	5.3	9.7
(%)	3	4
Textiles	12.2	18.3
(%)	7	8
Paper	1.9	3.0
(%)	1	1
Chemicals	52.4	61.8
(%)	30	27
Non-metallic minerals	10.8	17.7
(%)	6	8
Basic metals	46.3	59.3
(%)	27	26
Metal products	20.8	28.3
(%)	12	12
Other	21.9	29.4
(%)	13	13
TOTAL	174.8	231.8
(%)	100	100

Electricity Intensities By Mfg Subsector
China

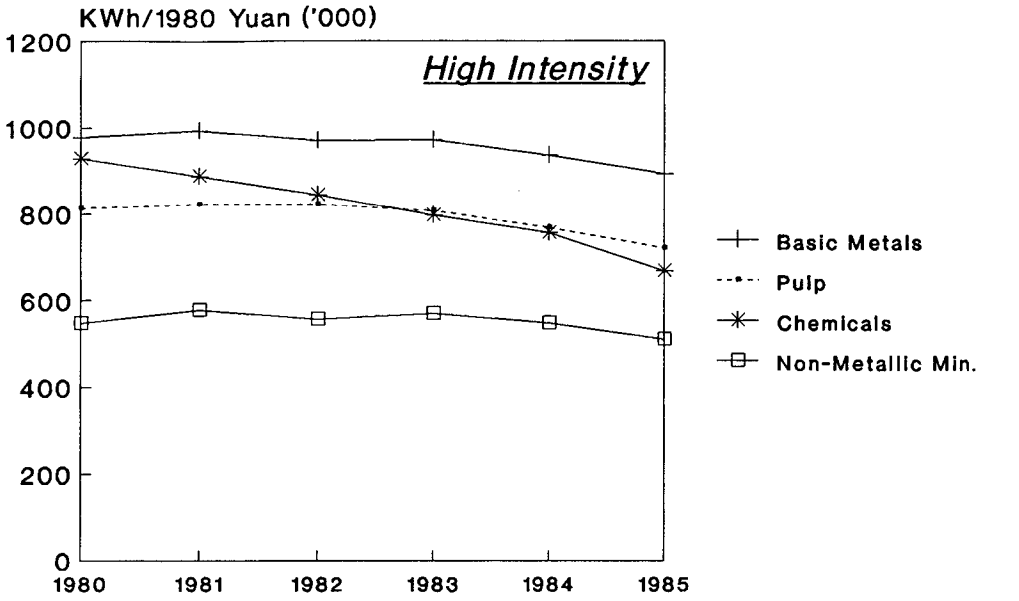

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Figure 5-3a

Electricity Intensities By Mfg Subsector
China

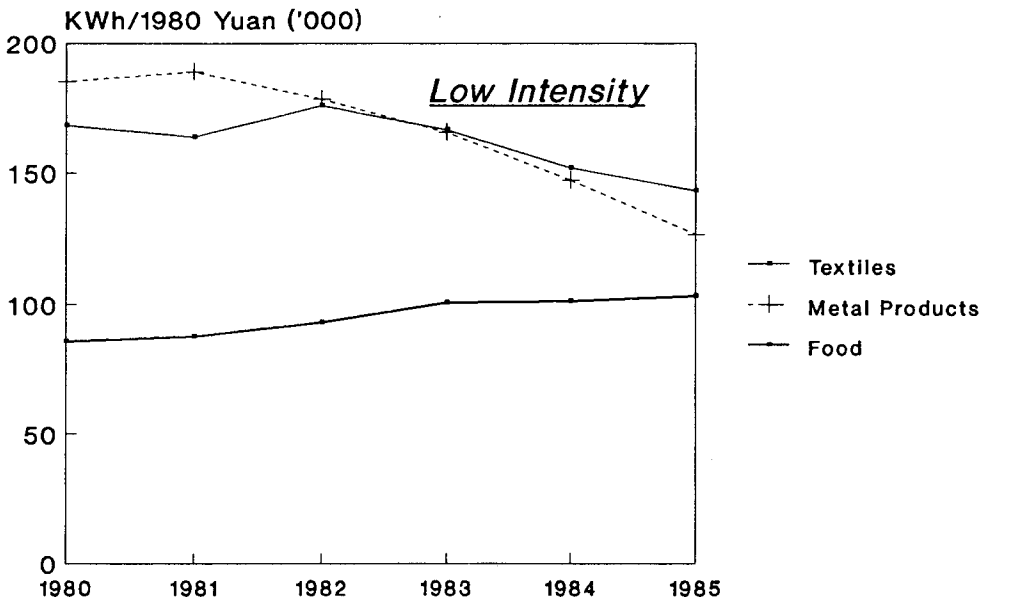

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Figure 5-3a

6. THAILAND

Electricity consumption by industry in Thailand, which is mostly attributable to manufacturing, grew rapidly and steadily between 1970 and 1987 (Figure 6-1). (Consumption data include self-generation.) The increase averaged 11.5% per year. The growth in consumption has been much faster than that of value-added, with the result that *manufacturing electricity intensity* nearly doubled since 1970. There has been steady growth in intensity since 1978.

6.1. Structural Change

Thailand's manufacturing sector has grown substantially since 1970. The large share of food in 1970 indicates the relatively undeveloped state of manufacturing at that time. The main change in the composition of manufacturing value-added between 1970 and 1986 was a large increase in the share of textiles from 15% to 28% (Figure 6-2 and Table 6-1). The share of food declined considerably, while the share of machinery increased slightly.

Table 6-1
Value-Added in Manufacturing
Thailand
(10^9 1972 baht)

Sub-sector	1970	1978	1986
Food	10.2	17.6	23.7
(%)	44	34	29
Textiles	3.5	12.1	22.9
(%)	15	23	28
Paper	0.7	2.1	3.2
(%)	3	4	4
Chemicals	3.3	8.2	12.8
(%)	14	16	15
Non-metallic minerals	1.2	3.2	4.9
(%)	5	6	6
Basic metals	0.4	0.6	0.8
(%)	2	1	1
Machinery	2.5	6.5	9.8
(%)	11	12	12
Other	1.6	2.3	4.5
(%)	7	4	5
TOTAL	23.3	52.5	82.6
(%)	100	100	100

