THE RELATIONSHIP BETWEEN ELECTRICITY AND ECONOMIC ACTIVITY, AND THE SATURATION LEVEL OF THE ELECTRICITY SHARE IN THE SECONDARY ENERGY USAGE

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April 1990

Submitted to the University of Cape Town in fulfilment of the requirements for the degree of Master of Science in Engineering

I, Kung-Yuan Lin, submit this thesis in fulfilment of the requirements for the degree of Master of Science in Engineering, I claim that this is my original work and that it has not been submitted in this or any other form for a degree at any University.

Signed by candidate _____

ACKNOWLEDGEMENTS

I wish to express my gratitude to Prof R K Dutkiewicz for his supervision and advice, and to my wife, Chin Lu, for her encouragement.

The assistance of the Energy Committee of the Ministry of Economic Affairs of the Republic of China and the University of Cape Town is kindly acknowledged.

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CHAPTER 1. INTRODUCTION

1.1 Introduction

The consumption of electric power is pervasive in the lives of all of us. Electricity heats and cools homes, offices and factories. Electricity helps preserve and prepare food. It powers office machinery, and in manufacturing establishments provides energy to utilize the capital stock. In some processes electricity is a direct input into the production process. The electric energy consumption of the world is continuing to grow and is influenced by a myriad of interrelated factors, as illustrated in Figure 1-1.

Economic growth, usually as measured by Gross Domestic Production(GDP), has been closely associated with increasing electricity use(Figure 1-2). Statistically, the correlation between electricity and GDP has been quite high. Other trends which link aggregate economic activity and electricity have also been relatively stable. However, aggregate economic activity operates through many paths to affect the use of electricity.

The aggregate relationship is the net result of a complex web of forces. A full understanding of the linkages is important because their impact on electricity growth may be changeable in many ways that may make conclusions from the aggregate relationships misleading. This understanding of the complexities can improve forecasting and planning in the ways that superficially straightforward aggregate relationships can not.

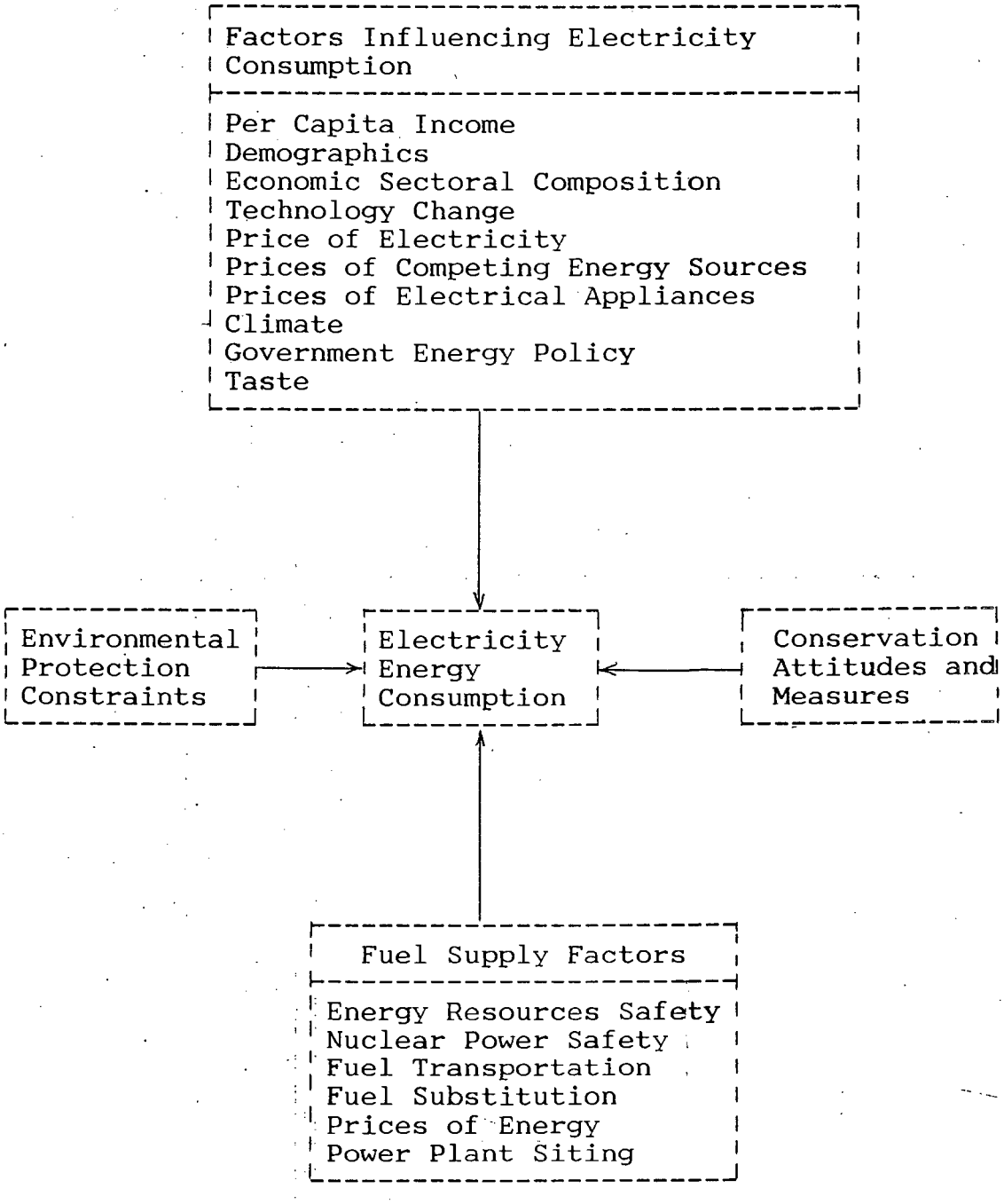
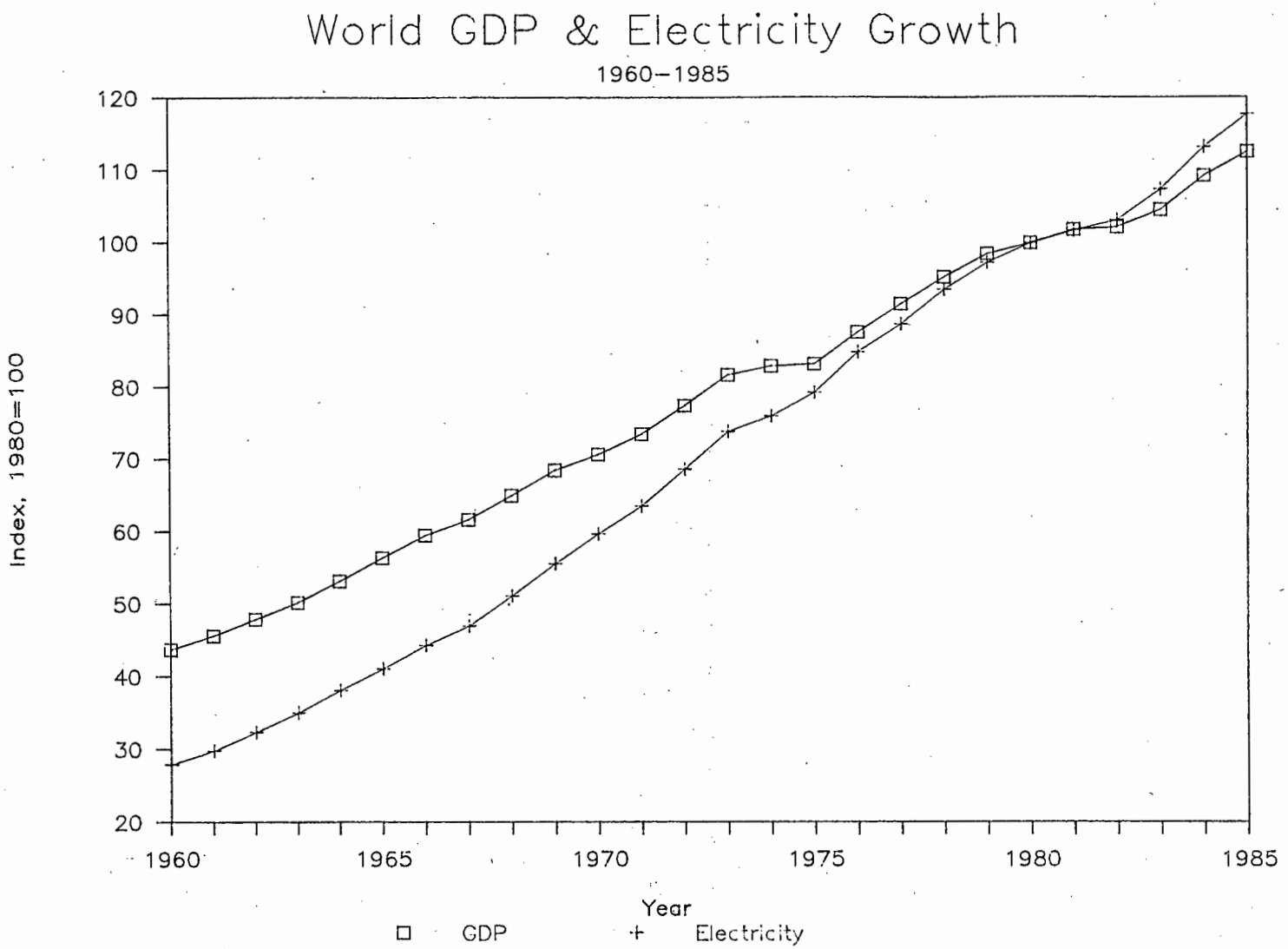


Figure 1-1. Interrelated Factors Influencing Electricity Consumption



Source: Ref.[1]-[5].

Figure 1-2. The Growths of World Electricity Consumption and Gross Domestic production.

1.2. Objectives of the Study

In this study an attempt is made to examine the historical relationships between electricity consumption and economic activity for various countries and at the aggregate level. The economic activity affects electricity use but GDP can offer only a partial explanation. Other factors, including price, do matter. But, as will be discussed, those other factors themselves are often not independent of the level of economic activity. Also, the causal paths linking electricity and GDP work in both directions. This study will focus on the effects of economic activity on electricity, and try to establish a relationship model.

The development of electric energy generation in most countries has registered a considerable growth during the past years. In the years before the oil crises, annual growth rates of electricity consumption were very high, since they corresponded to the intensive industrial development of most countries, but later the rates decreased considerably, due to the economic recession created by the oil crises.

It is expected that the increased penetration of electricity in the total final energy usage will be asymptotic to a saturated level, and the trend will be along an S shape curve, i.e., the growth is initially slow, then increases and finally flattens out to an asymptote or final value. The value to which this curve would be asymptotic would vary from country to country

depending on the economic sectoral mix and the alternative sources of energy and their price, Dutkiewicz[6] has highlighted this for South Africa.

Another contribution of the study is that an attempt is made to estimate the saturation levels of the share of electricity of the total final energy for the selected countries, and to discuss their differences between countries and the reliability of these estimations.

1.3. The Scope and Limitations of the Study

The countries to be selected and compared in this study differ fundamentally in their economic structures. According to 1985 per capita incomes (for data restriction, 1985 is chosen as base year; and for comparing with other studies, 1985 per capita income is converted to 1980 US dollars), the selected countries which include the United States(USA), the United Kingdom(UK), West Germany(Germany), Japan, Republic of China(Taiwan), South Korea(Korea), Singapore, India, and the Philippines, etc, are divided into three groups: high-income countries, whose per capita income excesses 7000 1980 US dollars; middle-income countries, whose per capita income is between 7000 and 1000 1980 US dollars; and low-income countries, whose per capita income is below 1000 1980 US dollars. In this study the high-income countries are also designated as developed countries, and middle-income and low-income countries as developing countries. Table 1-1 shows the per capita income in these selected countries in 1985.

Table 1-1. Per Capita Income in the Selected Countries in 1985

(1980 US dollars)

High-income Countries	United States	12,788
	United kingdom	10,284
	Germany	14,209
	Japan	10,626
Middle-income Countries	Taiwan	2,866
	South Korea	2,184
	Singapore	6,138
Low-income Countries	India	282
	The Philippines	629

Source: Ref.[1],[9].

This study employs the national accounting measure of gross domestic product(GDP) rather than gross national product (GNP). For most countries, the difference between the two indicators is quantitatively minor, but GDP has the scope of covering only a nation's domestic activity, excluding net factor income originating in overseas enterprises and investments, and is the more appropriate national accounts measure for a nation's domestic energy consumption.

To convert GDP to US dollars, the standard method is to use market exchange rates. This reflects the size and power of the economy in terms of the world market. However, market exchange rates can be misleading when a comparison is made of standards of living or changes in production within each economy. A much more appropriate method use in this study is to adjust the market exchange rate by a factor which corrects for the true local purchasing power of each currency - the purchasing power parity

adjustment(ppp).

A cross-country study of the relationships of energy-output and electricity-output always faces the problem of how to make the data for these countries consistent and compatible; as some of the energy sources are transformed before they are consumed, while others are consumed directly, the various forms of energy are used in a great variety of ways and with a wide range of efficiencies. Many aspects of the problem have already been discussed by Darmstadter, Teitelbaum, and Polach[7] as well as B.W.Ang[8].

To overcome this measuring problem, one can measure energy consumption in terms of useful energy requirements. This is possible only if detailed energy consumption data, both by sources and by end-uses, and end-use efficiencies are available. However, for some developed and most developing countries detailed data on end-uses and end-use efficiencies are not available.

In many developing countries, such as the Philippines, India, and most of African countries, non-commercial fuels form a significant portion of their total energy use. Reliable data on non-commercial energy use are generally not available. These fuels are used with very low efficiencies compared to commercial fuels. Their inclusion in total energy consumption greatly alters the energy-output relationship.

There also exists the problem of measuring the thermal equivalent of hydro and nuclear electricity in a comparative

study. The different conventions can make a considerable difference to the total energy consumption for countries with high contributions of hydro and nuclear electricity generation such as Canada and France. To avoid such problems, comparisons of energy usages in this study are basically in terms of primary energy and electricity consumption accounting for intercountry variations is expressed in kilowatt hours(kWh).

1.4. Outline of the Study

The subject of Chapter 2 is the specification of the development of energy consumption(including the changes of intensity), sectoral energy usages and the final fuel share pattern on each of the selected countries. Since economic growth has been associated with increasing electricity use, the electricity-economy activity relationship analysis carried out for this study is described in Chapter 3. The same chapter covers the establishment of an econometric model of electricity consumption whose principal variables are GDP, primary energy consumption, and time lagged coefficients for grouping of the countries.

The proportion of the total final energy used in a nation to generate electricity is an important issue for national energy planning. Methods for estimating the saturation levels of the electricity share of the total final energy for the selected countries will be presented in Chapter 4, and the result of these saturated levels will be discussed in the same chapter.

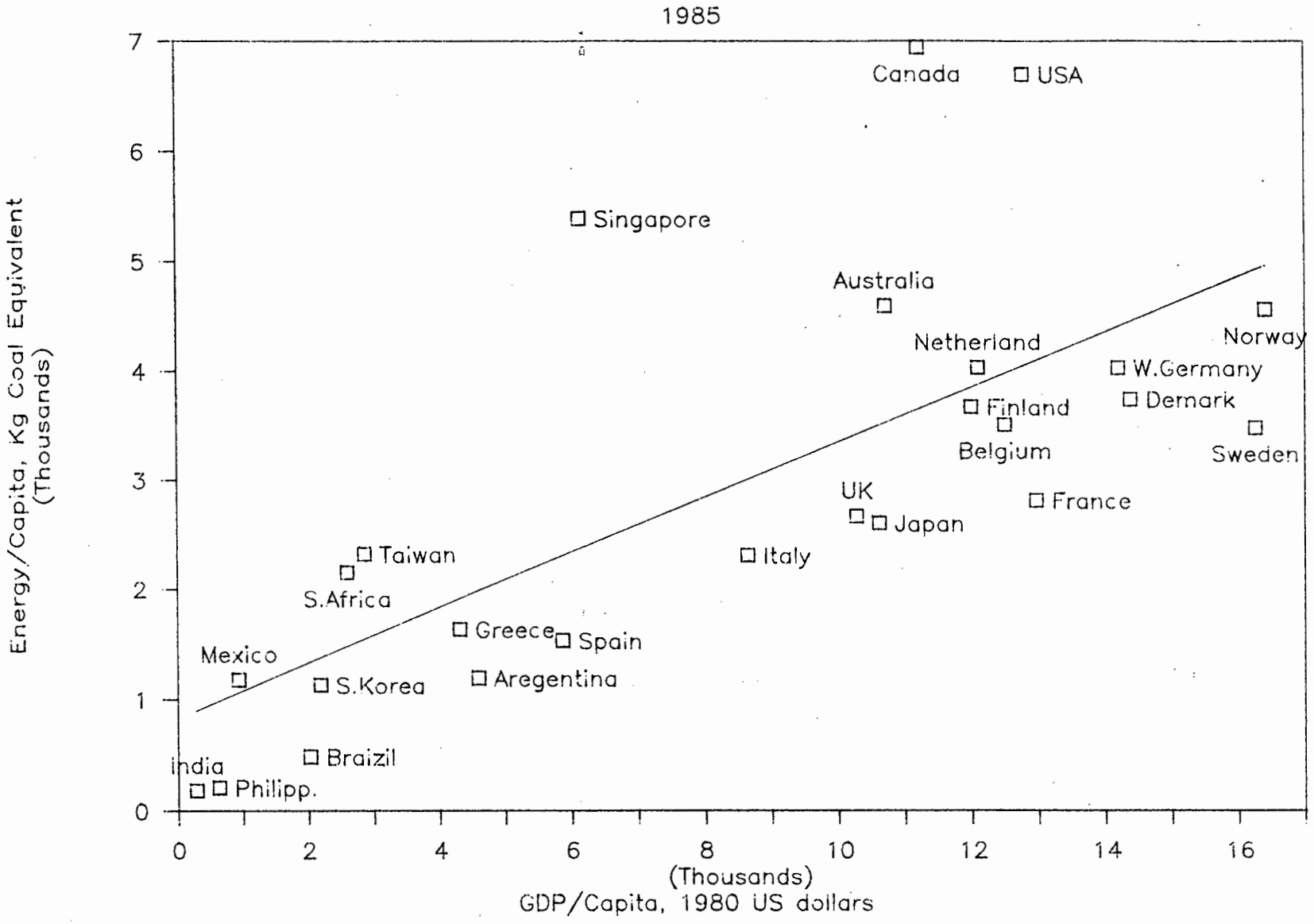
Chapter 5 summarizes the conclusions. References and

CHAPTER 2. ENERGY AND ECONOMY

2.1. Introduction

The significance of the contribution to civilization of heat, light, and power -- and, hence, of the primary energy resources upon which heat, light, and power are based -- is undeniable. Even though primary sources of energy(i.e., coal, oil, natural gas, falling water)play an obviously necessary and strategic role in promoting and sustaining economic progress, their inability to achieve that goal without the mobilization of a great many other resources should be equally clear. Availability of cheap and abundant energy within a nation's border is no more a guarantee of successful development than is its absence a bar to progress. Thus, many countries rich in petroleum resources rank low on the international scale when measured by income; while others -- Denmark, for example, with virtually total dependence on imported fuels -- may be among the most prosperous countries in the world. The point need not to be labored: for energy-rich countries, the additional provision of other natural resources, of education, technology, and still other endowments constitutes a necessary condition for growth; whereas energy-deficit countries can acquire needed fuel supplies through international trade if their economies possess other resources facilitating development and exports.