Electricity and Manufacturing
Thailand

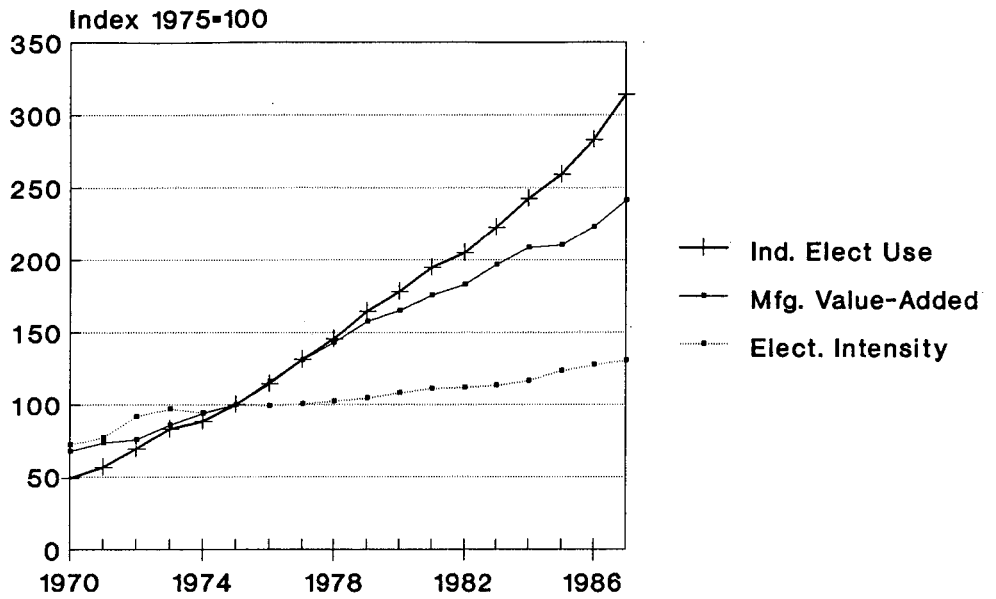

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Figure 6-1

Manufacturing Composition
Thailand

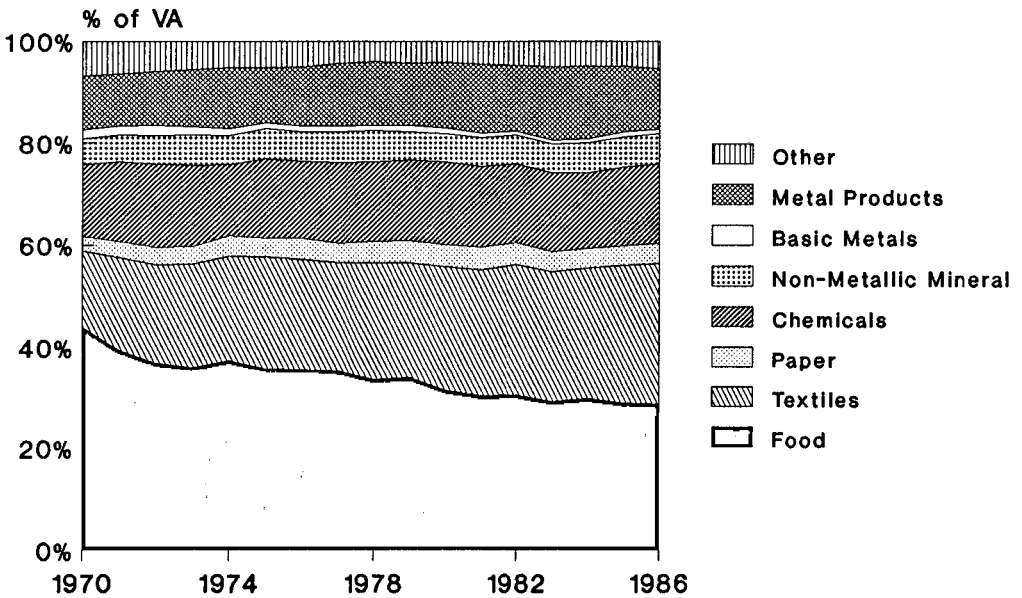

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Figure 6-2

6.2. Analysis of Change in Manufacturing Electricity Intensity

We did not have multi-year data on electricity consumption at the 2-digit level for Thailand, and were thus unable to quantitatively separate the effects of structural change and change in electricity intensity at the 2-digit level on aggregate manufacturing electricity intensity. Speaking qualitatively, it would appear that *structural change* among 2-digit sectors would have pushed modestly upward on aggregate intensity. The main factor is that textiles displaced food in terms of share of value-added; the former is more electricity-intensive than the latter. But it appears that most of the increase in aggregate intensity must have been caused by growth in intensity at the 2-digit level. Mechanization of processes no doubt played a role in increasing intensity, especially in textiles, which increased greatly in share of value-added. It is likely that structural change within 2-digit sectors also contributed to increase in their electricity intensity, but we did not have information to verify this.

6.3. Composition of Manufacturing Electricity Consumption

We did not have multi-year data on electricity consumption by sector in Thailand. Data for 1987 show that textiles and food are the largest consuming sectors.

Table 6-2
Composition of Manufacturing Electricity Consumption, 1987
Thailand

Sub-sector	10^9 kWh	%
Food	2.1	19
Textiles	2.3	21
Paper	0.4	3
Chemicals	1.3	12
Non-metallic minerals	1.4	12
Basic metals	1.0	9
Metal products	0.7	7
Other	1.9	17
TOTAL	11.2	100

7. BRAZIL

Electricity consumption by manufacturing in Brazil grew rapidly in the 1970s, slowed for several years in the early 1980s, and then grew rapidly in the 1984-1986 period (Figure 7-1).[1] The growth in consumption has been faster than that of value-added, with the result that *manufacturing electricity intensity* has nearly doubled since 1975. Intensity increased especially fast during the recession period of 1982-1984.

7.1. Structural Change

We had data on economic output in constant prices (gross output value instead of value-added) from 1970 only through 1980. The shares of chemicals and basic metals increased somewhat during this period, as did the share of metal products (Figure 7-2 and Table 7-1).

Table 7-1
Manufacturing Production
Brazil
(Value of shipments in 10^9 1970 Cr.)

Sub-sector	1970	1980
Food	26.9	49.6
(%)	23	18
Textiles	14.8	23.5
(%)	13	9
Paper	2.8	5.5
(%)	2	2
Chemicals	18.2	49.2
(%)	16	18
Non-metallic minerals	4.9	12.1
(%)	4	4
Basic metals	14.5	37.4
(%)	12	14
Metal products	21.7	67.9
(%)	19	25
Other	12.8	30.5
(%)	11	11
TOTAL	116.6	275.7
(%)	100	100

[1] Consumption data include reported self-generation by industries.

Electricity and Manufacturing
Brazil

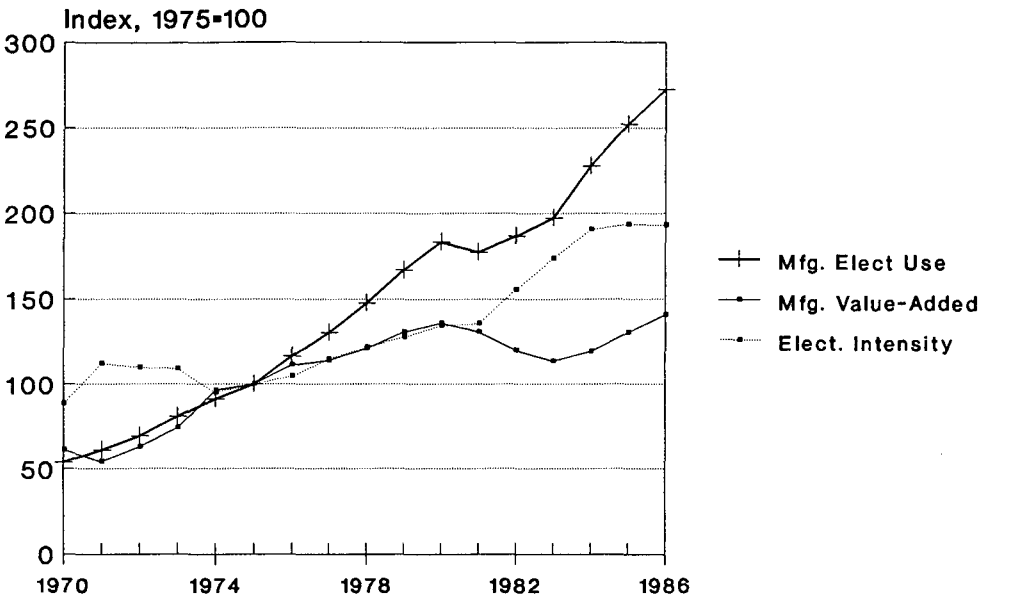

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Figure 7-1

Manufacturing Composition
Brazil

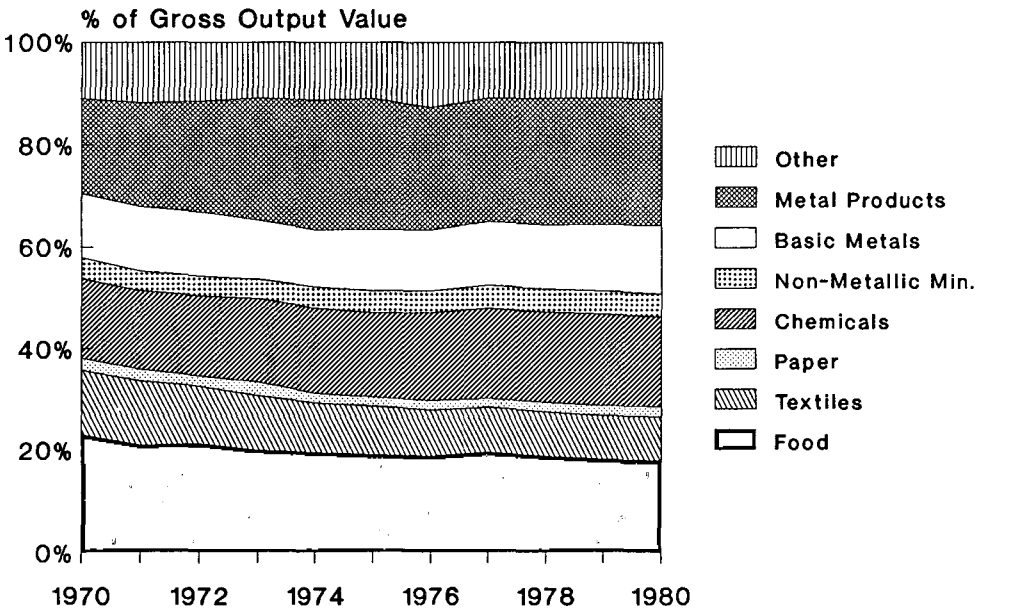

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Figure 7-2

7.2. Analysis of Change in Manufacturing Electricity Intensity

We did not have data on electricity consumption at the 2-digit level for all manufacturing sectors in Brazil. There is also some uncertainty about the match between the data on electricity consumption by sector and the data on economic output. Thus, we are unable to separate out the effects of structural change and change in intensity at the 2-digit level on aggregate manufacturing electricity intensity, and can only speculate on the causes of the growth in intensity after 1980.

Speaking qualitatively, it would appear that the *structural change* described above pushed upward on aggregate manufacturing electricity intensity, but it is clear that increase in *electricity intensity* at the 2-digit level played the major role. The available data show increase in several sectors between 1970 and 1980, with the largest increase occurring in basic metals (Figure 7-3). Much of the increase in sectoral intensities was probably due to substitution of electricity for oil for industrial heating in the years after the 1973 oil price shock. This trend was encouraged by special low electricity prices designed to reduce use of imported oil and provide a market for the large amount of hydro-electricity that was available. Greater mechanization may have also played a role in increasing intensity of food and textiles manufacturing.

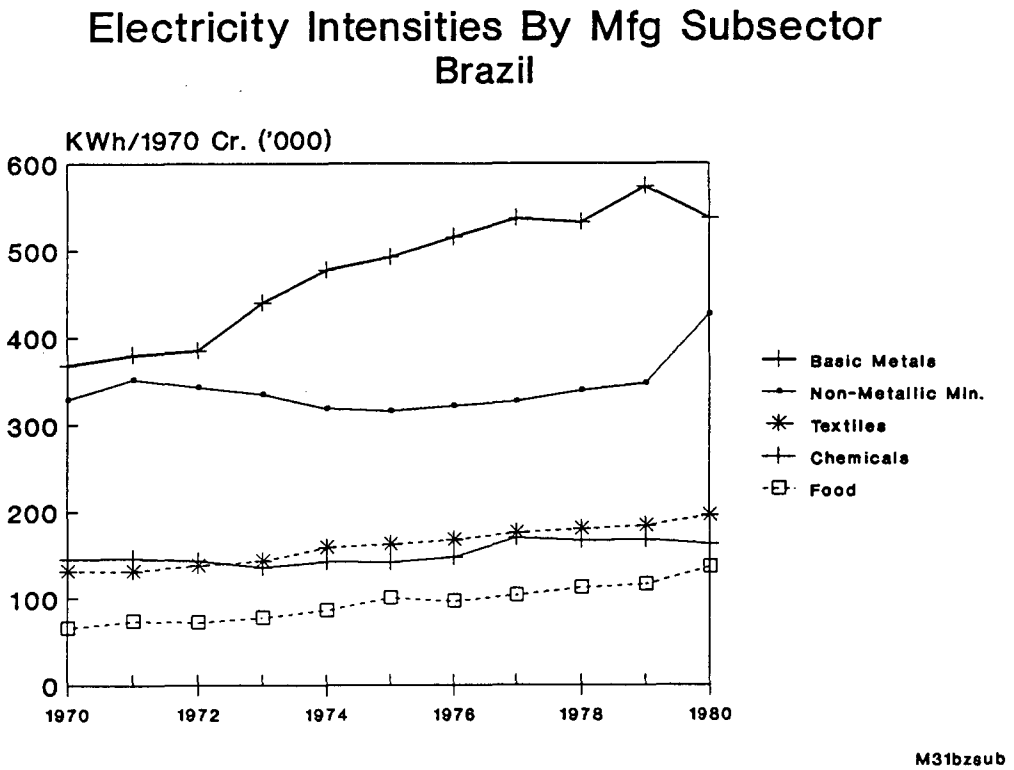

Figure 7-3

7.3. Composition of Manufacturing Electricity Consumption

As a result of structural change and change in intensity, the composition of manufacturing electricity consumption has changed somewhat since the the early 1970s (Table 7-2). The main change was the substantial growth in the share of basic metals. This growth was the result of both increase in the sector's output and its electricity intensity.

Table 7-2
Composition of Manufacturing Electricity Consumption*
Brazil
(10^9 kWh)

Sub-sector	1970	1979	1987
Food	5.8	18.3	32.1
(%)	9	9	10
Textiles	6.6	13.6	18.8
(%)	11	7	6
Paper	5.5	15.0	23.0
(%)	9	8	7
Chemicals	8.9	26.3	42.1
(%)	14	14	13
Non-metallic minerals	5.3	13.3	23.3
(%)	8	7	7
Basic metals	18.0	64.3	118.0
(%)	29	33	37
Metal products**			
(%)			
Other	11.9	42.9	60.1
(%)	19	22	19
TOTAL	62.0	193.6	317.4
(%)	100	100	100

* Includes self-generation.
** Included in Other.