Figures 2-1 shows the relationship between energy



Source: Ref.[1], [4], [9], [10].

Figure 2-1. Per Capita Income versus Per Capita Energy Usage.

consumption and GDP in 1985 both on a per capita basis; the per capita outputs have been converted to 1980 US dollars using PPP adjustment. The obvious point in this figure is that there are large vertical differences between countries at roughly the same level of per capita GDP as well as the expected differences between countries at different income levels.

The wide variation in energy consumption can be seen in the fact that the United States, France, and Belgium have almost equal per capita incomes, but per capita energy consumption in the United States is about twice that of Belgium and almost 2.5 times that of France. But Canada's level of income per capita was lower than the US level, while its level of per capita energy consumption was slightly higher than that of the United States. The United Kingdom and Japan were disproportionately low per capita consumers of energy when their per capita GDP was compared with that of the United States,etc. Chern and James[11] indicated that the differences between countries can be explained by a number of things, such as pricing policies, product mix, the climate, the degree of industrialization, the degree of foreign dependence on energy sources, and geography etc., which can further shift individual countries from the mean trend line.

2.2. Trends in Total and Per Capita Energy Consumption

The salient features of the statistics of the selected countries from 1960 to 1985 are recorded in a set of two summary tabulations(Table 2-1 and Table 2-2) showing total and per capita energy consumption and percentage growth rates for each of these two indicators.

Table 2-1. The Change in Total and Per Capita Energy Consumption in the Selected Countries and Selected Years,1960-1985

Country	1960	1973	1979	1985
	Total Energy Consumption(billion tons coal eq.)			
USA	1508.9	2582.6	2622.1	2426.5
UK	256.0	312.9	289.9	276.8
Germany	208.3	379.6	387.5	379.4
Japan	120.6	443.6	469.6	496.7
Taiwan	5.2	18.5	34.5	44.3
Korea	6.5	30.3	52.1	70.3
Singapore	0.7	4.3	9.5	19.7
India	64.5	122.4	137.4	216.6
Philippines	4.3	13.2	17.9	18.8
	Per Capita Energy Consumption(100 Kg coal eq.)			
USA	8.35	12.30	11.65	10.14
UK	4.89	5.60	5.19	4.89
Germany	3.76	6.13	6.31	6.22
Japan	1.28	4.08	4.05	4.11
Taiwan	0.49	1.20	1.99	2.32
Korea	0.26	0.89	1.39	1.71
Singapore	0.37	1.99	3.99	7.69
India	0.15	0.21	0.21	0.29
Philippines	0.16	0.33	0.38	0.35

Source: Ref.[1]-[5],[9],[10].

Table 2-2. Average Annual Percentage Rates of Change in Total and Per Capita Energy Consumption in the Selected Countries and Selected Periods, 1960-1985

Country	1960-1973	1973-1979	1979-1985
	Total Energy Consumption Rate (%)		
USA	4.22	0.25	-1.28
UK	1.56	-1.26	-0.77
Germany	4.72	0.35	-0.35
Japan	10.54	0.95	0.94
Taiwan	10.29	10.87	4.26
Korea	12.62	9.39	5.13
Singapore	16.37	13.83	12.93
India	5.05	1.95	7.88
Philippines	12.88	4.36	3.57
	Per Capita Energy Consumption Rate (%)		
USA	3.03	-0.91	-2.29
UK	1.04	-1.25	-0.99
Germany	3.83	0.49	-0.24
Japan	9.32	-0.11	0.24
Taiwan	7.17	8.75	2.53
Korea	9.86	7.65	3.51
Singapore	13.75	12.26	11.57
India	2.69	-0.12	5.34
Philippines	5.86	2.43	-1.63

Source: Ref.[1]-[5],[9],[10].

With the higher price of oil since 1973, developed countries were forced to seek remedies by curtailing energy demand and substituting for oil. The energy conservation measures which developed countries used are summarized as follows:

(a) Tax credits, subsidies, grants, and other measures are provided to encourage the consumer to conserve energy.

(b) Mandatory standards are promulgated to ensure that manufacturer will make available to consumers devices that are energy-conserving.

(c) Various measures are employed to foster energy-saving techniques among industry.

etc. that led to the per capita energy consumption of the developed countries gradually decreased. But in the developing countries, although their economies were also affected by the sharply rising oil prices, the per capita energy consumption has steadily risen. The reasons for such different trend are:

(a) The fast industrialization and urbanization caused more energy consumed.

(b) lack of the access to essential energy conservation techniques or to adequate capital.

2.3 Interfuel Shifts in Energy Consumption

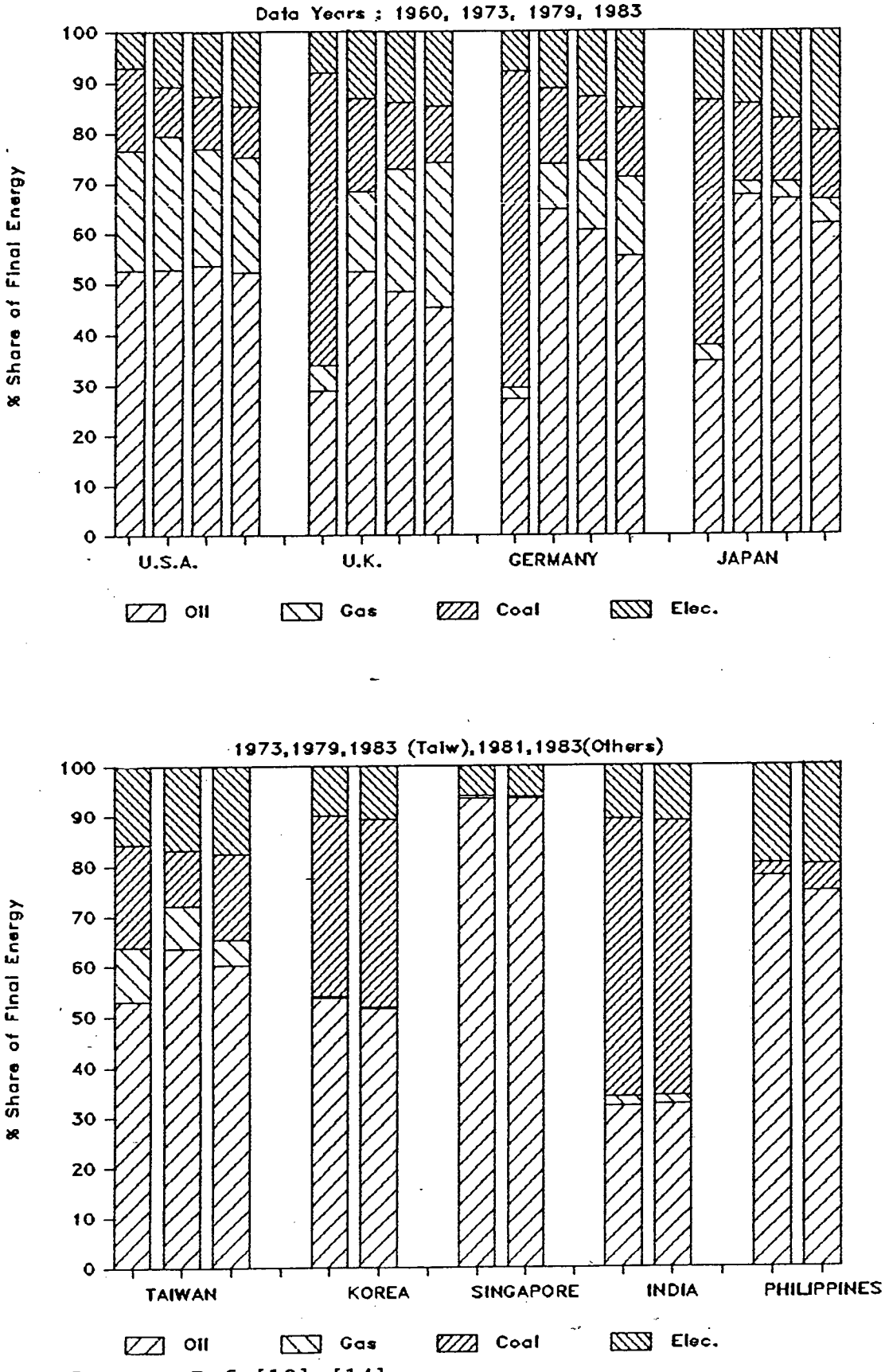
Energy consumption cannot be treated in just an aggregative fashion Not only does such an aggregation obscure fundamental shifts among the different energy sources, but the size and growth of total energy use is affected by the changing role of these fuels as their individual properties are exploited: for the creation of new products and industries, for the realization of greater efficiency and convenience in use, and, through such changes, for the attainment of higher levels of national well-being.

More basic still is the fact that the complexity of different periods of economic history may frequently bear a distinct relationship to the emergence of specific energy sources and forms.

The changes in the fuel mix are the result of changes in the economy's sectoral structure and of changes within sectors. The changes of fuel uses are measured in terms of final energy,and the overall development of the final fuel shares for the selected countries for the selected years (1960,1973,1979, and 1983 for high-income countries; 1973,1979,and 1983 for Taiwan; 1981 and 1983 for the rest of countries due to the data constraint) is shown in Figure 2-2. Although the share of oil has been decreasing since the mid-1970s as an aftermath of the oil crises, it still has the largest share in the total energy consumption in all the selected countries, with the exception of India (with coal as the largest). The fuels which substituted for oil were electricity in most countries, and electricity and gas in the UK and Germany. This pattern was partly the result of the increasing real price of oil and relatively stable or even declining real price of electricity as well as the continuing growth of gas demand in the European and US fuel markets.

Since the inherent disadvantage of coal, i.e. its contribution to environmental pollution, inconvience in end-use, and high cost in inland transportation etc., inhibits it from increasing its share in the energy market, and the share of coal has been declined over time in most countries except Korea.

Natural gas is a clean-burning, non-polluting fuel which does not suffer from environmental disadvantage. In most western countries, i.e., the USA, the UK, and Germany etc., where plentiful supplies of natural gas are available, the switch-over



Source: Ref.[12]-[14].

Figure 2-2. Final Energy Shares by Energy Source.

from oil to natural gas after 1973 was more pronounced, and natural gas took over sectors of the industrial, commercial and residential markets once served by oil. In contrast with western countries, the share of gas was small in most Asia countries--i.e. Japan, Taiwan, Korea, India, and the Philippines etc.-- owing to the lack of available supply and essential technologies.

In what has been essentially a factual review, the preceding sections have examined shifts in the relative contribution of the different secondary fuels to the total secondary energy consumption. In spite of the exception noted in the selected countries, the basic historical story is that of the declining position of coal and oil as well as the ascendancy of electricity in most countries, and of gas in the western countries.

Sectoral Energy Usages

In this section the focus is turned to the examination of the structure of energy usage. The sectors distinguished are industry, transport, agriculture, commercial, and residential. These five sectors cover nearly 95% of the total final energy consumption in most countries. Due to the data limitation, the data years are designated as 1960, 1973, 1979, and 1983 for high-income countries; 1973, 1979, and 1983 for Taiwan; and 1981 and 1983 for others.

The relative importance of the sectors distinguished here in terms of energy consumption can be seen in Figure 2-3. The

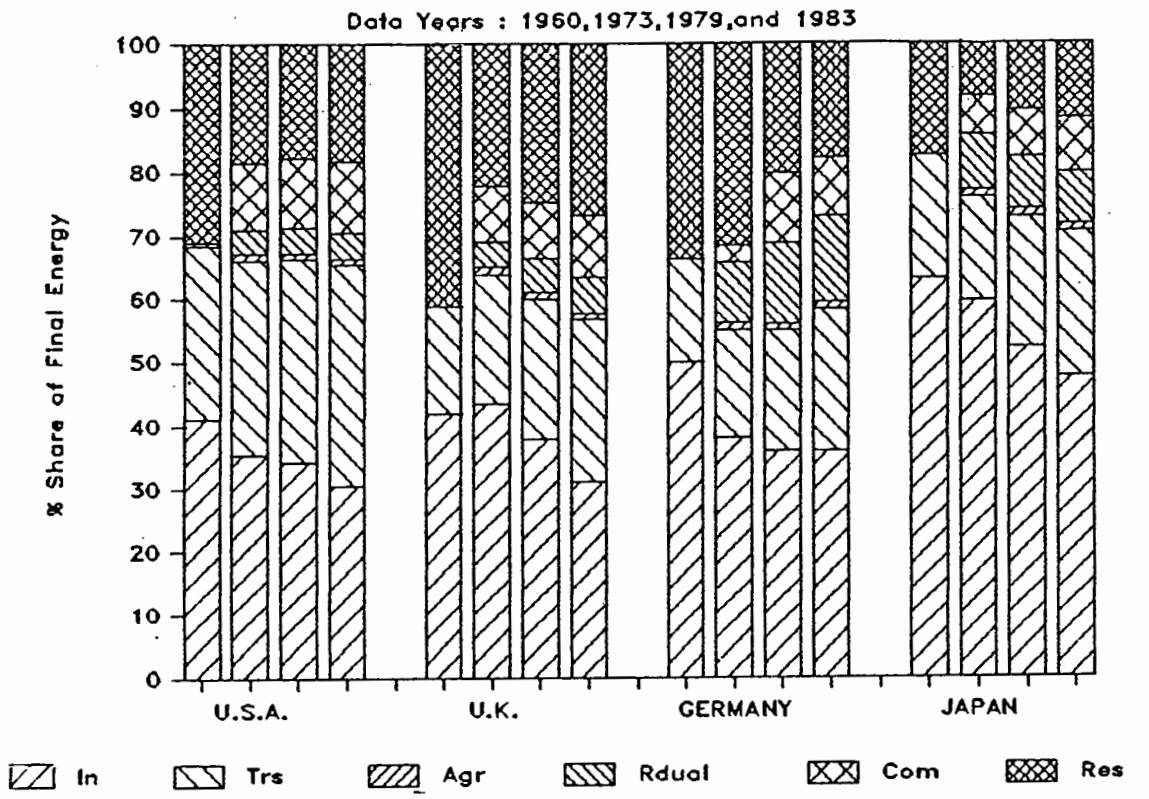
following characteristics are worth noticing:

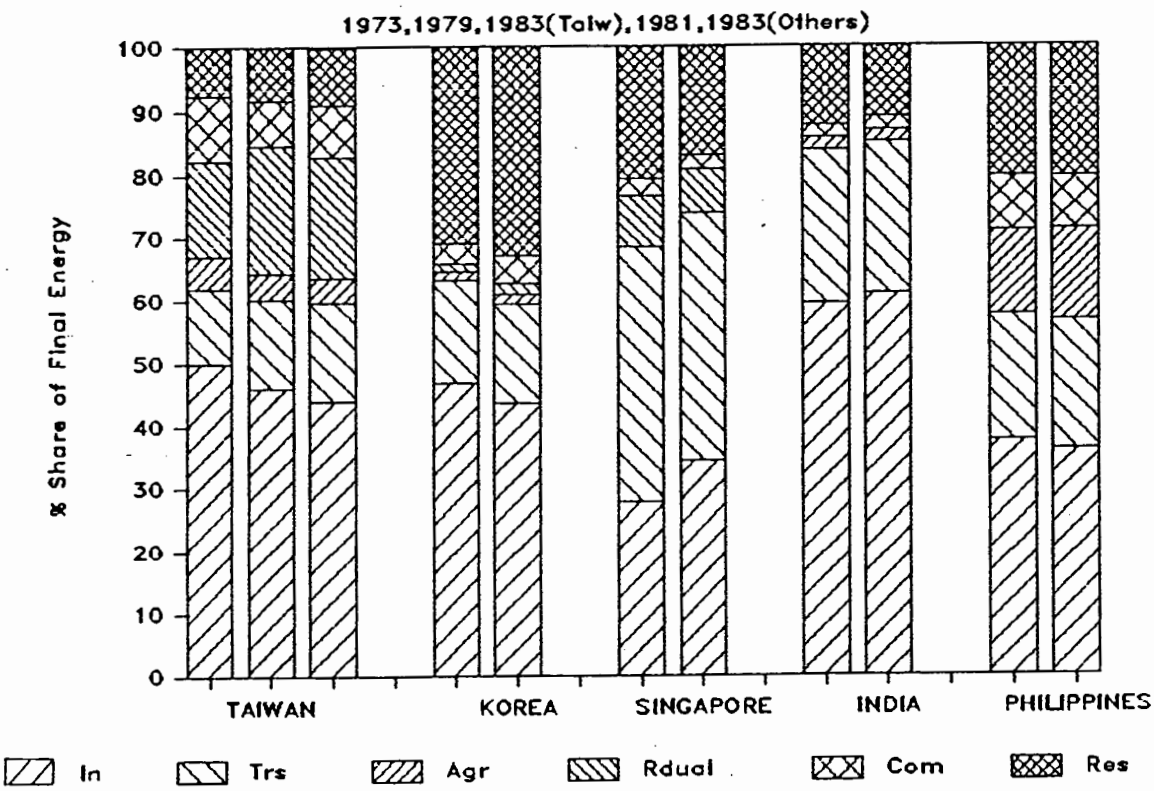
First of all, industry has been the largest energy consumer in most countries, with the exceptions of the USA and Singapore where the transport sector is an important consumer of energy. However, industry's share of energy consumption continually decreased in most selected countries over time due to the structure changes in industry where energy-intensive sectors are being replaced by secondary industry. This decline has also been hastened by the growing adoptions of energy conservation measures.

Secondly, the transport's share of energy consumption tended to increase in the high-income countries and in Taiwan because of strong economic activity, whereas the share decreased in the remaining countries as the growth of energy consumption in the transport sector is slower than that of the total energy consumption.

The share of the commercial and residential sectors of the total energy consumption increased in most countries due to high living standards as incomes increased. The share of agriculture in the total energy consumption was small and it decreased slightly in all the selected countries with the exception of the Philippines.

The different changes of the sectoral energy use among countries are affected by the factors including per capita income, economic sectoral composition, price of energies, technology change, policies, climate, etc.





Source: Ref.[12]-[14].

Figure 2-3. Major Sector's Shares of the Total Final Energy.