8. ARGENTINA, MEXICO, AND VENEZUELA

We did not have data on total electricity consumption by manufacturing or by manufacturing sectors for Argentina, Mexico, and Venezuela. Thus, our analysis of the trend in electricity intensity is limited. We had historic data on total *industrial* electricity consumption, which is mostly attributable to manufacturing, and economic data on sectoral output (though not for a lengthy period in the case of Mexico), which together allow for a rough interpretation of the trend in intensity.

8.1. Argentina

Electricity consumption by industry in Argentina grew considerably between 1970 and 1986 despite there being no net growth in manufacturing value-added between 1974 and 1986 (Figure 8-1).[1] (Consumption data include self-generation.) While consumption did respond somewhat to declines in output in 1978, 1980-1981, and 1985, overall it grew much faster than value-added, with the result that *industrial electricity intensity* increased by 50% between 1974 and 1986. There was especially strong growth in intensity in the recession period of 1981-82, though intensity declined with the rebound of production in 1983.

The data on sectoral output show very little *structural change* in manufacturing in the 1970-1985 period (Figure 8-2 and Table 8-1). One might expect that the recessionary periods would have affected some sectors more than others, but the data do not show such a development.

[1] The high level of inflation in Argentina makes it difficult to create a reliable constant-price series for manufacturing value-added, but the trend is probably roughly accurate. There could be under-reporting of production in some areas during periods of economic difficulty.

Electricity and Manufacturing
Argentina

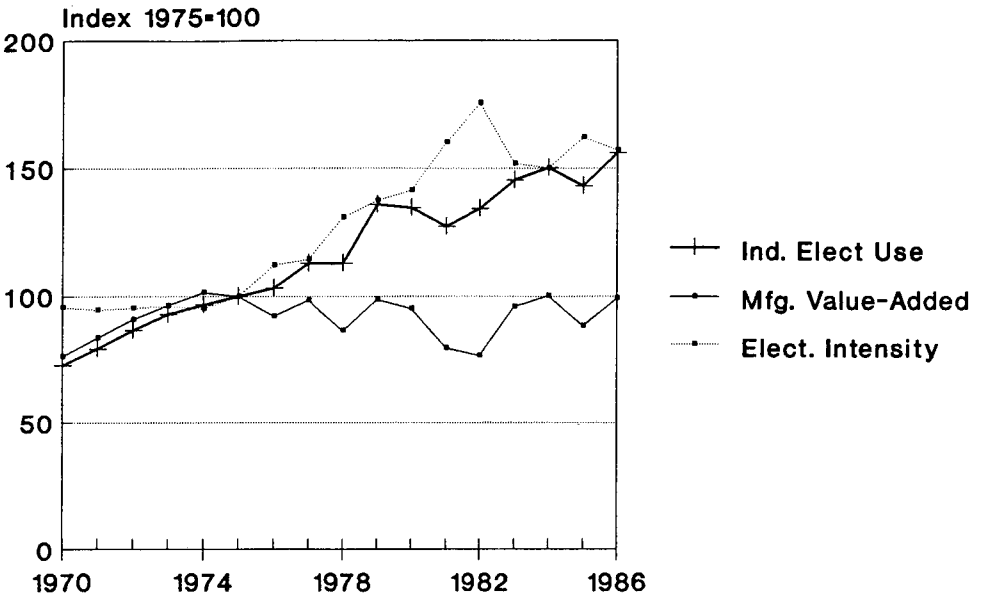

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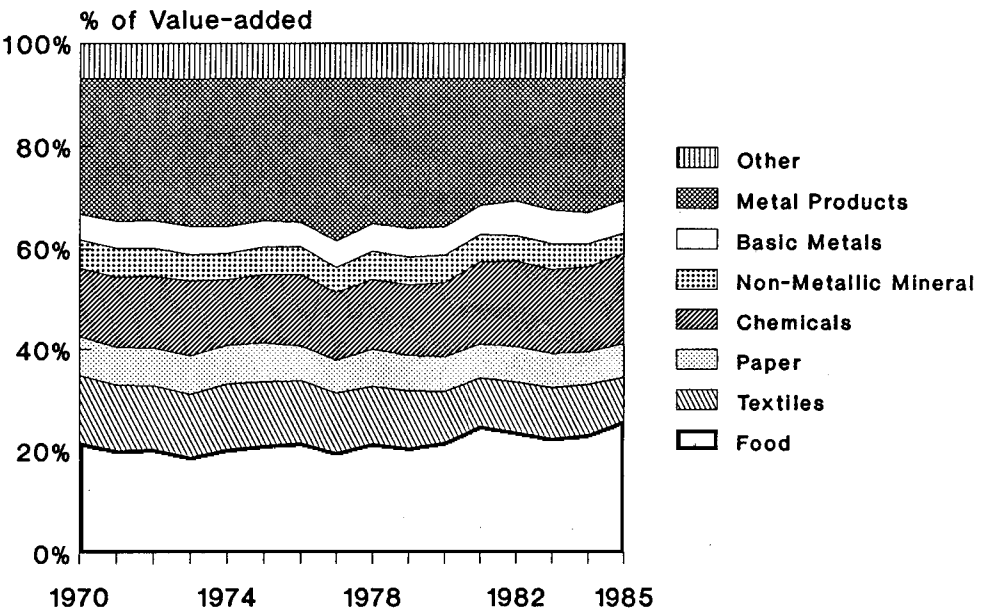
Figure 8-1

Manufacturing Composition
Argentina



m08arman

Figure 8-2

Table 8-1
Value-Added in Manufacturing
Argentina
(10^9 1980 australes)

Sub-sector	1970	1978	1985
Food	455	500	528
(%)	22	22	26
Textiles	277	261	174
(%)	13	11	9
Paper	163	170	136
(%)	8	7	7
Chemicals	285	322	365
(%)	14	14	18
Non-metallic minerals	118	129	80
(%)	6	6	4
Basic metals	105	127	131
(%)	5	5	6
Metal products	553	655	484
(%)	26	28	24
Other	145	161	141
(%)	7	7	7
TOTAL	2099	2325	2038
(%)	100	100	100

Modest growth in the shares of chemicals and basic metals between 1978 and 1985 probably contributed somewhat to increase in aggregate intensity. Assuming the economic data are accurate, however, one is drawn to conclude that the growth in aggregate electricity intensity was mainly due to *increase in electricity intensity at the 2-digit level.* The stagnation of the economy has limited new capital investment, and has probably resulted in lack of proper maintenance of equipment as well. These factors may have contributed to growth in intensity. The increase in intensity during recessionary periods is partly attributable to certain electrical uses being relatively fixed (i.e., not sensitive to changes in production). This is particularly the case for heavy industries. For variable uses, low levels of production may lead to operation of equipment at low capacity, which tends to decrease operating efficiency.