Industrial Fuel Mix

Moving to the sectoral level, the changes of fuel uses are examined only for the industrial, commercial, and residential sectors which have the greatest impacts on the overall fuel mix. The consumption of agriculture's energy is relatively small in most of the selected countries and the fuel mix in the transport sector is relatively stable because there is hardly any substitute for petroleum products. The remaining services are relatively unimportant in terms of energy consumption and are also difficult to analyze due to unreliable data. Figure 2-4. shows the fuel share of the industry(i.e., non-mining, manufacturing, and construction, which comprise the industrial sector as defined in U.N. energy consumption statistics), also on a final energy basis.

As oil offered outstanding advantages in transportation and as a petrochemical feedstock in the industrial sector, the share of oil continued its dominancy in industry in most selected countries but has been declining since the early 1970s. The reason for the reduction in oil demand was the replacement of oil by alternative energy sources, mainly coal and natural gas and to some extent electricity. The switch-over from oil to other fuels in industry was most noticeable in countries where such fuels were easily available at prices less than that of oil.

In most countries where industry has significantly increased the share of coal utilization due to conversion of existing oil-fired facility in industry was more easily available than in other sectors. UK is the only country where the share of

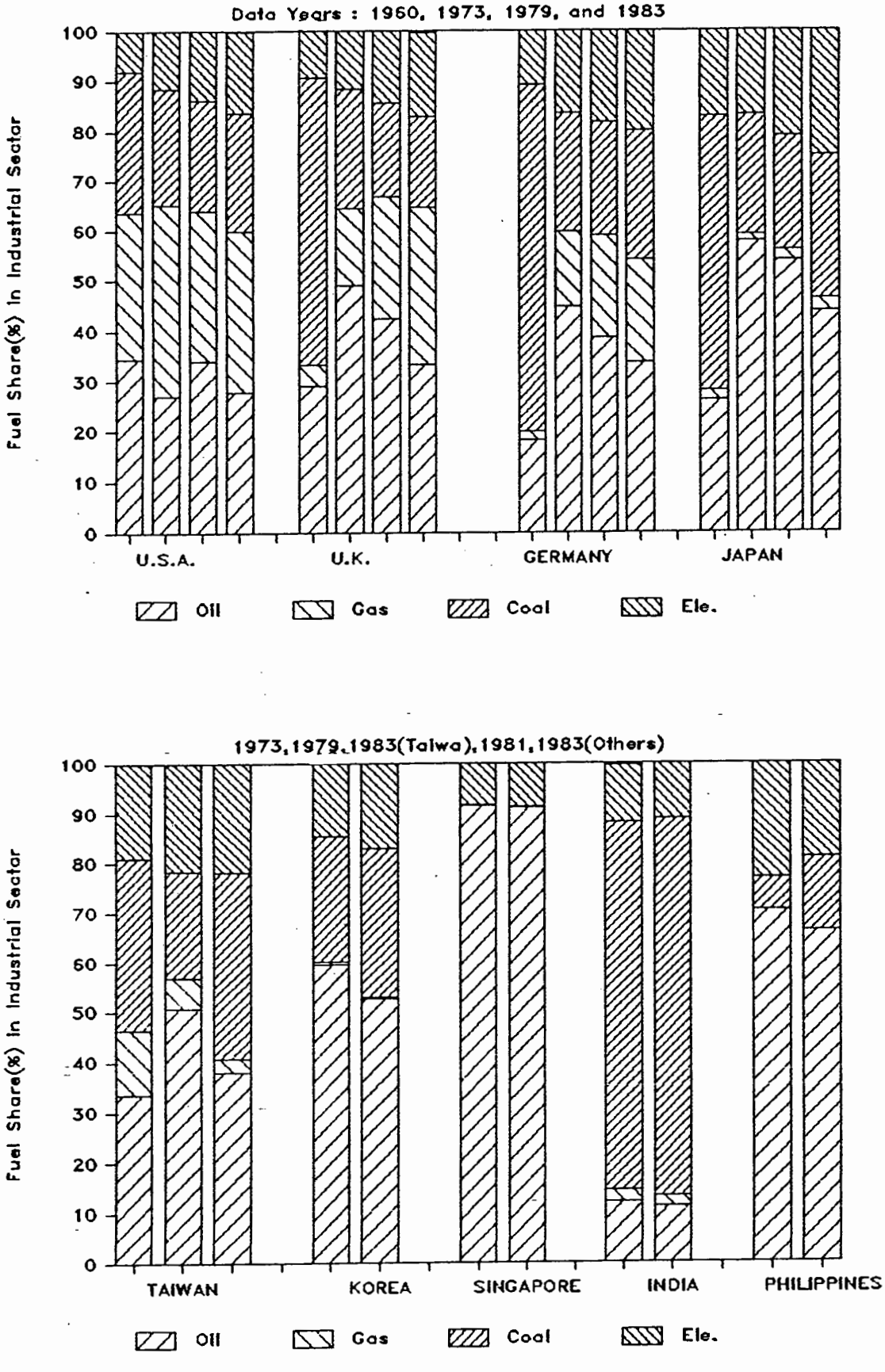


Figure 2-4. Energy Shares of the Industrial Sector.

gas in the industry increased faster than in the country as a whole due to the large resources of indigenous gas supply and the relatively low price[15]. All this leads to the conclusion that the process of substituting other fuels for oil was more pronounced in the industrial sector than in other sectors.

The share of electricity steadily increased in the high-income and middle-income countries with structural changes towards more electricity intensivity; whereas it decreased in some low-income countries with fast industrialization which consumed oil and coal rather than electricity.

Residential Fuel mix

Figure 2-5 shows the fuel shares of the residential sector on a final energy basis. The use habit and supply availability are two important factors which affect the use of different sources of energy in the residential sector.

In most Asian countries, liquefied petroleum gas(LPG) has been the main fuel for cooking and hot water supply resulting in the predominance of oil in those countries; and the share of gas became the highest in the residential sector in the USA and the UK.

Due to the inconvience in end-use of coal, its share steadily decreased in the residential sector in all the selected countries with the exception of the USA, where the share of coal increased because the district heat network are based largely on coal. The share of electricity increased in all countries as the

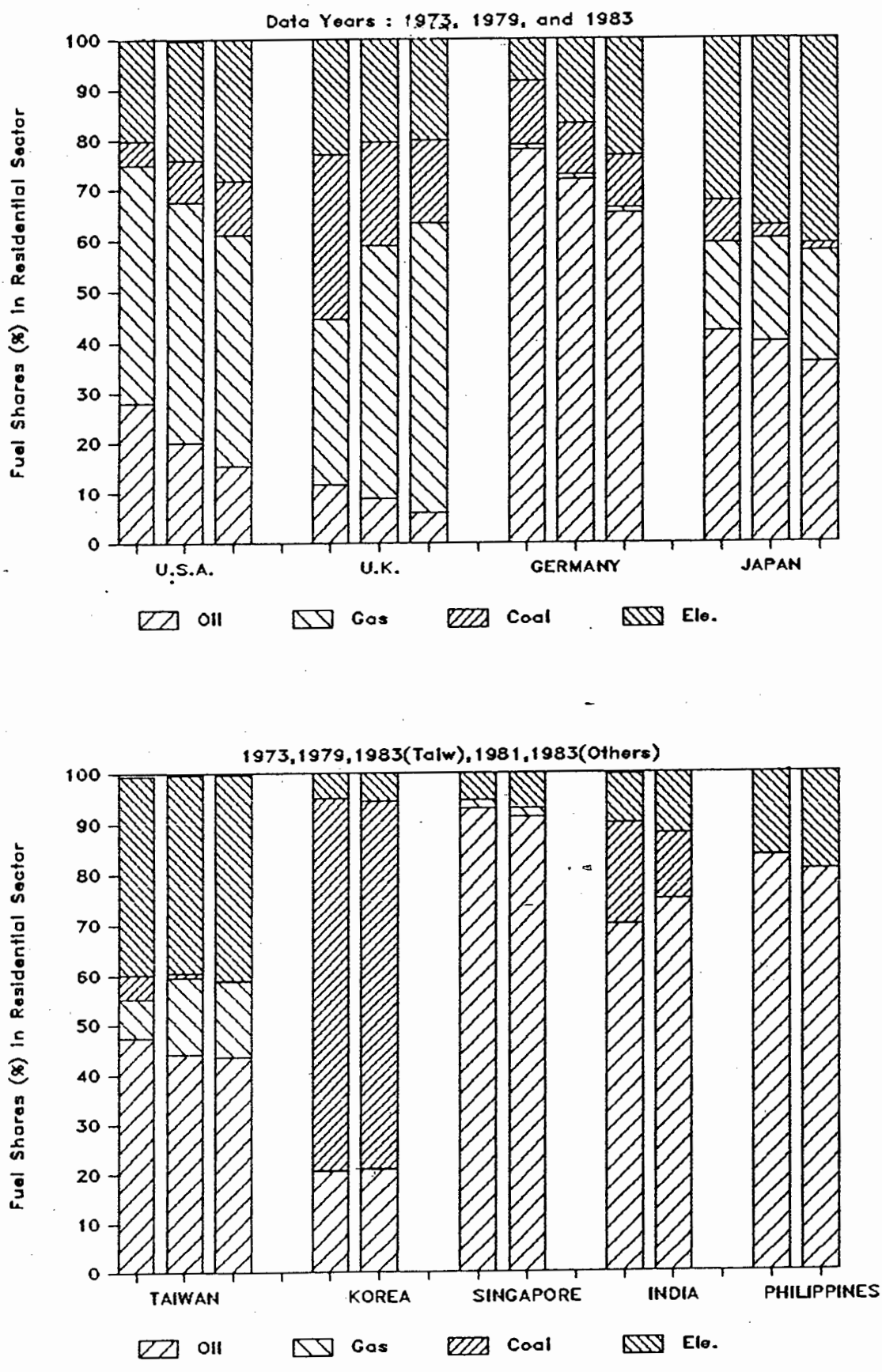


Figure 2-5. Energy Shares of the Residential Sector.

use of electrical appliances increased in the residential sector.

Commercial Fuel Mix

Figure 2-6 shows the fuel shares of the commercial (including public services) sector. In Germany, Japan, Taiwan, and Korea, oil is the most important fuel of the commercial sector; in the USA, gas and electricity; in the UK, electricity and oil; in India, Singapore and the Philippines, it is electricity. The patterns are by no means consistent.

There are large differences among countries at the sectoral fuel mix partly because of the availability of domestic sources, essential technologies, and the use habit in each country. The detailed data for above figures in this chapter are presented at Appendix A.

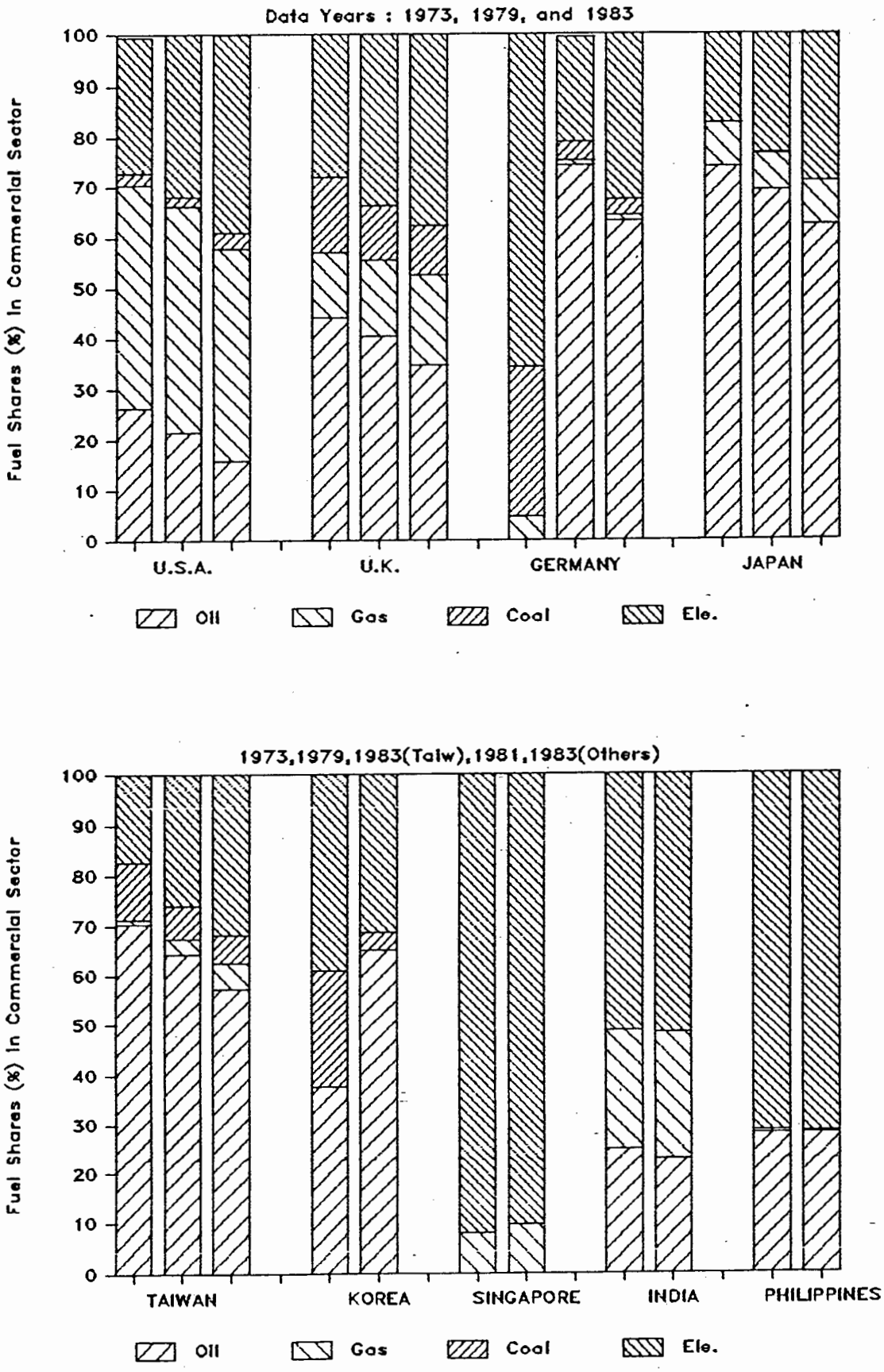


Figure 2-6. Energy Shares of the Commercial Sector.

2.4. Energy and GDP

A prominent characteristic of per capita consumption of energy forms in the selected countries is its systematic and quantitatively close association with indicators of general economic development. This relationship between GDP and energy holds both internationally and historically: the higher a nation's income or output, the higher, in general, its level of energy consumption; as its GDP rises over time, so does its energy consumption-in close, even if not proportionate, conformity. The one-to-one relationship only existed before 1973. The two oil price shocks caused more efficient use of energy in the developed countries, and economic recession in the low-income countries resulting in the conventional relationship between per capita energy consumption and per capita GDP moving away from its collinear connection. The correlation results of these two indicators in the selected countries for the 1955-1973 and the 1973-1985 periods are shown in Table 2-3.

Table 2-3. The Correlation Results(R squared)* between Per Capita Energy Consumption and Per Capita GDP in the Selected Countries

Country	1955-1973	1973-1985
USA	0.96	0.39
UK	0.75	0.42
Germany	0.92	0.15
Japan	0.99	0.06
Taiwan	0.99	0.94
Korea	0.91	0.96
Singapore	0.97	0.90
India	0.72	0.49
Philippines	0.94	0.34

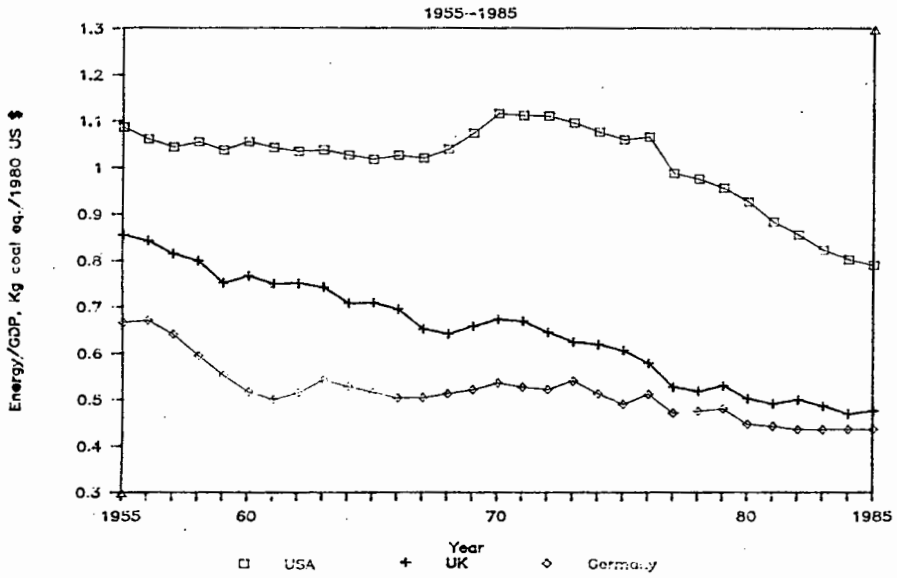
* The correlation coefficient R usually expresses the correlation result, and always lies between -1 and +1. If the coefficient is -1 or +1 then the observed data points all lie exactly on the regression line; if there is no correlation, then the coefficient is zero.

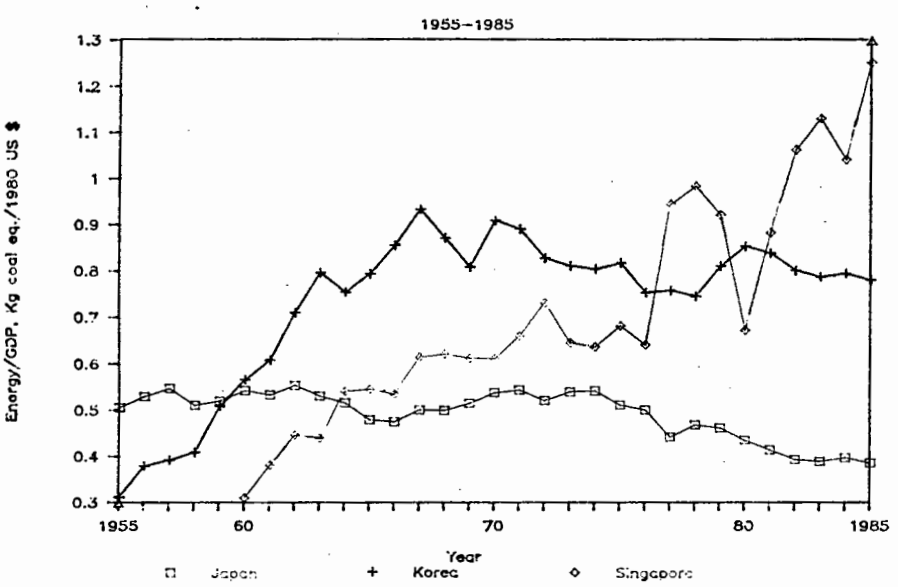
Intensity of Energy

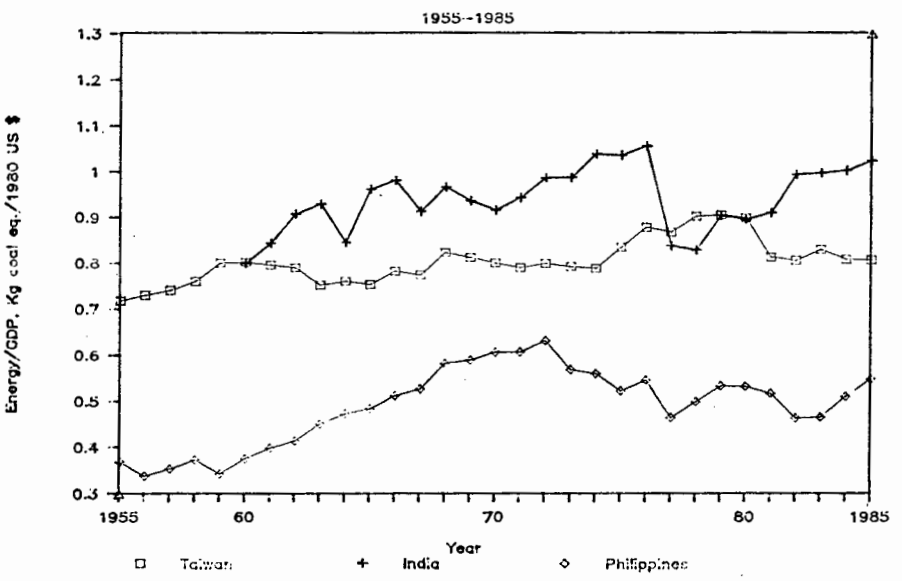
One of the meaningful ways of expressing the energy and GDP relationship is the energy per GDP coefficient or energy intensity, which measures the quantity of energy per unit of GDP.

The changes of energy intensity for the nine selected countries are shown in Figure 2-7, which illustrates developments over roughly three decades. A declining energy/GDP trend was found for high-income countries - USA, UK, Germany, and Japan; a sharply rising ratio for Singapore; and a fluctuating ratio (but not decisive up or down movement in the last decade and a half) for Taiwan, Korea, India, and the Philippines.

Figure 2-8 presents the energy-GDP intensities for primary energy using the PPP conversion for GDP on a per capita basis. The intensities increased significantly with income increase in early years in the middle-income and the low-income countries, but decreased in recent years in all of the sample countries, except Singapore. The reductions for the high-income countries are particularly striking, especially the slightly larger rates of decline for the two energy-intensive countries, the UK and the USA. In both countries this decline has been going on for many decades. Edmonds and Reilly [16] examined energy intensity for the USA and the UK, and indicated that the change of



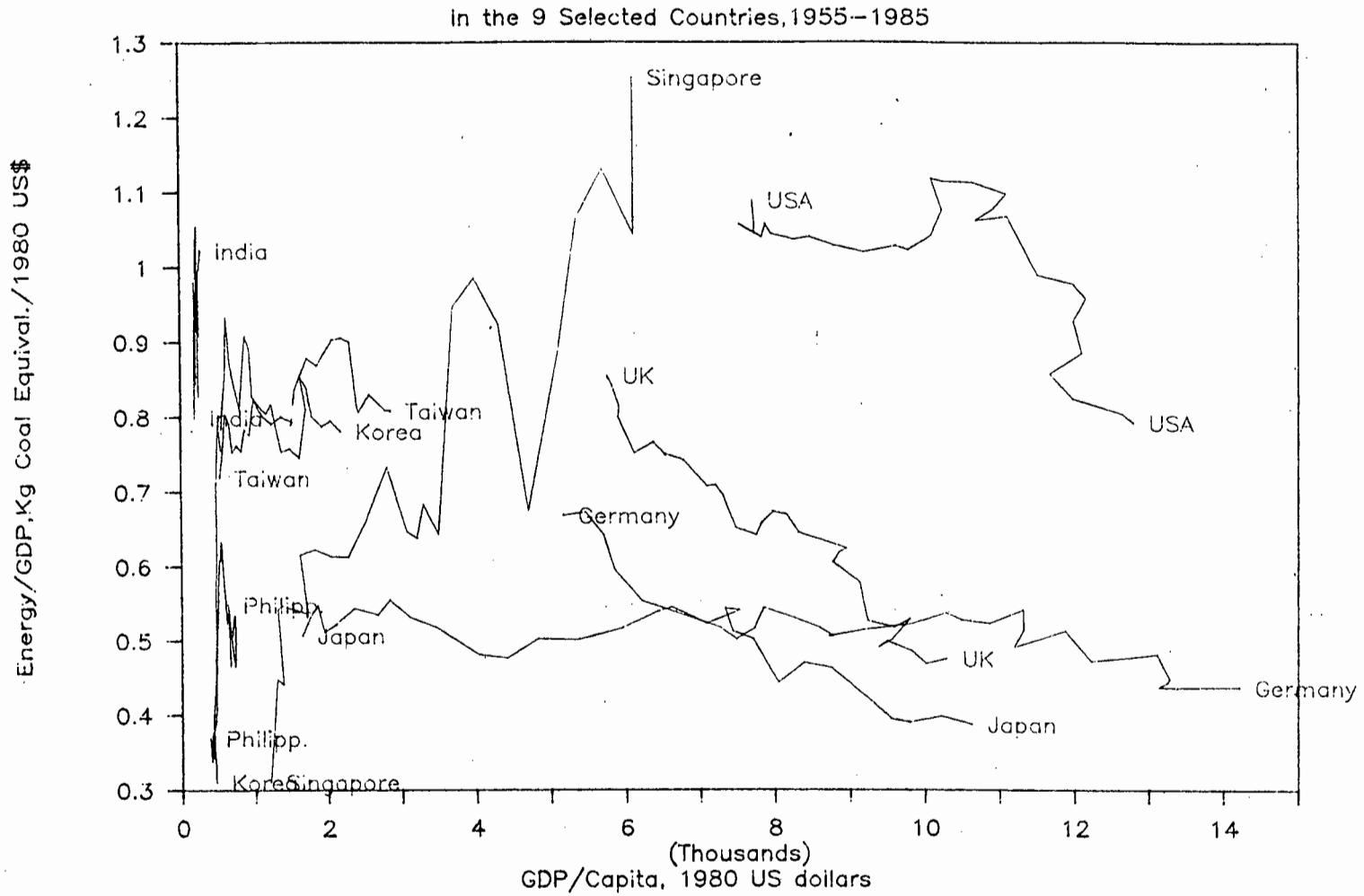




Source:Ref.[1]-[5],[9],[10].

Figure 2-7.

The Changes of Energy Intensity for the 9 Selected Countries, 1955-1985.



Source: Ref.[1]-[5],[9],[10].

Figure 2-8. Energy/GDP Versus Per Capita GDP in the Selected Countries for 1955-1985.

the rates is significantly affected by energy prices.

Figures 2-7 and 2-8 are illuminating in other respects. The normal view is that energy-GDP intensities always rise in low-income and middle-income countries since nearly all the major economic changes associated with development-- including increased industrialization and urbanization, greater demands for transport with higher incomes, the rise in electricity demand in the household/commercial sector, and the expansion of the energy conversion industries, etc.-- point towards an increased energy intensity. B.W. Ang[17] has identified these factors as also affecting the energy consumption for six Southeast Asian countries. In the high-income countries, energy intensity declined both because the economic structure was changing towards a low energy-intensive service sector and also because in many areas there was a growing application of energy-saving technologies[18]. During the observation period these changes were started or accelerated by the oil price increases.

Another relationship between energy and GDP is the energy/GDP elasticity, which can be measured as the percentage change in energy use over the percentage change in GDP. It is a unitless parameter which can be used for inter-country comparisons.

The energy/GDP elasticities for the nine selected countries and for various subperiods between 1960-1985 are shown in Table 2-4. In the high-income countries, energy consumption decreased in the UK after the first oil crisis, and in the USA and

Germany after the second oil crisis, and the growth rates of energy have been slower than those of GDP in Japan since 1960. The reason for these shifts has been mentioned in the previous sections.

Table 2-4. Energy/GDP Elasticities for Various Subperiods between 1960-1985 in the 9 Selected Countries

	1960-1973	1973-1979	1979-1985
USA	1.076	0.098	-0.681
UK	0.492	-0.845	-0.747
Germany	1.082	0.149	-0.282
Japan	0.997	0.263	0.235
Taiwan	0.990	1.288	0.679
Korea	1.321	1.0	0.884
Singapore	1.640	1.897	1.764
India	1.503	0.565	1.387
Philippines	1.612	0.82	2.437

Source: Ref.[1]-[5],[9],[10].

For the middle-income countries, the changes of elasticities in Taiwan and Korea were similar to those in developed countries except during the 1973-1979 period in Taiwan. The upward trend of this period for Taiwan was probably the result of delaying the effect of real oil costs by the government in order to maintain economic growth during the recession period. The high ratios of elasticity in Singapore were caused by the fact that a large refining industry had been developed in the 1970s and Singapore, as an international transport centre, consumed large quantity of aviation gasoline. In the low-income countries-- India

and the Philippines--- the decline during the 1973-1979 period was probably due to the sharply rising oil prices causing an economic recession.

CHAPTER 3. THE RELATIONSHIP BETWEEN ELECTRICITY AND ECONOMIC ACTIVITY

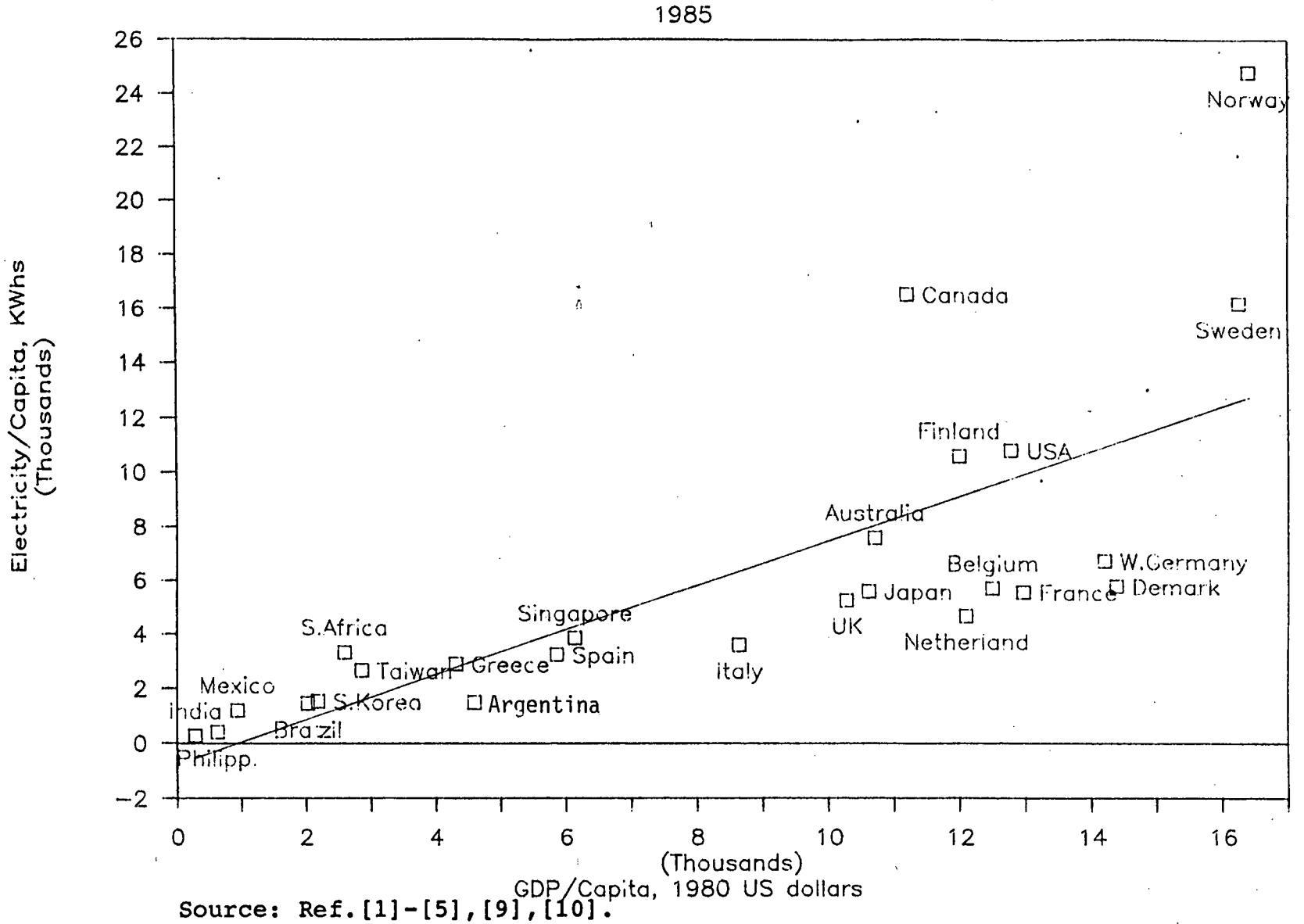
3.1. Introduction

Electricity is today a multipurpose energy form providing light, heat and motive power for a very wide range of applications in the industrial, transport, agricultural, commercial, and residential sectors of the economy. It is a form of energy notable for its flexibility at the production stage where various primary energies can be converted, either at source or at some other suitable location, and in plants of optimum size, into a secondary energy which can be economically transmitted over long distances.

Electricity consumption varies significantly among countries(Figure 3-1). For example, the per capita consumption in Canada, USA, Finland, Norway, and Sweden in 1985 was over 10000 kWh per year, while it was under 1200 kWh per year in India, the Philippines, and Mexico. The wide variations in per capita electricity consumption and income are shown in Table 3-1. These differences reflect variations in income, electricity policy, energy sources, electricity price, efficiency of use, type of industrial output, and other factors.

3.2. Trends in Total and Per Capita Electricity Consumption

The features of the statistical record of total and per capita electricity consumption and percentage growth rates of the



Source: Ref.[1]-[5],[9],[10].

Figure 3-1. Per Capita Income versus Per Capita Electricity Consumption.

selected countries from 1960 to 1985 are shown in Table 3-2. and Table 3-3. In contrast to the marked reduction in per capita energy consumption, the per capita electricity consumption has increased in most selected countries over time because of increasing electrification, but the growth rate of per capita electricity consumption has declined since 1973 due to increased energy cost caused by the oil crises.

Table 3-1. GDP and Electricity Consumption in 1985 on a Per Capita Basis (USA:100)

Country	GDP	Electricity Consumption	Country	GDP	Electricity Consumption
Norway	128.3	229.8	Italy	67.6	33.3
Sweden	127.1	149.9	Singapore	47.9	35.6
Denmark	112.5	53.4	Spain	45.8	29.9
W.Germany	111.1	62.3	Argentina	35.9	13.7
France	101.4	51.4	Greece	33.7	26.7
USA	100.0	100.0	Taiwan(ROC)	22.4	24.5
Belgium	97.7	52.7	S.Africa	20.8	30.5
Netherlands	94.6	43.1	S.Korea	17.0	14.1
Finland	93.9	98.2	Brazil	15.8	13.4
Canada	87.7	153.2	Mexico	7.3	10.9
Australia	83.8	70.3	Philippines	4.9	3.6
Japan	83.1	51.7	India	2.2	2.3
UK	80.4	48.5			

Source: Ref.[1]-[5],[9],[10].

Table 3-2. The Change in Total and Per Capita Electricity Usage in the Selected Countries and Selected Years, 1960-1985

	1960	1973	1979	1985
	Total Electricity Usage(billions of Kwh)			
USA	849	1979	2348	2566
UK	136	282	300	294
Germany	123	309	372	409
Japan	111	468	589	673
Taiwan	3.2	19	37	50
Korea	1.7	15	38	63
Singapore	0.6	3.7	6.4	9.8

India	20	73	112	188
Philippines	2.7	13	17	21
	Per Capita Electricity Usage(kWhs)			
USA	4697	9428	10434	10724
UK	2616	5047	5366	5205
Germany	2221	4990	6067	6706
Japan	1184	4309	5088	5575
Taiwan	305	1226	2140	2649
Korea	71	446	1006	1521
Singapore	374	1698	2709	3838
India	47	126	173	251
Philippines	99	328	362	386

Source: Ref.[1]-[5],[9],[10].

Table 3-3. Average Annual Percentage Rates of Change in Total and Per Capita Electricity Consumption in the Selected Countries and the Selected Periods,1960-1985

	1960-1973	1973-1979	1979-1985
	Total Electricity Consumption Rate(%)		
USA	6.73	2.89	1.49
UK	5.72	1.02	-0.29
Germany	7.34	3.16	1.56
Japan	11.68	3.91	2.24
Taiwan	14.53	11.86	5.36
Korea	18.07	16.34	8.82
Singapore	14.90	9.61	7.27
India	10.40	7.57	8.93
Philippines	12.88	4.36	3.57
	Per Capita Electricity Consumption Rate(%)		
USA	5.51	1.70	0.46
UK	5.18	1.03	-0.51
Germany	6.42	3.31	1.68
Japan	10.44	2.81	1.53
Taiwan	11.79	9.72	3.62
Korea	15.18	14.49	7.14
Singapore	12.32	8.10	5.98
India	7.92	5.39	6.37
Philippines	9.62	1.63	1.09

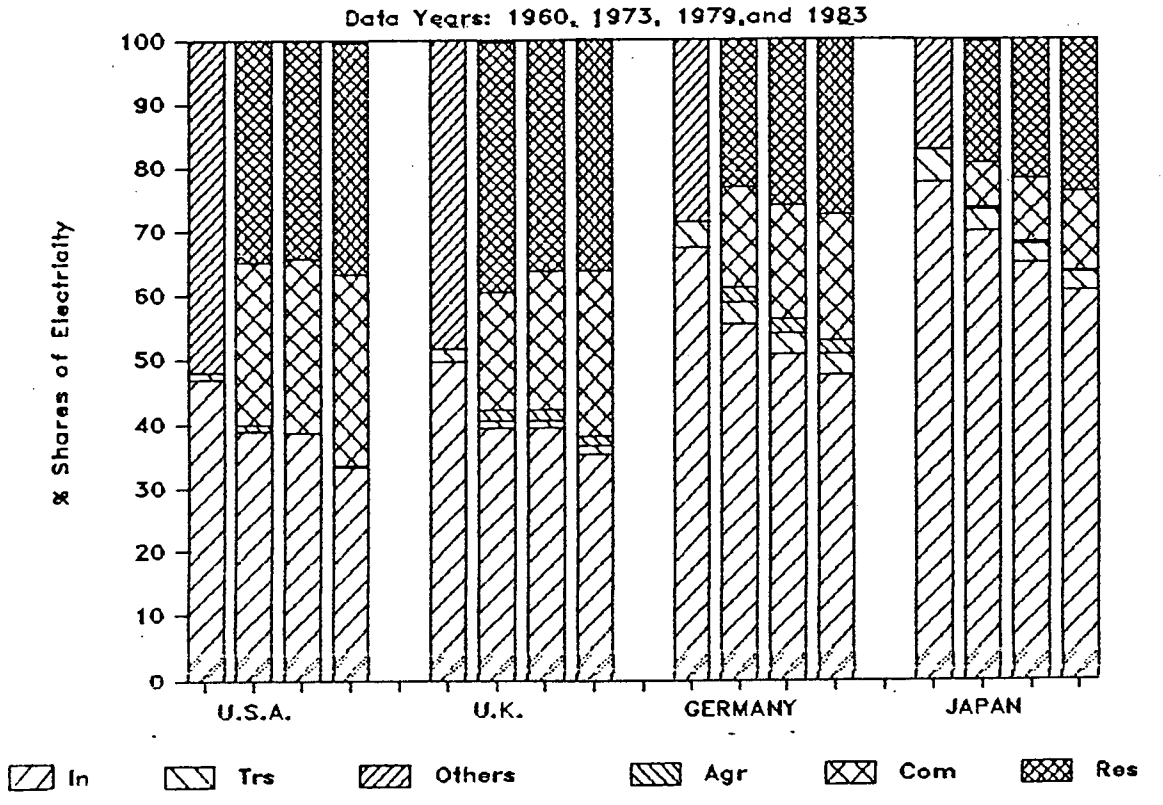
Source:Ref.[1]-[5],[9],[10].