8.2. Mexico

Electricity consumption by industry in Mexico grew steadily at an average rate of 7.9% per year between 1970 and 1987 (Figure 8-3). (Consumption data include self-generation.) Growth in consumption roughly paralleled that of manufacturing value-added between 1970 and 1981, and there was thus little increase in *industrial electricity intensity*. Value-added began a period of stagnation in 1982, but electricity consumption continued to grow, averaging 5.7% per year increase in the 1981-1987 period.

The data on sectoral output only cover the period 1976-1983, and thus do not shed much light on the increase in intensity in the 1980s. In any case, there was little structural change in this period, though there was some growth in the share of chemicals (Figure 8-4 and Table 8-2).

Table 8-2
Value-Added in Manufacturing
Mexico
(10^9 1970 pesos)

Sub-sector	1976	1983
Food	39	54
(%)	25	27
Textiles	20	25
(%)	13	12
Paper	8	11
(%)	5	5
Chemicals	37	56
(%)	24	28
Non-metallic minerals	6	6
(%)	4	3
Basic metals	15	17
(%)	10	8
Metal products	25	28
(%)	16	14
Other	6	7
(%)	4	3
TOTAL	156	203
(%)	100	100

The lack of economic data after 1983 makes it difficult to interpret the trend in manufacturing electricity intensity in the 1980s, but it is likely that some of the factors discussed for Argentina also played a role in increasing intensity during Mexico's period of stagnation in production. Structural change within 2-digit sectors may also have been a factor.

Electricity and Manufacturing
Mexico

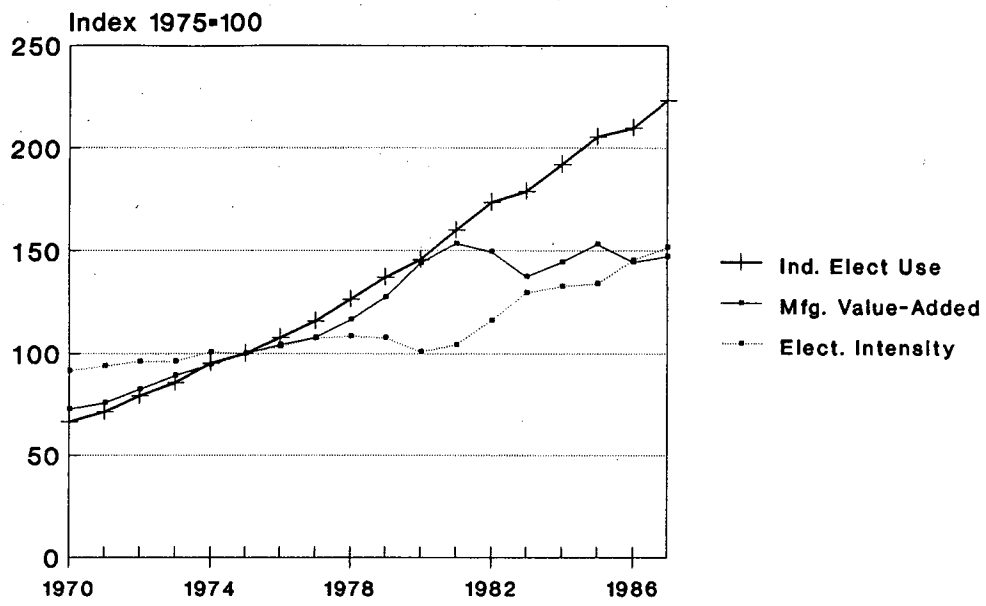


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Figure 8-3

Manufacturing Composition
Mexico

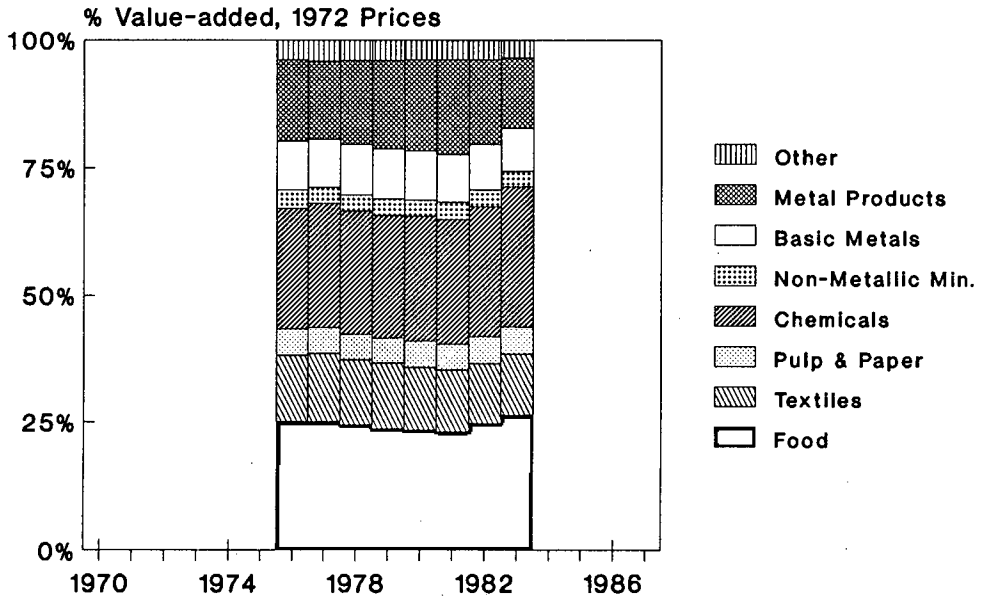

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Figure 8-4

8.3. Venezuela

Electricity consumption by industry in Venezuela grew at a moderate pace between 1970 and 1978, and then increased enormously with the expansion of aluminum and steel production (Figure 8-5). There was a decline in 1981-1982, followed by further rapid growth in 1983-1984. (Consumption data include self-generation.) Growth in consumption roughly matched that in value-added between 1970 and 1978, so that *industrial electricity intensity* increased little. In the 1978-1984 period, however, manufacturing value-added grew only modestly, but industrial electricity intensity increased substantially in 1979-1980 and again in 1983-1984.

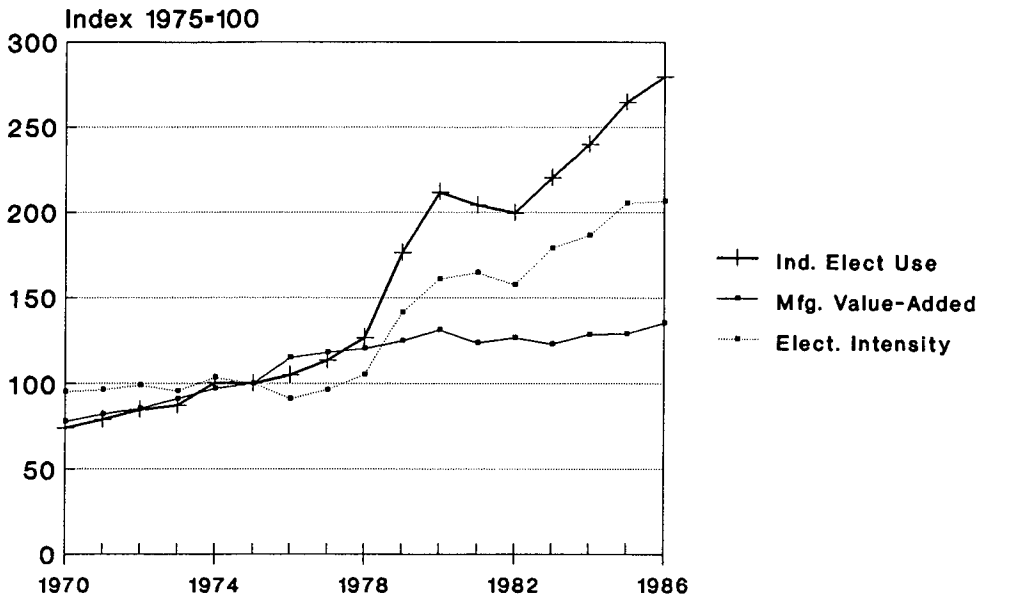
The data on sectoral output show significant *structural change* in manufacturing in the 1970-1986 period (Figure 8-6 and Table 8-3). The most significant in terms of electricity use was the considerable increase in the share of basic metals from 5% in 1970 to 11% in 1986. There was also growth in the share of metal products, and some decline in the share of chemicals.