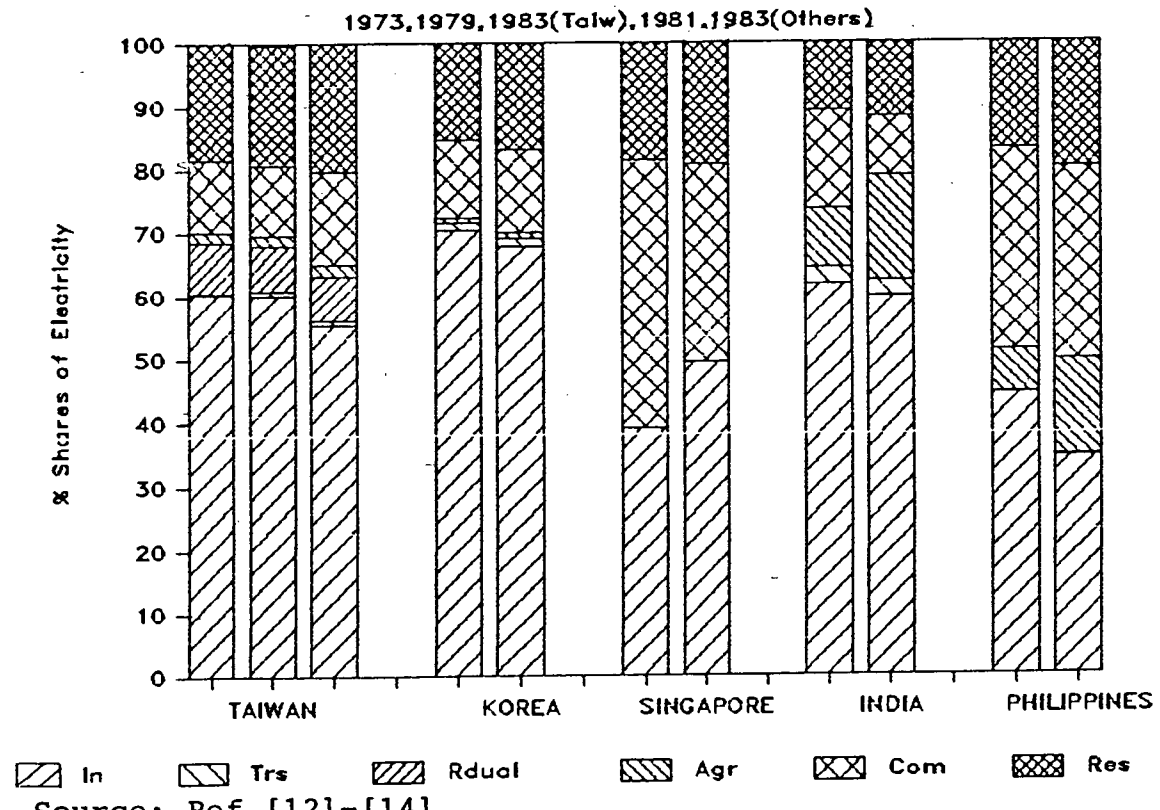
Figure 3-2 shows the sectoral shares of the electricity consumption in the nine selected countries. Industry decreased in kWh demand (though the share of electricity in industrial energy consumption increased) due to decrease of electricity-intensive industries such as aluminum and steel, but the residential commercial sector increased in most countries as the rise in appliance penetration caused increased electricity use. The two effects roughly balance, so the total increased trend of electricity consumption was not much altered. Factors affecting changes in electricity will be discussed in more detail in later sections.

3.3. Electricity Intensity

The electricity-GDP relationship can also be expressed as a ratio of electricity consumption per dollar of GDP or electricity intensity. To examine the historical trends of electricity/GDP ratios across countries, the data has been calculated from the long-term statistics which were available for the United Kingdom from 1896-1985 and for the United States from 1920 to 1985. Figure 3-3 shows the calculated electricity/GDP ratios for these two countries. In the case of the United Kingdom, the ratio slowly increased up to 1972 as UK industrialized, with a slow decrease thereafter. The United States showed a similar trend, but with the decrease started in 1976.

The electricity/GDP pattern for Japan, over the period from 1930-1985 is shown in Figure 3-4. The electricity/GDP ratio





Source: Ref.[12]-[14].

Figure 3-2. Major Sector's Shares of the Electricity Consumption.

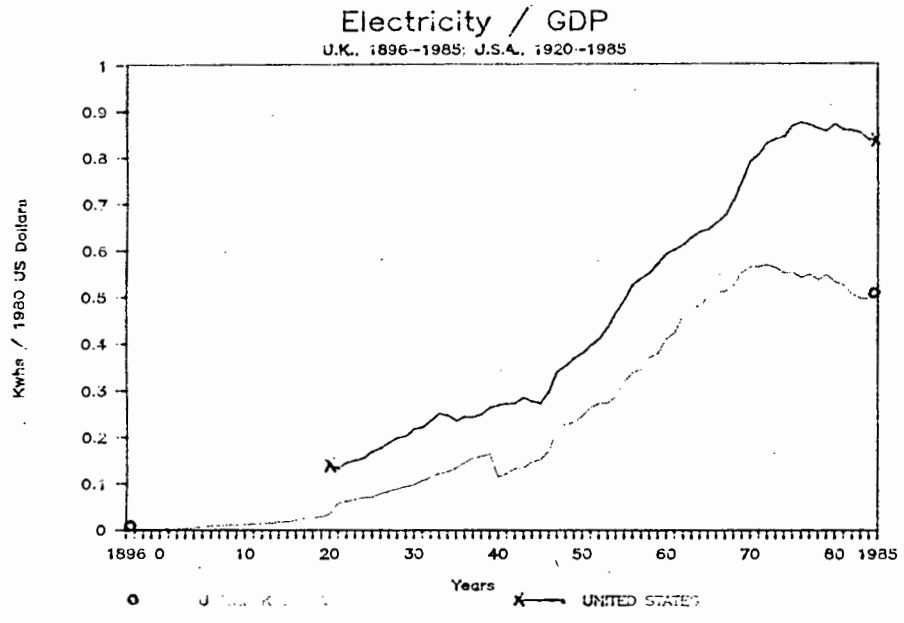


Figure 3-3. Historical Trends of Electricity Intensity for UK from 1896-1985, and USA from 1920-1985.

Source:Ref.[19],[20].

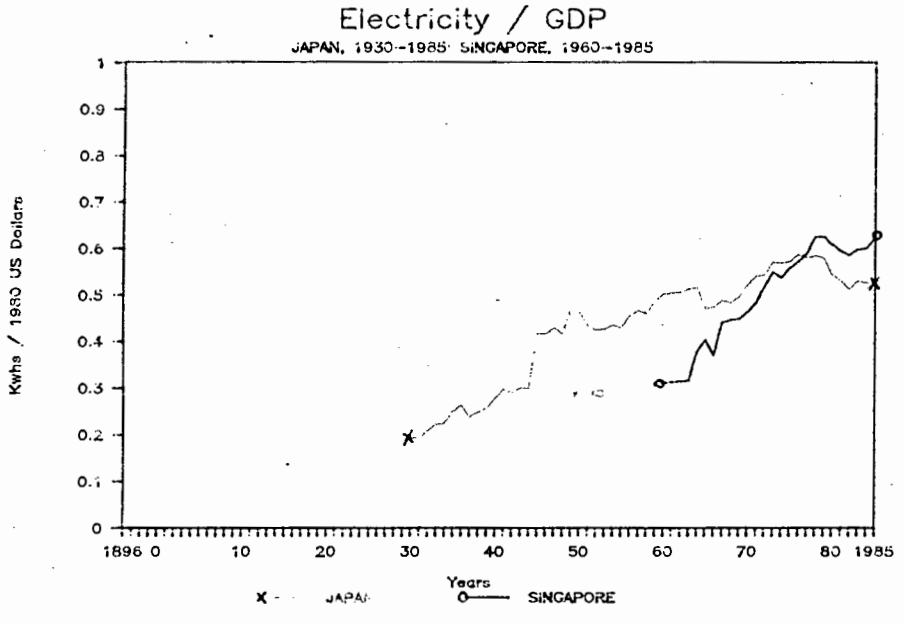


Figure 3-4. Historical Trends of Electricity Intensity for Japan from 1930-1985, and Singapore from 1960-1985.

Source:Ref.[1]-[5],[21].

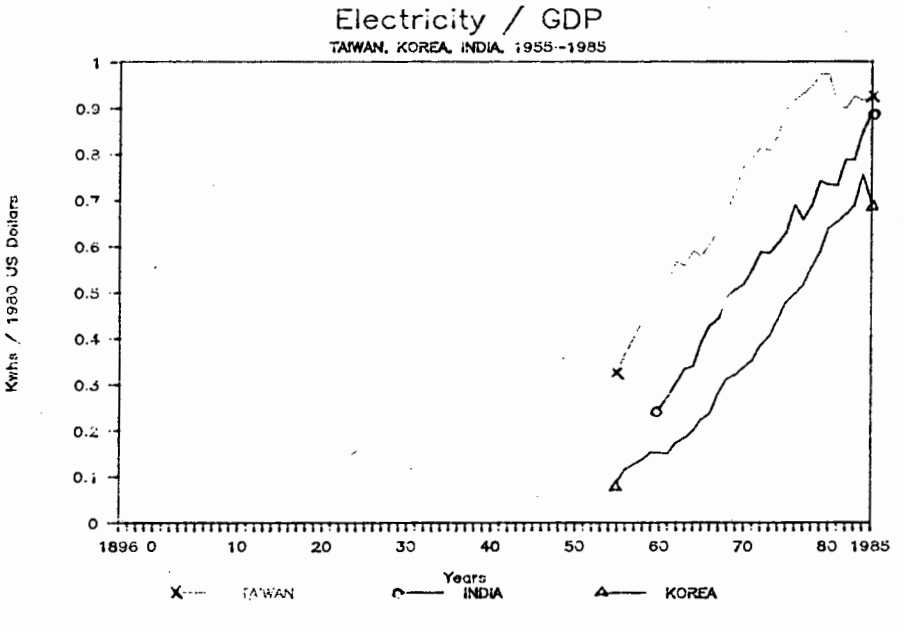


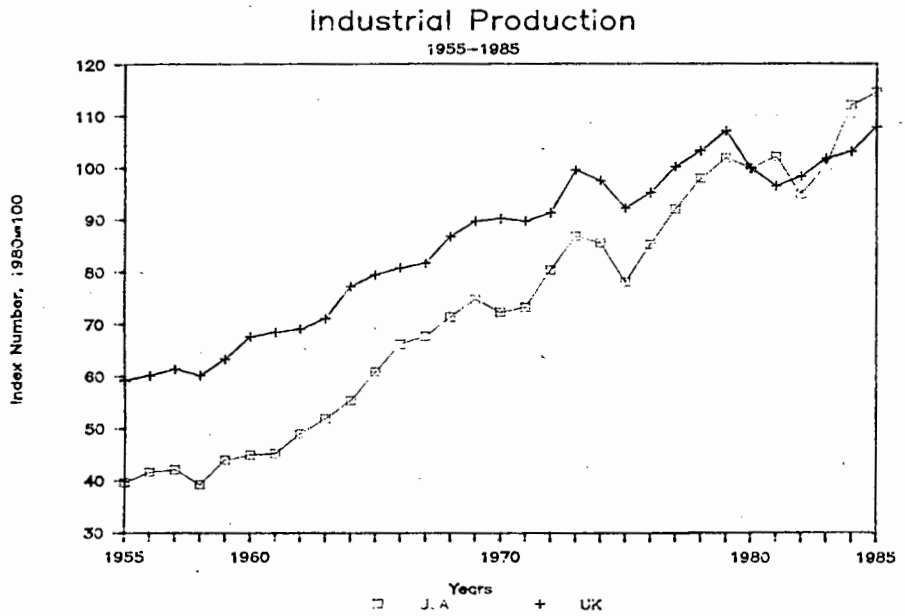
Figure 3-5. Historical Trends of Electricity Intensity for Taiwan, Korea, and India, 1955-1985.

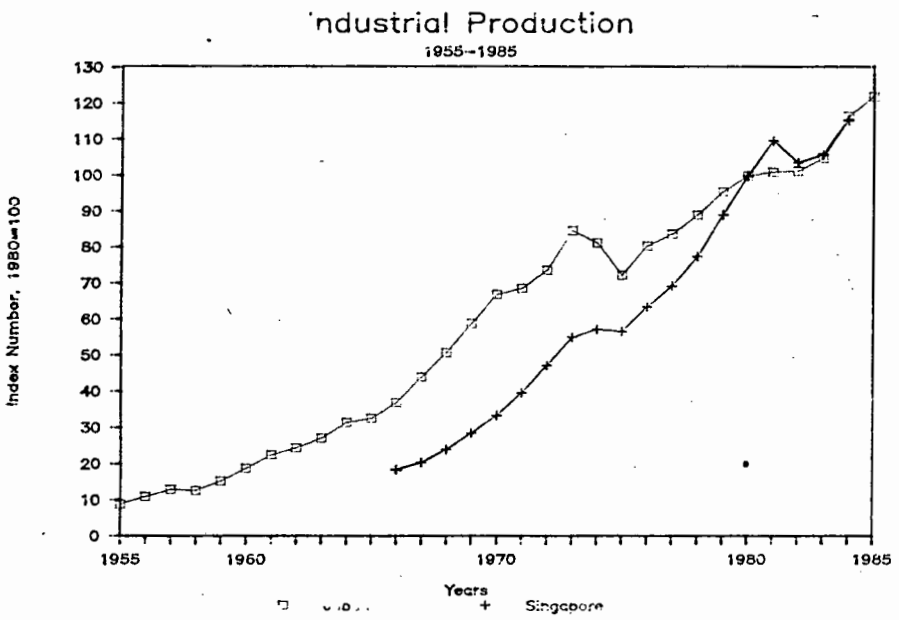
Source:Ref.[1]-[5],[22].

showed a cyclic change, which increased and then declined steadily three times between 1930 and 1985. Comparing this with Singapore, over the short-term period from 1960-1985, the ratio showed a similar tendency as that from the period 1930-1955 in Japan.

Figure 3-5 compares the electricity/GDP ratios among Taiwan and Korea over the period from 1955-1985 and India from 1960-1985. The growth of the ratios in these countries increased rapidly and had similar steep slopes. The ratio of Taiwan fell after 1980; Korea showed a similar tendency but peaked around 1984; India maintained an increasing trend.

As industry has been the largest electricity consumer, the changes of industrial production for these three groups of countries were examined in Figure 3-6. No systematic variations in industrial production were found for each group of countries, except for the USA and UK group in the 1955-1985 period. Although the growth of US industrial production was faster than that in UK, the industrial production of the USA and the UK had the similar trend before 1979 as that of electricity intensity. This is partly due to the fact that the UK had lost her industrial productivity because of the high production cost and the industry structure, and this phenomenon was more apparent during the period of the two oil crises. The different changes in electricity/GDP ratio are a reflection of underlying factors, such as the state of technology, the price of electricity , environmental constraints, the level of activity in individual electricity-using sectors, the composition of GDP, the population, nature sources, electricity efficiency,





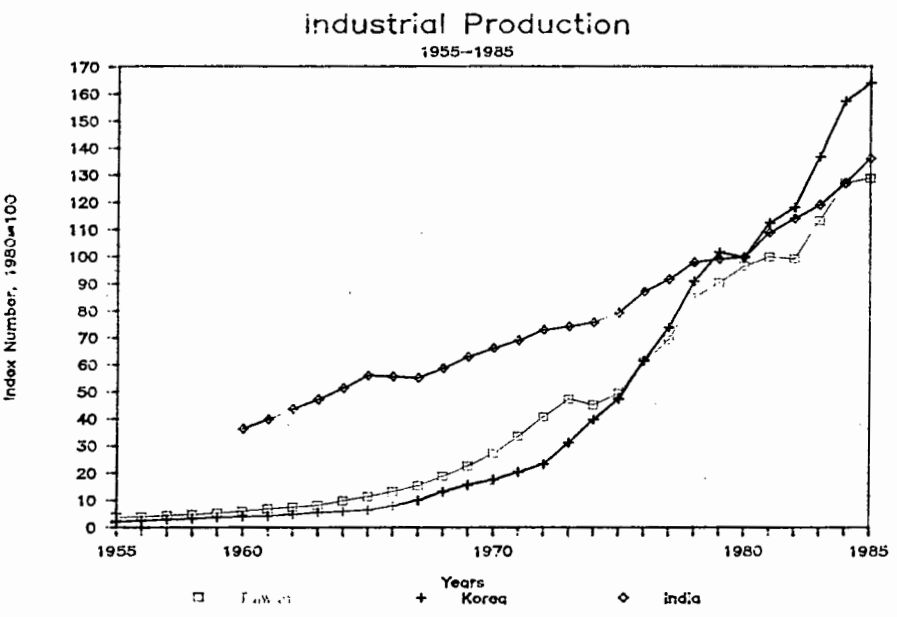


Figure 3-6.

The Changes of Industrial Production for These Groups of Countries.

Source:Ref.[1],[9].

tastes and demographic and sociological factors,etc.