Table 8-3
Value-Added in Manufacturing
Venezuela
(10^9 1968 bolivares)

Sub-sector	1970	1978	1986
Food	2.3	4.2	5.1
(%)	28	33	33
Textiles	0.8	1.0	1.1
(%)	10	8	7
Paper	0.5	0.7	0.9
(%)	6	5	6
Chemicals	2.8	3.2	3.6
(%)	34	25	24
Non-metallic minerals	0.4	0.7	0.7
(%)	5	5	5
Basic metals	0.4	0.8	1.7
(%)	5	6	11
Metal products	0.8	2.0	1.9
(%)	10	16	12
Other	0.2	0.3	0.2
(%)	2	2	1
TOTAL	8.3	12.9	15.3
(%)	100	100	100

It is difficult to estimate how much of the enormous increase in aggregate manufacturing electricity intensity was due to structural change, but it seems likely that the substantial growth in share of basic metals in general and aluminum in particular accounted for a good portion of the increase. This is evident in the jump in intensity in the 1979-1980 period, when production of aluminum and steel grew considerably.

Electricity and Manufacturing
Venezuela



m24vnel

Figure 8-5

Manufacturing Composition
Venezuela

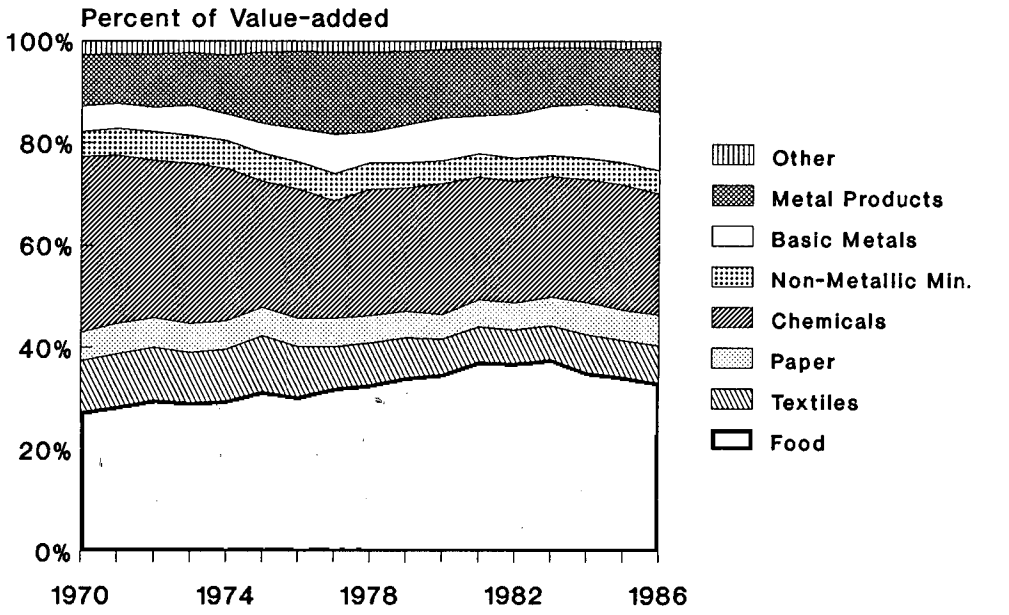


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Figure 8-6

9. COMPARING ELECTRICITY INTENSITY AMONG COUNTRIES

Comparing the electricity intensity of manufacturing among countries is somewhat problematic due to: (1) Possible differences among countries in accounting for manufacturing value-added; and (2) The need to convert local currencies to a common unit, which typically entails using exchange rates and therefore introduces a source of uncertainty. In addition, uncertainty regarding inclusion of self-production of electricity in consumption data, or reliability of such data where they are included, are also factors.

Despite the above problems, it is clear that aggregate manufacturing electricity intensity differs considerably among countries. A comparison of aggregate manufacturing electricity use per unit of value-added (converted to U.S. dollars using 1985 average exchange rates) shows that intensity in the mid-1980s varied by more than a factor of two among six countries (Table 9-1). China and India, both of whom have relatively old equipment in their industries, are at the top of the range, while South Korea and Taiwan, both of whom have relatively new equipment, are at the low end.[1]

Table 9-1
Aggregate Manufacturing Electricity Intensity and Industrial Electricity Price, 1985

	kWh/1985 US$	US cents/kWh
China	2.2	0.8
India*	2.0	5-7
Brazil	1.6	1.5
Thailand**	1.2	6.1
S. Korea	1.2	6.7
Taiwan	0.9	6-7

* Refers to 1983.
** Refers to 1986.

With the exception of India, there is a clear correlation between electricity intensity and the average price of electricity to industry.[2] The countries with lower intensity all have relatively high price of electricity, while China and Brazil have relatively low price of electricity and high

[1] Self-production is reportedly included in the consumption data for China and India. We are uncertain whether it is included in the other cases. Since there is considerable self-production in China and India due to the unreliability of the power system, this could be partly responsible for the higher ranking of these countries.

[2] The prices given in Table 9-1 represent the approximate average amount paid by industrial customers per kWh purchased, inclusive of demand charges. Actual prices faced by customers vary considerably depending on the size of the user's demand. For India and Taiwan, we have used partial data to estimate a range in which the average price likely falls.

intensity. For reasons that are unclear, India has both high intensity and relatively high electricity price. The low price of electricity in China and Brazil, along with the presence of indigenous raw materials, has encouraged production of electricity-intensive commodities. It has apparently encouraged inefficient production as well (more in China than in Brazil), though factors other than price also play a role.

As should be clear at this point, however, differences in *aggregate* manufacturing electricity intensity are due in part to differences in the composition of the manufacturing sector. For example, China and India both have a higher share of heavier industries which are inherently more electricity-intensive than do Taiwan and South Korea. To gain a better sense of the relative efficiency of manufacturing, it is thus preferable to compare intensity among 2-digit sectors. Here too it may be the case that differences in sectoral composition influence intensity (particularly in basic metals), but the comparability among countries is greater.

We are able to compare 2-digit sector electricity intensity in the mid-1980s, expressed in terms of electricity use per unit of value-added, for four countries.[3] Without data on the composition of the sectors in each country, the results are somewhat difficult to interpret, but several observations can be made. In most sectors, there is a fairly wide range in intensity (Table 9-2). The chief exception to this is non-metallic minerals, where the values are all rather close.

The relative ranking of countries varies among sectors. In the least electricity-intensive sectors, food and metal products, Thailand has the highest intensity (though data for India are missing). South Korea is lowest in food, while Taiwan is lowest in metal products. In textiles, Taiwan and South Korea are very close, and higher than India or Thailand. This may be due in part to greater mechanization of production in these more-developed countries. In chemicals, India has much higher intensity than the other countries; this may be due to the composition of the sector as well as low efficiency of production. The greatest range in intensity is seen in basic metals, which is the most electricity-intensive sector. This is to be expected, since the electricity intensity of this sector is most sensitive to the mix of products (especially the share of aluminum production in value-added) and the type of processes used. Here, Thailand and India are both much higher than South Korea and Taiwan. Higher reliance on older equipment and less-advanced processes may be partly responsible for this result.

[3] The data that we had on economic output at the 2-digit level for China and Brazil are expressed in terms of *gross output value* as opposed to value-added. Thus, it would be improper to use these data in the comparison.

Table 9-2
Electricity Intensity in Manufacturing Sectors
(kWh per US$ value-added)

	Taiwan 1985	S. Korea 1985	Thailand 1986	India 1983
Food	0.57	0.41	0.80	NA
Textiles	1.55	1.59	0.89	1.21
Paper	2.56	2.06	1.01	2.78
Chemicals	1.55	1.06	0.91	2.74
Non-metallic minerals	2.84	2.73	2.50	2.91
Basic metals	1.97	3.25	11.8	7.08
Metal products	0.48	0.64	0.67	NA

One interesting result of our somewhat limited comparison is that it is more difficult than expected to make a generalization across countries as to particular industries having high or low electricity intensity. Food and metal products are definitely of low intensity, and basic metals is high (except in Taiwan). Non-metallic minerals is also relatively high, as is paper. Textiles and chemicals occupy a middle range. However, the relative ranking of industries varies among countries, suggesting different composition within the sectors.

10. COMPARING CHANGE IN ELECTRICITY AND FUEL INTENSITY

One would expect that electricity intensity and fuel intensity in manufacturing industries would have followed different paths since the early 1970s. There are two primary reasons for this: (1) There was substantial increase in the price of oil products, the main fuel used by manufacturing industries; and (2) Growing mechanization of production would tend to increase electricity intensity but not fuel intensity.

Time-series data on fuel consumption at the 2-digit level are lacking for most of the countries that we examined. Even where they are reported, such data are likely to be less reliable than data on electricity consumption. However, we are able to shed light on the above hypothesis in the case of three countries: Taiwan, South Korea, and Brazil. The latter is a somewhat unusual case because there was considerable substitution of electricity for oil for heating purposes.

Comparison of the trends in electricity intensity and fuel intensity for 2-digit industries shows that, in most cases, electricity intensity increased, while fuel intensity decreased, sometimes very substantially (Table 10-1). (Note that the periods covered are different for each country. The net change shown — which refers to the percentage change of the last year from the first year — obscures fluctuations during the period covered.) The divergence between the trends for electricity intensity and fuel intensity was especially marked in the lighter industries: food, textiles, and metal products. In these industries, electricity intensity increased substantially in most cases, while fuel intensity declined considerably. These are industries where greater mechanization probably played an important role in increasing electricity intensity, while higher oil prices encouraged conservation.

In the heavier industries, the relationship between electricity and fuel intensity is less clear. In non-metallic minerals, electricity intensity increased or declined modestly, while fuel intensity decreased in all cases. In chemicals, there was not a great deal of difference between the net changes in electricity and fuel intensity. In basic metals, the changes in intensity were dominated by structural change within the sector, and there is no common pattern among the three countries.

For all of manufacturing, fuel intensity declined more than electricity intensity in Taiwan and South Korea, while it increased less than electricity intensity in the case of Brazil (in part due to substitution). Interpretation of the data at this aggregated level is complicated by structural change, however.

Table 10-1
Net Change in Electricity and Fuel Intensity
(Percent)

	Taiwan	S. Korea	Brazil
Food			
Electricity	+24	+32	+100
Fuels	-34	-52	-37
Textiles			
Electricity	+18	+37	+49
Fuels	-26	-61	-23
Paper			
Electricity	-3	NA	+59
Fuels	-33	NA	+60
Chemicals			
Electricity	-21	-16	+12
Fuels	-15	-28	+21
Non-metallic minerals			
Electricity	+11	-12	+30
Fuels	-10	-32	-41
Basic metals			
Electricity	-59	+6*	+46
Fuels	-15	+10*	+6
Metal products			
Electricity	+7	+65	NA
Fuels	-23	-83	NA
Total manufacturing**			
Electricity	-17	-7*	+44
Fuels	-29	-29*	+11
Period covered	1978-87	1971-87	1970-80

* Period is 1975-87 due to missing data.
** Includes Other industries.

11. SUMMARY AND CONCLUSIONS

11.1. Change in Manufacturing Electricity Intensity

The trend since 1975 in aggregate manufacturing electricity intensity has differed considerably among the countries studied. There have been large *increases* in intensity in Thailand, Brazil, Argentina, Mexico, and Venezuela, large *decreases* in Taiwan and China, and little net change in South Korea and India (Table 11-1). It is interesting to note that the three countries that experienced net decline in electricity intensity all had very fast growth in manufacturing value-added, while the Latin American countries had slow growth in value-added and considerable increase in intensity. This is not surprising, since faster growth in manufacturing industry brings with it greater penetration of new, more modern factories, processes, and equipment. A more stagnant economic situation encourages continued reliance on existing factories and equipment, and in some cases, inefficient use of equipment. Of course, the degree of change in the composition of the manufacturing sector has also varied among the countries, though in general it has not been as great as one might expect.

Table 11-1
Net Change in Aggregate Manufacturing Electricity Intensity

	% Change	Avg. Growth Manuf. V.A. (%/year)	Period
Taiwan	-25%	10.8	1975-87
South Korea	-7%	12.0	1975-87
India	+3%	5.1	1975-83
China	-25%	12.1	1980-85
Thailand*	+35%	7.6	1975-87
Brazil	+93%	3.2	1975-86
Argentina*	+55%	0.0	1975-86
Mexico*	+50%	3.3	1975-87
Venezuela*	+105%	3.4	1975-86

* Electricity use is for total industry.

Interpretation of the trends is hampered by lack of data in most cases, but it is clear that the factors shaping change have differed among countries. Surprisingly, perhaps, the evidence suggests that even in these developing countries, many of which had rapid growth in manufacturing industry, the effect of structural change on aggregate electricity intensity in manufacturing was much less important than the effect of change in intensity at the 2-digit level. An exception to this is Venezuela, where there was considerable increase in the share of basic metals. In some cases, structural change apparently worked to modestly increase aggregate intensity

(e.g.,Thailand, Brazil). In the case of South Korea, structural change worked to increase aggregate intensity from 1975 through 1983, but to decrease it thereafter.