Figure 3-7 shows the cross-country electricity-GDP intensities for electricity consumption using the PPP conversion for GDP on a per capita basis. There are significant differences in the ratio between these selected countries. For developing countries electricity-GDP ratio displayed a rapidly rising trend as income increased; but in developed countries the ratio rise was slight as income increased, except for the USA. This is probably due to the fact that the USA placed a priority on the development of high value-added manufacturing and service industries.

As in the energy/GDP elasticity, the electricity/GDP elasticity can be measured on the percentage change in electricity use over the percentage change in GDP. Table 3-4 shows the changes of electricity/GDP elasticities for various subperiods between 1955 and 1985 in the nine selected countries. Electricity growth rates were greater than those of GDP before 1973 for all countries but they were slower than those of GDP after the oil shocks; the elasticity came near to one, or even fell below one in the UK, USA, Japan, Taiwan, and Singapore between 1979 - 1985. The average annual growth rate of elasticities declined consistently not only in individual countries but also across countries after 1973. This shift in high-income and middle-income countries is probably a result of the changing composition of that economy away from energy and electricity-intensive industries toward high value-added manufacturing and service industries. The only exception to the declining elasticity trend in the selected countries is the

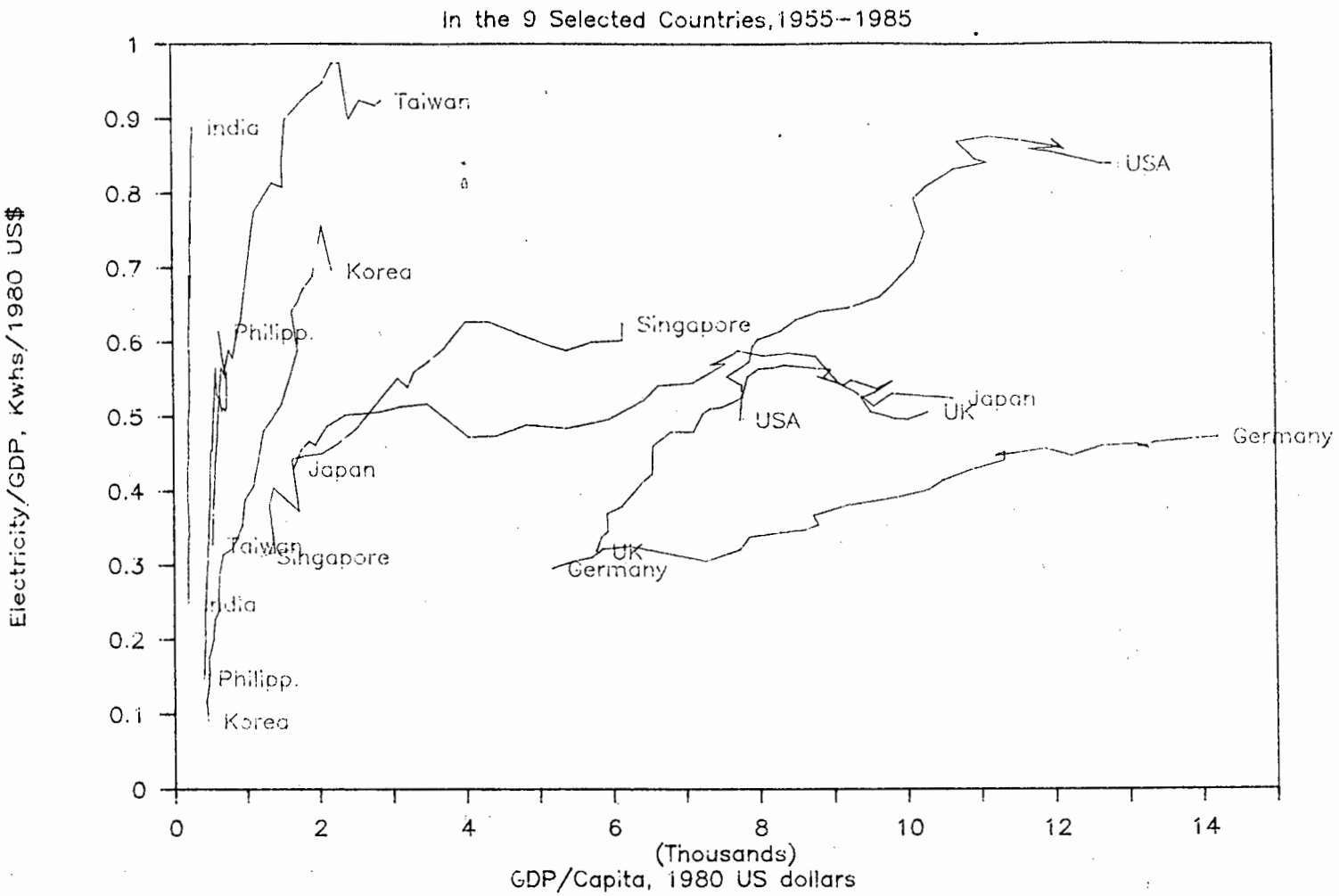


Figure 3-7. Electricity/GDP Versus Per Capita GDP in the Selected Countries.

Source: Ref.[1]-[5],[9],[10].

Philippines, because the elasticity at the 1979-1985 period was extremely high. This is a result of the economic recession owing to the unstable political situation.

Table 3-4. Electricity/GDP Elasticities for Various Subperiods between 1955-1985 in the Selected Countries

	1955-61	1961-67	1967-73	1973-79	1979-85
USA	2.51	1.41	2.19	1.13	0.79
UK	2.87	2.14	1.48	0.68	-0.28
Germany	1.13	1.76	1.65	1.35	1.26
Japan	1.31	0.95	1.32	1.08	0.56
Taiwan	2.31	1.34	1.41	1.40	0.85
Korea	3.47	2.59	1.56	1.74	1.52
Singapore	-	1.88	1.32	1.31	0.99
India	-	3.58	2.46	2.19	1.57
Philippines	2.86	2.49	2.22	0.69	11.16

Source: Ref.[1]-[5],[9],[10].

3.4. Factors Affecting Changes in Electricity Demand

For any country, the changes in electricity use observed in the past and to be expected in the future may be divided into a list of causal relationships or effects. The main items in the list include GDP and economic sectoral structure, government policies, prices, technical change, interfuel competition, conservation practices etc. However, not all these effects can be totally identified for each individual country.

The fundamental problem in assessing electricity demand is the uncertainty in the prediction of economic growth. Changes in capital or labor markets, increased competition in

international trade, and even the adjustments to increased energy prices have all made the future levels of economic growth more difficult to predict. In addition, major changes are taking place in the composition of the industrial output and in the pattern of the household behavior, with significant implications for electricity demand. In a few countries the continuing growth of such electricity-intensive industries as aluminum and chemicals will accelerate the growth of electricity demand, but in most industrial countries these industries appear to be declining relative to other sectors.

Government policies will have an effect on both the rate of growth and the composition of economic output, with direct implications for electricity demand. The relationship between the growth in GDP and in electricity will vary through time and from country to country.

Real fuel prices which were declining before 1973 have subsequently increased. The future development of energy prices and the relationship of electricity prices to those of gas and oil are still highly uncertain. In many countries the improvement in the competitive position of electricity as a result of the gas and oil price increases in the 1970s has not been fully felt.

The development of new electricity-using technologies for the industry and buildings will also be important, both in competition with other fuels, and in determining the growth of electricity-specific uses. Prices also have an important influence on the degree and rate of improvement in the efficiency of

electricity use. Much of the rise in electricity prices in the 1970s has not yet been reflected in the full stock of appliances, lighting fixtures, buildings and motors. Moreover, sharp and unexpected changes in oil prices in the future are possible. They would affect electricity demand directly by changing the competitive balance in those markets where electricity and other fuels compete, and indirectly by affecting the cost of fossil fuel inputs to electricity generation. Increasing real fuel prices by themselves would tend to improve the competitive position of electricity against other energies in the end use because the cost of fuel inputs is only one component of electricity prices.

3.5. Correlation between Electricity Consumption and Economic Activity in the Individual Selected Countries

The historical relationships between per capita electricity consumption and per capita GDP for the nine selected countries --- USA, UK, Germany, Japan, Taiwan, Korea, India, Singapore, and the Philippines, are shown in Figure 3-8.

Some distinct periods were found in each selected country. The UK and USA have shown the downward slope shifts in recent year. Fereidoom P.[25] has described this shift for the USA as being due to the changing composition of the US economy away from energy and electricity-intensive industries toward high value-added manufacturing and service industries. In the United Kingdom it is probably a result of the GDP increment due to the North Sea oil development, which created no additional electricity

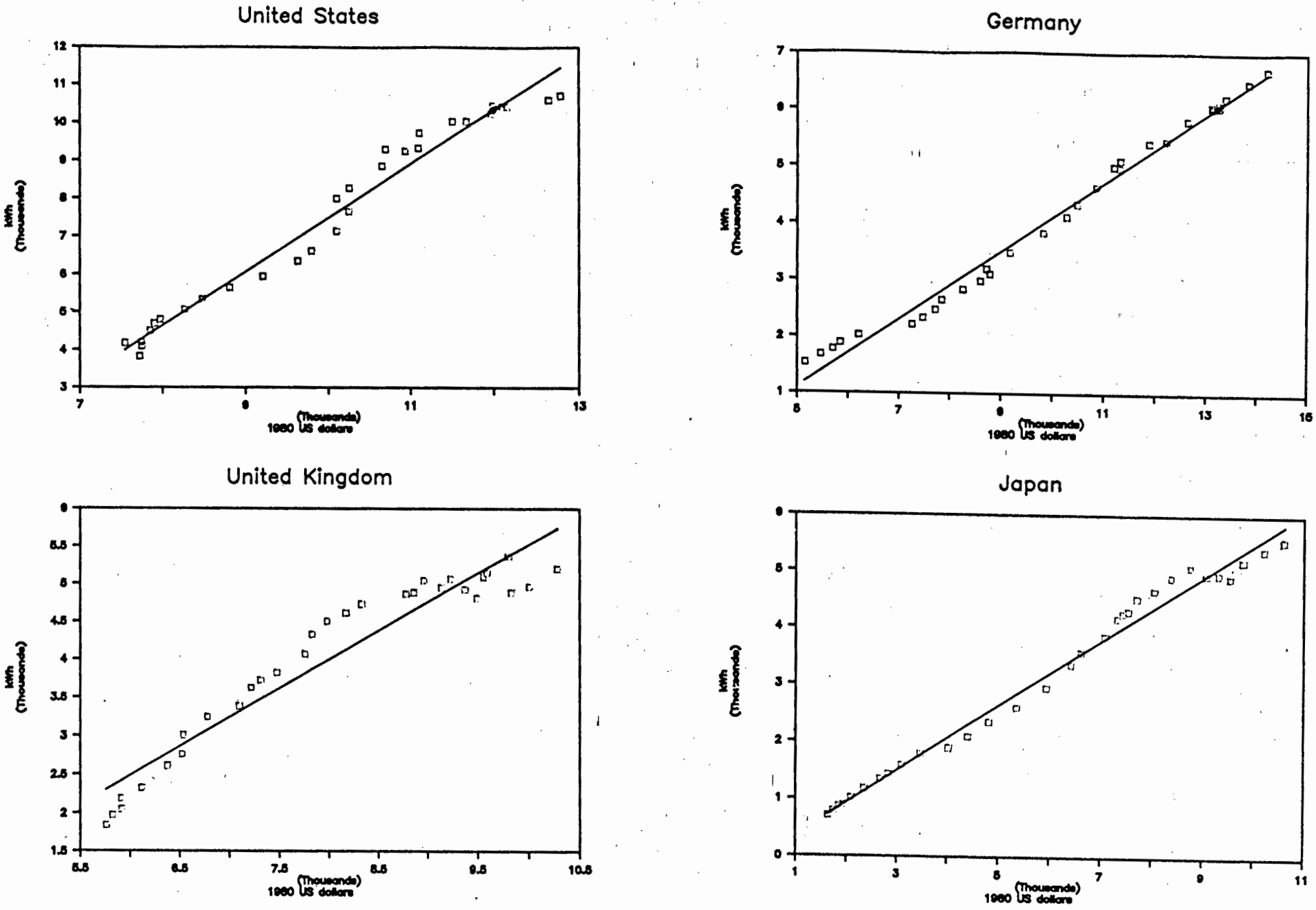


Figure 3-8(a). The Relationship between Electricity and GDP for each Selected Countries, 1955-1985.
Source: Ref.[1]-[5],[9],[10].

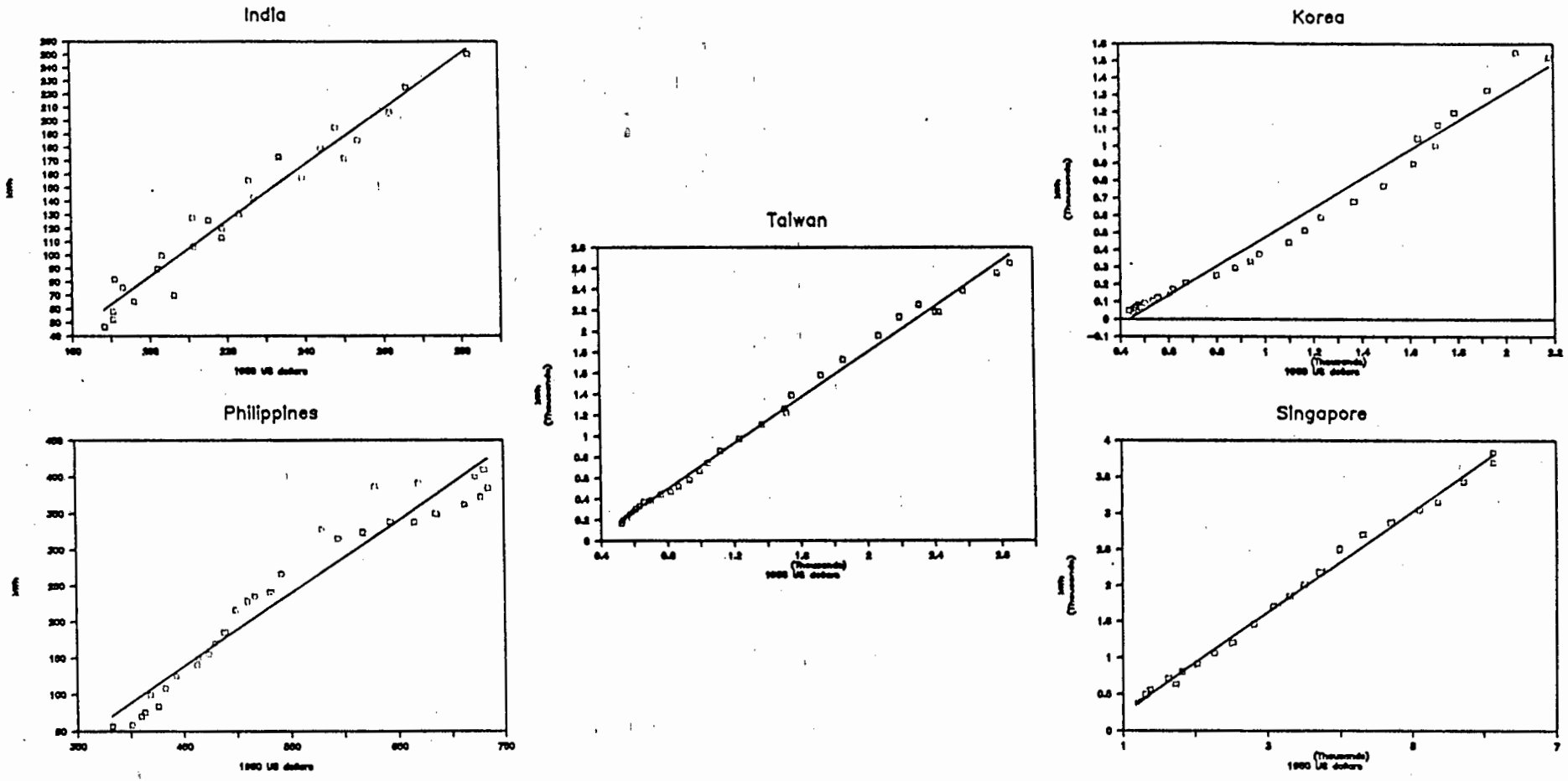


Figure 3-8 (b).

demand. Chauncey Starr[26] has mentioned a similar point of view.

The upward slope in Germany is a result of the increased rates of electrification. In Germany, per capita electricity growth averaged 3.54 %/year from 1970-1985 which was 50 per cent higher than the average per capita GDP growth of 2.33 %/year over the same period. The figure for Japan displays the steep gradient for the electricity/GDP slope before 1979; then the slope decreased sharply from 1979 to 1982; and with a moderate upward gradient thereafter. This is probably the result of the electricity demand stagnation between 1979 and 1982/83 due to the economic recession caused by the second oil crisis[27].

The electricity-GDP connection is not limited to the industrialized countries, but is also strong in three industrializing countries (Taiwan, Korea, and Singapore) and two developing countries(India and the Philippines). In fact, these countries are experiencing increased rates of electrification, which is evident from the increased slope of the relationship in the last decade and a half.

The relationships shown in Figure 3-8 can be given by a simple linear model which Leonard[28] has prepared for the UK:

$$E_t = A + B\,(GDP_t) \qquad (3\text{-}1)$$

where E is per capita electricity consumption made available in the selected countries, GDP is annual per capita GDP in 1980 US dollar, and t designates the year.

The statistical correlation coefficients(R square) for this model in various selected countries for the 1955-1985 period are shown at Table 3-5, and display a very good long-term relationship between per capita electricity and real per capita GDP in each country.

Table 3-5. The Per Capita Electricity and Per Capita GDP Correlation R Squared for the Selected Countries for 1955-1985

High-income Country		Middle-income Country		Low-income Country	
USA	0.9747	Taiwan	0.9951	India	0.9549
UK	0.9206	Korea	0.9773	Philip-pines	0.9413
Germany	0.9879	Singapore	0.9955		
Japan	0.9870				

Source:Ref.[1]-[5],[9],[10].

3.6. Correlation between Per Capita Electricity Consumption and Per Capita GDP from Cross-Country Comparison

There are two different types of electricity-income intensities: one reflecting changes over time within each country, the other giving the combined intensity for the whole group of countries at each point in time.

The cross-country intensity is usually interpreted as an indicator of the general long-term electricity consumption pattern; i.e. the broad path that the average country will follow as it develops. This assumption of the electricity consumption

pattern may be reasonable if no structural breaks occur, although one is assuming that the economic and energy systems of all countries will develop along similar paths. However, no assumption of this kind can be valid for periods of the rapidly changing energy situation such as those during the 1970s.

In this section the study will focus on aggregate electricity intensities, or ratios, which relate electricity consumption to a macroeconomic variable such as GDP. In the comparisons, per capita GDP is converted to 1980 US dollars using purchasing power parity adjustment as indicated in the previous chapter.