Change in intensity at the 2-digit level can result from many factors, including structural change *within* each sector. In the case of Taiwan, for example, structural change within the basic metals sector — decline in the role of aluminum production — was apparently responsible for much of the decline in intensity. Decline in the intensity of basic metals was also a key factor in South Korea.

We did not have data or sufficient information about the manufacturing sub-sectors in all countries studied to analyze the causes of change in intensity at the 2-digit level. In several of the countries, there was increase in the electricity intensity of food and textiles production. Growing mechanization has probably been a factor shaping this trend. Change in the manufacturing processes used may have played a role in heavy industries. Introduction of new factories incorporating more efficient equipment and/or processes, or closing of old factories with inefficient equipment and/or processes, have undoubtedly been a factor in many industries. Efforts whose primary purpose was to conserve electricity have probably played a relatively minor role, though this judgment is largely conjecture.

Even in countries with stagnant or declining manufacturing output, there has been a large increase in electricity intensity at the 2-digit level (in Argentina, Brazil, and Mexico). Possible causes of this include the presence of uses that are relatively insensitive to the level of production, deteriorating capital stock and inadequate maintenance during periods of economic stress, and use of equipment at low capacity, resulting in low efficiency.

11.2. Comparing Electricity Intensity Among Countries

The relative electricity efficiency of manufacturing among countries is difficult to gauge with precision. A comparison of aggregate manufacturing electricity use per unit of value-added (converted to U.S. dollars) shows that intensity in the mid-1980s varied by more than a factor of two among six countries. China and India, both of whom have relatively old equipment in their industries, are at the top of the range, while South Korea and Taiwan, both of whom have relatively new equipment, are at the low end. With the exception of India, there is a clear correlation between electricity intensity and the average price of electricity to industry. The countries with lower intensity all have relatively high price of electricity, while China and Brazil have relatively low price of electricity and high intensity.

Since differences in aggregate manufacturing electricity intensity are due in part to differences in the composition of the manufacturing sector, comparison of intensity among 2-digit sectors gives a better sense of the relative efficiency of countries (though here too differences in sectoral composition may influence intensity). Our comparison for four countries shows a considerable range in intensity for most sectors.

11.3. The Need for More Analysis

Change in manufacturing electricity intensity is shaped by many factors. This study — limited as it was by lack of data — sheds some light on manufacturing energy use in developing countries, but perhaps raises more questions than it answers. At the very least, we hopefully have made clear why aggregate change in *intensity* should not be construed as change in *efficiency*, defining the latter in a more technical manner. Thus, the aggregate intensity of electricity use in manufacturing is at best a rough indicator of the energy efficiency of this sector.

With sufficient data (as in the cases of Taiwan and South Korea), it is possible to separate the effects of structural change and change in intensity at the 2-digit level. The same type of analysis could be applied to analyze change in intensity within 2-digit sectors. The insights gained through such an analysis would be of great utility in improving forecasts of electricity consumption in the manufacturing sector, and in estimating the potential effect of programs to improve end-use efficiency. More in-depth analysis into the differences among countries in electricity intensity of 2-digit manufacturing sectors, and of the role played by electricity prices, would also provide a better gauge of the relative efficiency of national industries, and give energy planners a better sense of the potential for improving efficiency.

Appendix 1
Data Sources and Notes

Republic of China (Taiwan)

Electricity consumption. Taiwan Energy Statistics 1987.

Manufacturing value-added. Data on total value-added for manufacturing in 1980 NT$ are from the ADB Key Indicators. Value-added at the 2-digit level was approximated using production indices, as given from 1978 on in *Statistical Yearbook of the Republic of China 1988.* In some cases, the production index at the 2-digit level was estimated from 3-digit indices using weights.

Republic of Korea (South Korea)

Electricity consumption. Yearbook of Energy Statistics 1989.

Manufacturing value-added. Korea Energy Economics Institute.

India

Electricity consumption. Data are from mimeo table from Central Electricity Authority. Total manufacturing electricity use was estimated by subtracting electricity consumption by coal mines from total industrial electricity consumption. The data nominally include self-generation. Electricity consumption by coal mines was interpolated for missing years.

Manufacturing value-added. UN National Accounts Statistics.

China

Electricity consumption. Data for most sectors are from: Wang Qinyi, *Energy in China,* Metallurgical Industry Publishing House, 1988. Data on "Other" consumption for 1980, 1984, and 1985 are the sum of petroleum, forest, clothing, leather, printing, and other, from the *China Statistical Yearbook 1987.* (It was clear that these data were not included in the sectors given by Wang.) "Other" consumption was estimated for 1981-1983. There are some differences between Wang and the *China Statistical Yearbook 1987.*

Manufacturing value-added. Data were available only for gross output value. Data for most sectors are from the above source. Data on total gross output value in 1980 constant prices for 1983-1985 are from the *China Statistical Yearbook 1986.* We had to estimate values for 1980-1982 because the value given in the *China Statistical Yearbook 1986* for 1980 was in 1970 prices. We derived output in "Other" manufacturing by subtracting sectoral totals in Wang from total output value.

Thailand

Electricity consumption. Data for total industrial consumption and sub-sectoral consumption for 1987 are from "Electric Power in Thailand 1987."

Manufacturing value-added. UN National Accounts Statistics.

Brazil

Electricity consumption. National Energy Balance report (1988). "Other" includes metal products.

Manufacturing value-added. Data on production (value of shipments) are from "Anuario Estatistico 1980."

Argentina

Electricity consumption. Data on total industrial electricity consumption are from various national sources.

Manufacturing value-added. Argentine Central Bank.

Mexico

Electricity consumption. Data on total industrial electricity consumption are from Pemex.

Manufacturing value-added. Total: Mexican National Accounts Statistics. By sub-sector for 1976-1983: UN National Accounts Statistics.

Venezuela

Electricity consumption. Data on total industrial electricity consumption are from various national sources.

Manufacturing value-added. UN National Accounts Statistics.

Appendix 2

Decomposition of Structure and Intensity Effects on Aggregate Manufacturing Electricity Intensity

The decomposition of structure and intensity effects on aggregate manufacturing electricity intensity is based on a Laspeyres index calculation. The index depicting the Intensity Effect holds industrial structure constant at 1975 values and illustrates the changes that would have taken place in electricity intensity if the structure of manufacturing output had not changed. This index compares the current (year i) electricity intensity using 1975 subsector output share weights, with 1975 aggregate intensity. The calculation formula is:

$$\text{for each year i, sector j} \quad \frac{\sum_{j=1}^{7} E_{ij}\left[\frac{VA_j75}{VA_{tot75}}\right]}{U_{tot75}/VA_{tot75}}$$

where E_{ij} is subsectoral electricity intensity for subsector j in year i, VA_j is value-added for subsector j, VA_{tot} is total manufacturing value-added, and U_{tot} is total manufacturing electricity consumption.

The index of Structure Effect is calculated analogously, holding electricity intensity weightings for each subsector at 1975 levels and comparing current subsectoral output shares at 1975 intensities with the 1975 aggregate intensity. The calculation formula is:

$$\frac{\sum_{j=1}^{7} E_{j75}\left[\frac{VA_{ij}}{VA_{toti}}\right]}{U_{tot75}/VA_{tot75}}$$

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