In Figure 3-9 electricity consumption is plotted against GDP, both on a per capita basis. Obvious points are that there are large vertical differences between countries at roughly the same level of per capita income as well as the expected differences between countries at different income levels. The slope of the trend line of all the selected countries for the 1955-1985 period, i.e., the average electricity intensity, is 0.5889, which indicates that to produce a unit 1980 US dollar valued output consumed 0.5889 kWh electricity. The data points for Germany are below the trend line, which indicates Germany consumed less electricity than the average for each dollar of the national output; the data points of USA, Taiwan are above the trend line, which implies that these two countries consumed more electricity to produce the same output than the others; and other selected countries are around (above and below) the line. The correlation

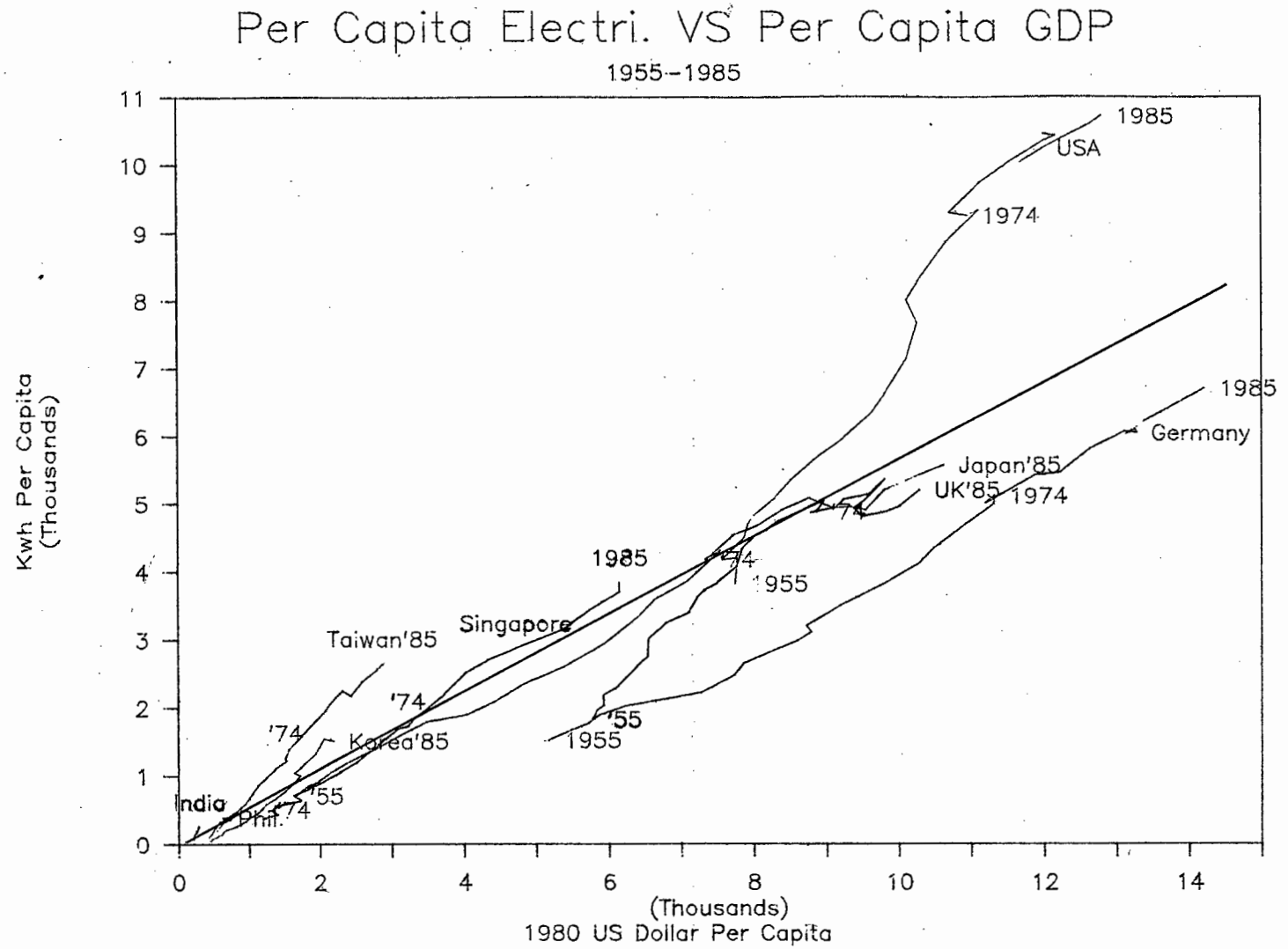


Figure 3-9. The Relationship between Electricity Per Capita and GDP Per Capita for the 9 Selected Countries, 1955-1985.

Source: Ref.[1]-[5],[9],[10].

coefficient, R squared, for the relationship between per capita electricity and per capita GDP of aggregated country falls to 0.8538.

In order to find out whether the relationship changed after the oil crisis, the whole period from 1955-1985 has been separated into two segments, one from 1955 to 1973 (Figure 3-10), the other from 1974 to 1985 (Figure 3-11). The correlation coefficient for the 1955-1973 period was 0.8652, and 0.8369 for the 1974-1985 period.

There are no systematic variations in electricity intensities over 1955-1973 segment that have been found at Figure 3-10; but two trends (A and B lines) exist in Figure 3-11 for the 1974-1985 period. The A line included USA, Taiwan, and India with a steep gradient for the electricity/GDP slope, and with the value of the slope at 0.8555; The B line had a shallower gradient, and with the slope at 0.4734 included the rest of the selected countries. Correlation coefficient of line A was 0.9992, and that of line B was 0.9732.

As the industrial sector has been the largest in electricity consumption, energy usage, and GDP in most of the selected countries, the industrial shares of GDP, of electricity, and of energy in the A line and B line countries were examined in Table 3-6. No uniform variations in the composition of industrial electricity use, energy consumption, and output for A line and B line countries have been identified.

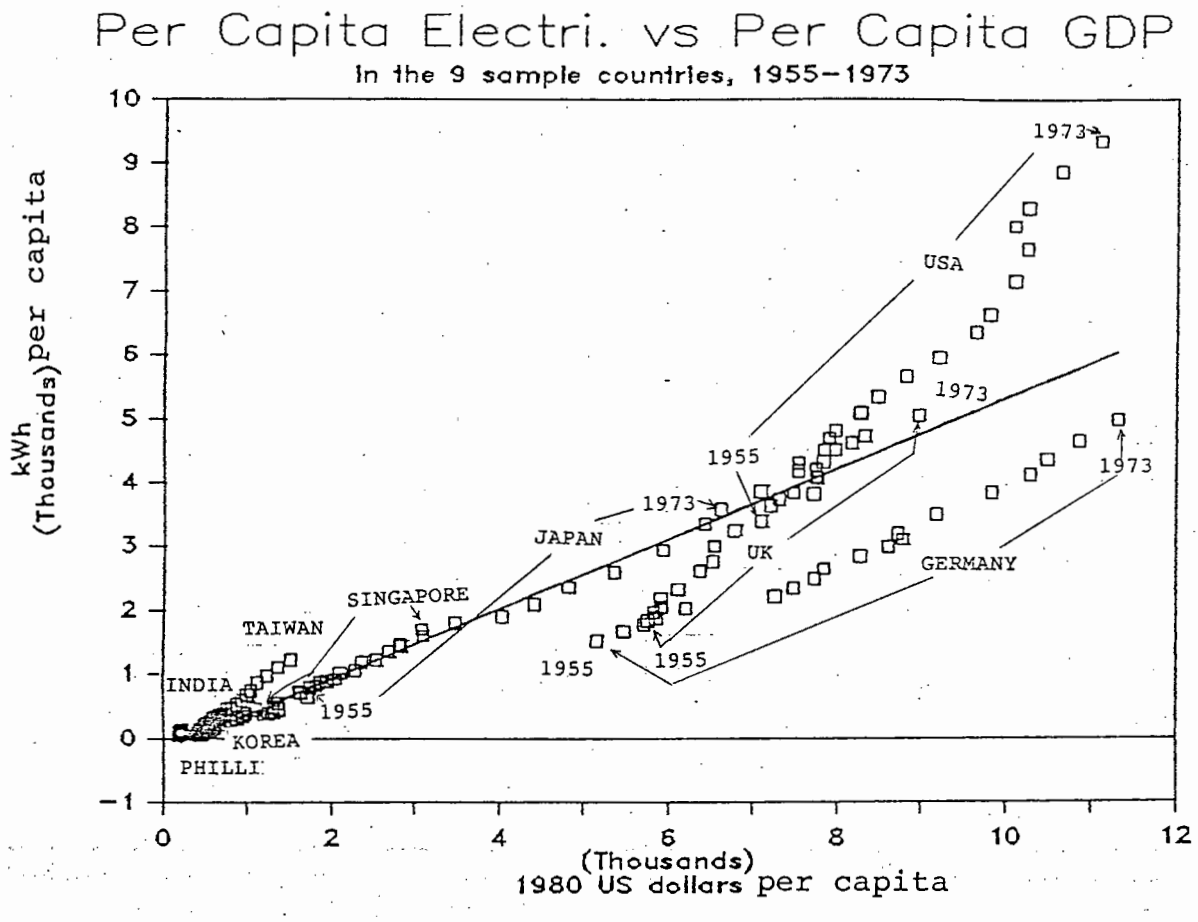


Figure 3-10. Electricity Per Capita versus GDP Per Capita for the 9 Selected Countries, 1955-1973.

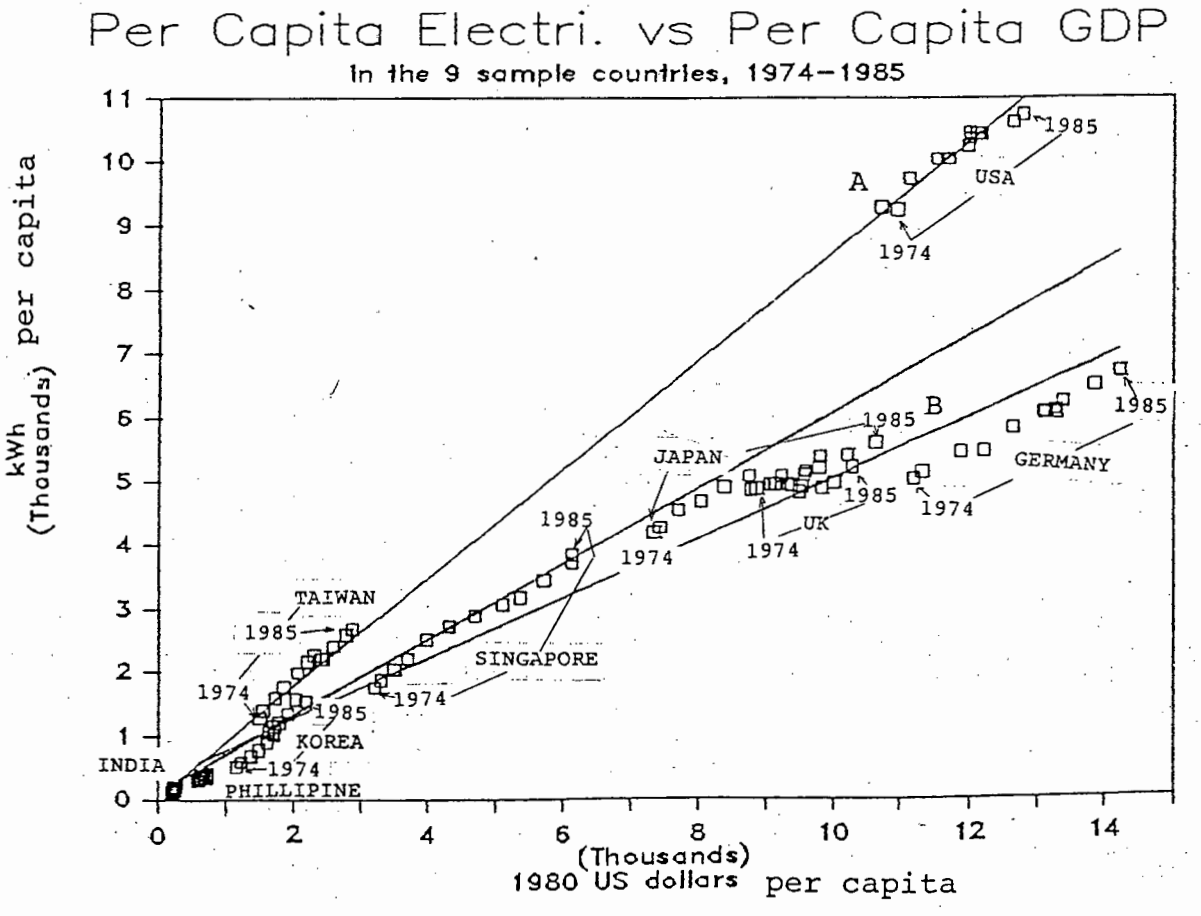


Figure 3-11. Electricity Per Capita versus GDP Per Capita for the 9 Selected Countries, 1974-1985.

Table 3-6. Industrial Share of GDP, Electricity, and Energy in the A Line and B Line Countries

	Country	Electricity	Energy	GDP
		(%)		
A line countries	USA	34	31	32
	Taiwan	55	48	49
	India	60	61	23
B line countries	UK	35	31	36
	Germany	47	36	38
	Japan	60	48	42
	Korea	68	44	39
	Singapore	49	34	38
	Philippines	35	36	36

Source: Ref.[12]-[14].

To examine the relationships existing in the two trends, another five countries were chosen as new sample countries, they are France, Italy, Greece, Spain and Brazil. These countries have also been divided into groups, depending on their GDP per capita ratio as for the previously selected nine countries. The high-income countries that are considered to have a GDP per capita ratio of greater than 1980 US $ 7000 per capita included France and Italy; middle-income countries that were between 1980 US $ 7000 and US $ 1000 per capita included Greece, Spain, and Brazil.

In Figure 3-12 the electricity per capita is plotted against GDP per capita in the fourteen countries (nine selected countries plus five new sample countries) for the 1955-1985

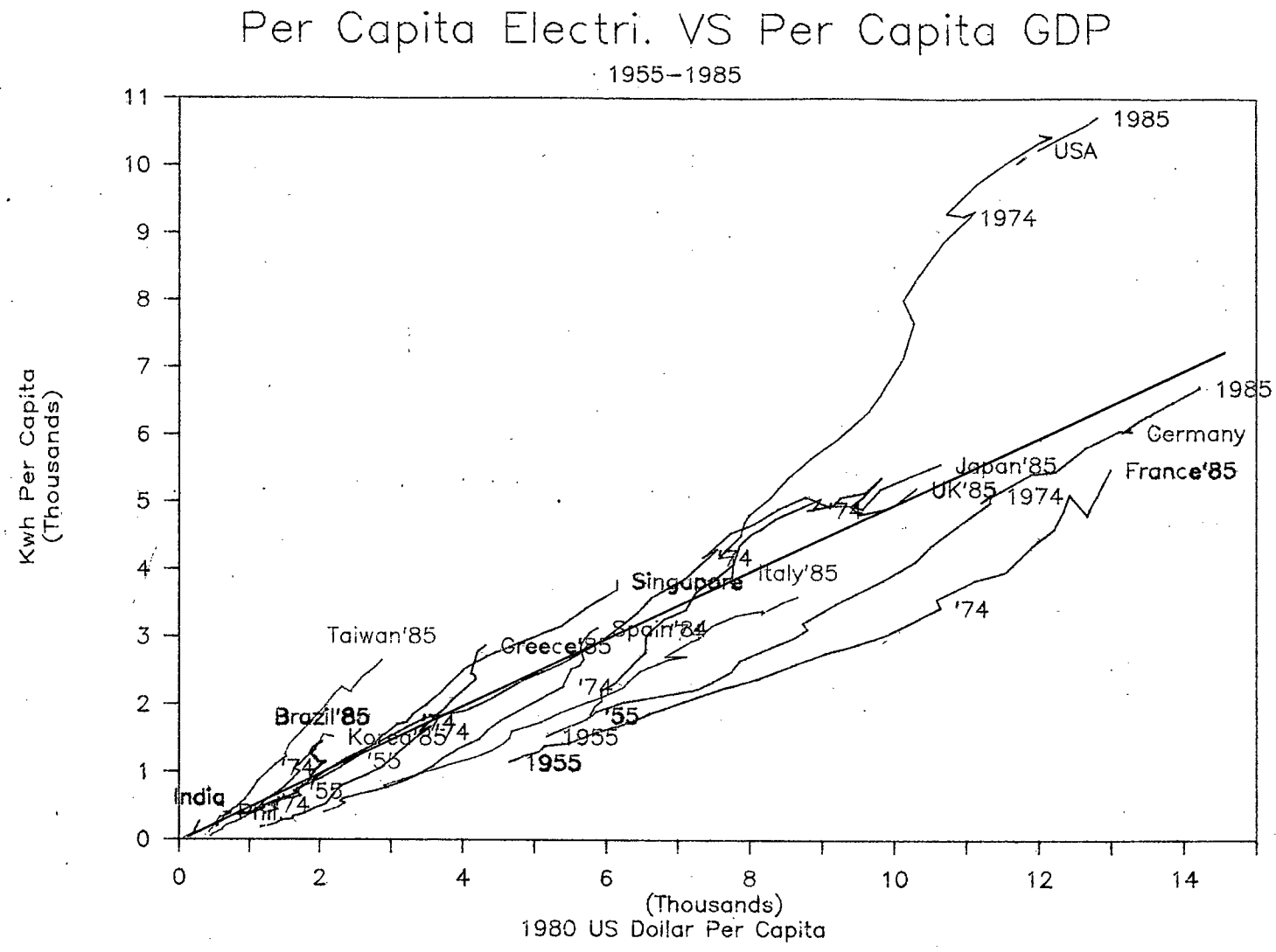


Figure 3-12. Electricity Per Capita Versus GDP Per Capita for the 14 Sample Countries, 1955-1985.

Source: Ref.[1]-[5],[9],[10].

period. The relationship is expressed by the equation:

$$E_t = -193.254 + 0.5354 \left(GDP_t \right) \qquad (3\text{-}2)$$

The correlation coefficient(R squards) for this equation is 0.8023. The intensities of all five new sample countries in 1974-1985 period are between 0.3 and 0.6(where A line is 0.8555, B line is 0.4734).

3.7. A Relationship Model of Per Capita Electricity Consumption

The relationship between the per capita electricity consumption and per capita GDP was replotted here on a double - natural logarithmic diagram. The gradient of the resulting line gives the income elasticity of electricity consumption as a quantitative expression of the correlation; i.e., the percentage change of electricity consumption associated with a 1 % change in GDP. The ln-ln relationship is shown in Figure 3-13 and is given by the equation:

$$\ln E_t = -1.33246 + 1.06318 \ln \left(GDP_t \right) \qquad (3\text{-}3)$$

The R squared for this equation is 0.9065 for the 1955-1985 period; 0.9153 for 1955-1973, and 0.9502 for 1974-1985.

As shown in equation (3-3), the use of per capita GDP "explains" 90.65 per cent of the variation in per capita electricity use over the 1955-1985 period. One of the factors which serves to explain part of the remaining variations in electricity per capita use is lags in the response of electricity

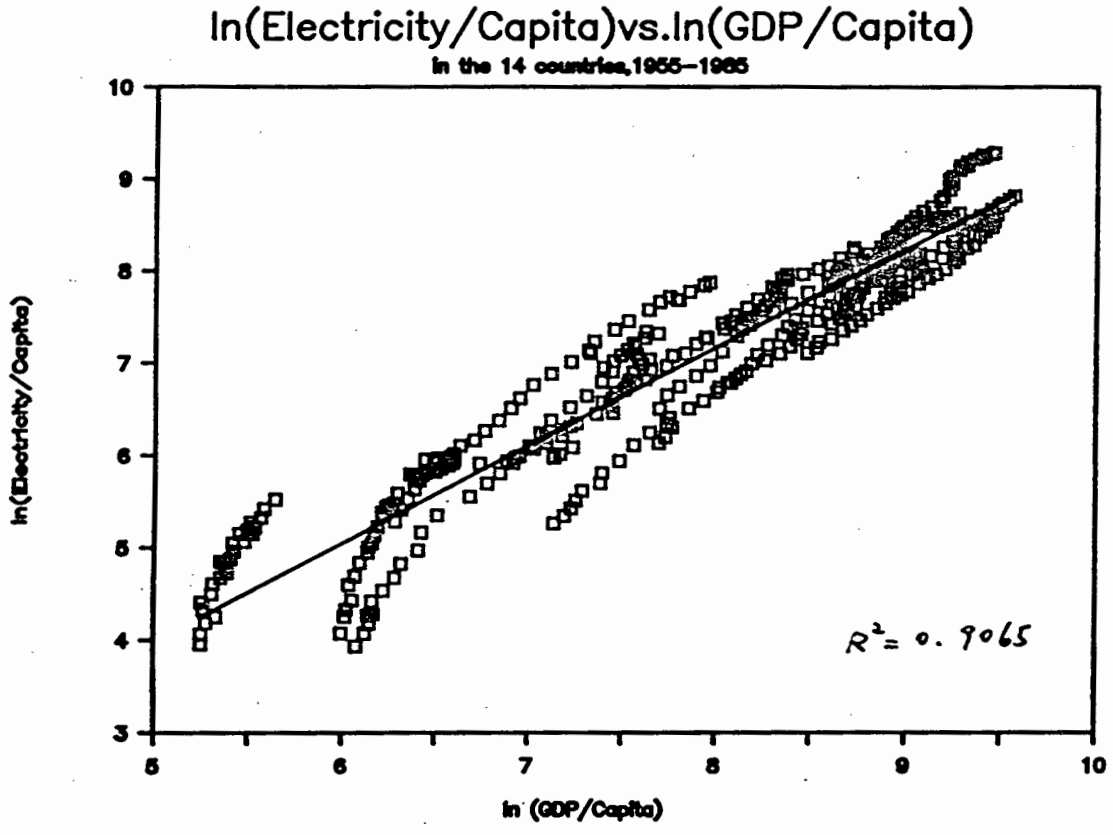


Figure 3-13. The log-log Relationship between Electricity and GDP.

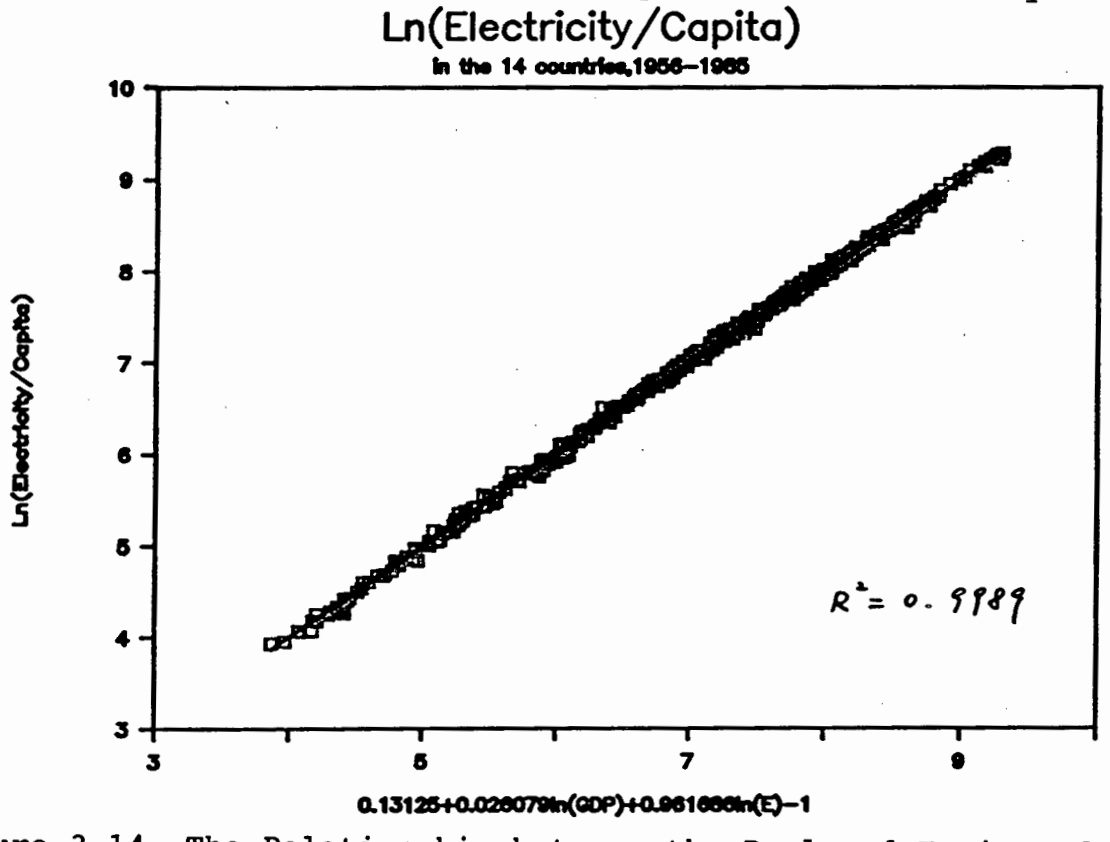


Figure 3-14. The Relationship between the Real and Estimated Per capita Electricity Consumption for the 14 Sample Countries, 1956-1985.

use to changes in economic variables, including GDP.

By combining per capita GDP and a lag per capita electricity consumption into a single equation the following relationship is obtained:

$$\ln E_t = 0.13125 + 0.026079 \ln (GDP_t) + 0.961686 \ln (E_{t-1}) \quad (3\text{-}4)$$

where subscript -1 denotes one - year lag value. The R squared for this equation for 1955-1985 is 0.998934.

The use of GDP and electricity consumption lagged one year on a per capita basis "explains" 99.89 per cent of the variation in per capita electricity use over the whole selected period; only 0.11 per cent of the variation now remains unexplained. Figure 3-14 shows the relationship between the real and estimated per capita electricity consumption.

To expand the explanation of the relationship equation and to get a more "precise" relationship model of per capita electricity consumption, another factor - per capita primary energy has been included as an independent variable. Since the electricity industry consumes more primary fuel than any other single industry(usually accounting on average for about one-third of the primary energy requirements of most countries), and an increased penetration of electricity into the secondary energy market occurred in most countries led to the electricity/ primary energy consumption exhibiting a long-run increasing trend. It seems obvious that there must exist a relationship between

electricity consumption and primary energy usage.

A partial adjustment is postulated, so the model also includes lagged variables, lag per capita electricity, energy, and GDP. Combining per capita GDP, per capita energy, and three lagged variables yields:

$$\ln E_t = A + B \ln(GDP_t) + C \ln(Energy_t) + D \ln(E_{t-x}) + F \ln(Energy_{t-x}) + G \ln(GDP_{t-x}) \quad (3\text{-}5)$$

where the regression coefficients B,C,D,F,G, can be interpreted as elasticities because the variables are in the form of logarithms; subscript -x denotes x - year lag value.

The excellent cross-country statistical results (R squared) for one-year lagged adjustment variables model for the 1956-1985 period are 0.9992. The R squared for five-year lagged adjustment variables model for the 1960-1985 period at aggregate level is 0.9954; and for ten-year lagged adjustment variables model for the 1965-1985 period is 0.9903. Although the value of the correlation coefficient R squared decreased gradually as time lag increased, the statistical results are still excellent. The equations of the relationships above can be expressed as:

$$\ln E_t = 0.08629 + 0.504539 \ln(GDP_t) + 0.178191 \ln(Energy_t) + 0.957768 \ln(E_{t-1}) - 0.4977 \ln(GDP_{t-1}) - 0.15095 \ln(Energy_{t-1}) \quad (3\text{-}6)$$

$$\ln E_t = 0.338366 + 0.678325 \ln(GDP_t) + 0.223538 \ln(Energy_t) + 0.804801 \ln(E_{t-5}) - 0.63765 \ln(GDP_{t-5}) - 0.10452 \ln(Energy_{t-5}) \quad (3\text{-}7)$$

$$\ln E_t = 0.513091 + 0.660386 \ln(GDP_t) + 0.298222 \ln(Energy_t) + 0.611029 \ln(E_{t-10}) - 0.56462 \ln(GDP_{t-10}) - 0.06172 \ln(Energy_{t-10}) \quad (3\text{-}8)$$

The results of the correlations of the relationship test and their figures, including electricity vs. GDP, total final energy, fuels, population, and sectoral production, etc., are presented in Appendix B.

The obvious question is why these relationships do not contain variables representing electricity price(which has been discussed by B.W.Ang[29] and Ronald J.[30] in their studies of electricity/GDP and energy/GDP), conservation, structural change, and other factors that have been mentioned previously? It is therefore appropriate to point out that in the analysis here the relevance of these factors is not neglected. The analysis simply implies that apparently relevant factors not explicitly included in the analysis are either collinear with one or more of the variables used or have effects which largely cancel each other. Humphrey[31] described a similar version in his study.

Gerald[32] has pointed out that whilst real electricity prices have increased in the last decade, the prices of competing

energy forms have risen even more, thus the ratio of electricity prices to competing energy prices continued its long-term decline after 1973. Saritt[33] also pointed out that on a national level time series cannot account for the fact that price schedules of different utilities move different amounts at different times. These movements show up as only relatively small change in the national scene. While higher electricity prices undoubtedly discouraged some electricity consumption, higher prices of other energy forms brought the substitution from those forms to electricity. i.e., electricity price changes are not the most important determinants of electricity consumption growth; the important force in electrification is the cheapening of electricity relative to other forms of energy. Therefore, the price schedule shifts are ignored in this analysis.

Nonprice induced conservation is very difficult to measure. One gets the impression that there have been some notable conservation successes and some notable failures. In part the successes have been offset by the increased use of electricity to avoid pollution problems at the point of end use.

The electricity-intensive industries, such as primary metals, have decreased in the industrial countries since the oil crises. If the trend goes toward the less intensive electricity use, it is likely to dampen the electricity growth in relation to the national output. However, changes in the composition of the national output toward the less electricity-intensive goods and services have been offset by an overall rise in the use of

electricity throughout the entire economy.

The economic growth results from a complicated interweaving of various factors of production-- capital, labor, materials, and energy-- whose relative contributions vary with time. Electricity use and gross domestic product have been, and probably will continue to be, strongly correlated. Other factors in the relationship between electricity consumption and economic activity included prices, technical changes, and interfuel composition only help to explain the departures from the mean trend line illustrated in Figure 1-2. However, the strength of their effects is not so great as to alter the fundamentally strong link between the growth in electricity use and the growth in GDP.

The relationship between electricity consumption and economic activity on a per capita basis has been investigated for various countries and at the aggregate level. It is found that the use of per capita GDP, per capita commercial energy, and the time lagged variables establish a general form of relationship model of per capita electricity consumption. The excellent statistical results from the cross-country comparison reveal that these factors may explain the trends in the per capita electricity use and confirms the close tie between electricity consumption and economic activity.

CHAPTER 4. ELECTRICITY CONSUMPTION AND SECONDARY ENERGY USAGE

4.1. Introduction

In Chapter 3 it has been observed that electricity consumption historically has grown at a faster pace than the economic development in most countries. More importantly, the relationship between electricity consumption and the economic growth has been much stronger than that between energy consumption and GDP (See Figures 2-8 and 3-7). While energy consumption dropped off in most countries in 1973 and again in 1979, electricity consumption continued to increase even during the recession periods. Three important contributing factors have improved electricity's competitive advantages relative to those of other forms of the end-use energy.

First of all, since 1973 electricity has gained a substantial cost advantage over other fuels in most countries; Secondly, the changing composition of the developed economy away from energy-intensive industries toward high value-added manufacturing and service industries favors the substitution of electricity for other forms of energy; and thirdly, electricity's unique properties - for example, cleanliness and high efficiency at the point of use, ability to adapt to many end-use applications, and unique control and adjustment properties, are not offered by other fuels.

Compared with the reduction of per capita energy usage,

the increasing per capita electricity consumption implied a rising share of electricity in the energy demand sector. The purposes of this chapter are to investigate the changing role of electricity in the energy mix and to discuss the saturation level of electricity share in energy in certain selected countries.

Commercial fuels and traditional fuels(non-commercial fuels) are rather distinct energy sources. Traditional energy sources are generally grouped into two categories, namely fuelwood(including charcoal), and other sources such as cow dung and crop residues. Figure 4-1 shows the commercial fuel and traditional fuel shares of the total energy usage for the 14 selected countries in 1985. In India, the Philippines, and Brazil traditional fuels form a significant portion of their total energy use. If such low-efficiency energy consumption is added to the total primary commercial energy consumption it would invariably increase the total energy consumption and greatly alter the electricity - energy relationship in some developing countries.

There also exists the problem of measuring the efficiency of electricity generation. Table 4-1 shows the yearly efficiency (input/output) of the thermal power plant in the selected countries from 1980-1985.The variations of the efficiency exist not only between countries but also within a country. The wide variation can be seen from the fact that the average efficiency between 1980 and 1985 was 40.3% in Korea, but only 24.5% in India; the yearly efficiency in each individual country varied from 39%(1985) to 32%(1984) in Singapore and 38%(1984) to

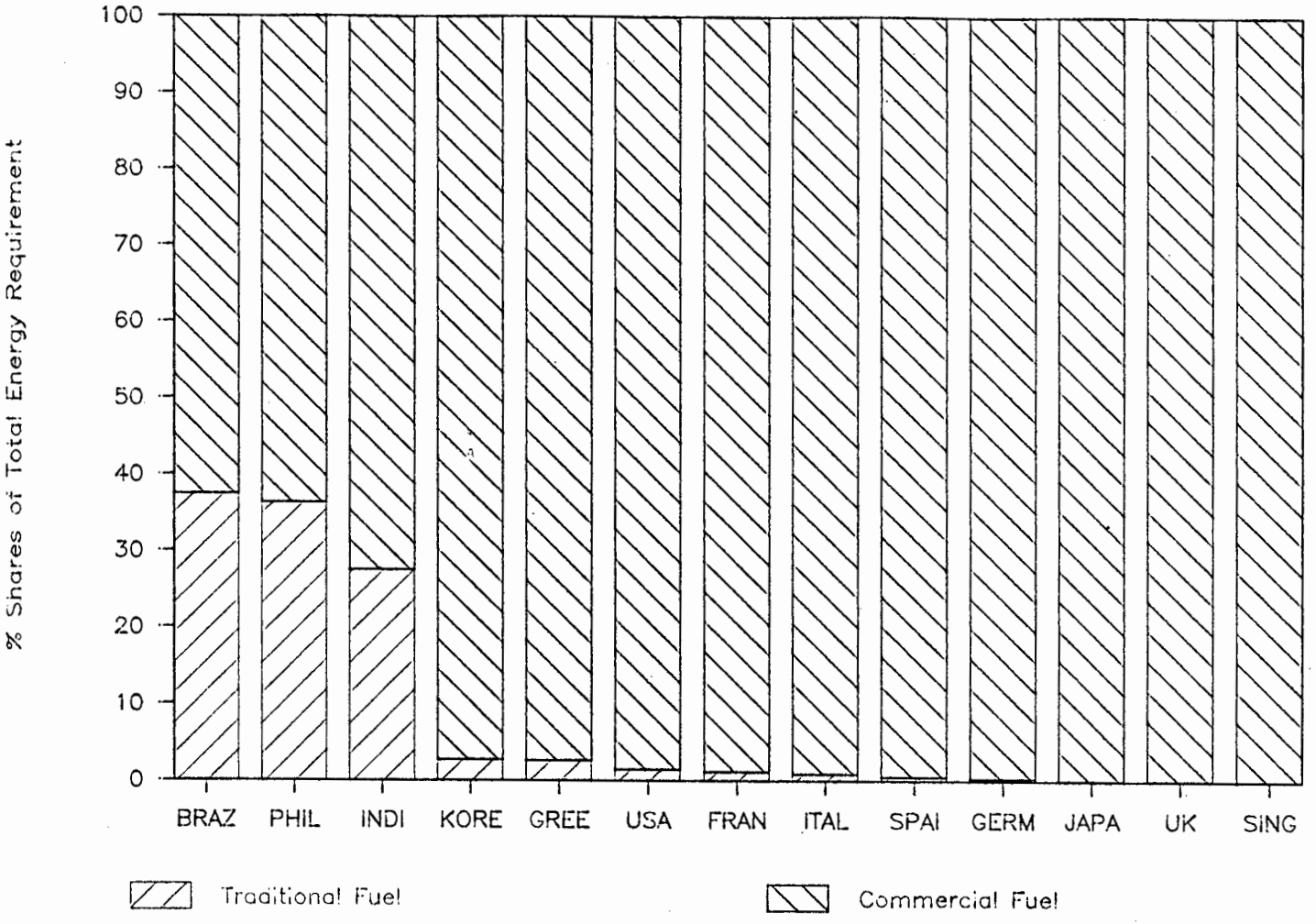


Figure 4-1. The Commercial Fuel and Traditional Fuel Shares of the Total Energy Usage.

Source: Ref.[5].

31%(1985)in the Philippines. The explanations for such differences include the operating technique, load management, and differences between peak load and off-peak load. To avoid these problems comparisons of energy use in this chapter are measured in terms of the secondary energy or final energy.

Table 4-1. Thermal Power Plant Efficiency in the Selected Countries Between 1980 and 1985, %

	1980	1981	1982	1983	1984	1985	Averaged
USA	37.0	36.9	36.8	36.9	37.2	37.1	36.9
UK	35.2	35.4	35.5	36.6	36.9	37.2	36.1
GERMANY	37.2	37.5	37.2	37.7	37.6	37.6	37.5
JAPAN	38.3	38.3	39.2	39.7	38.4	38.5	38.8
FRANCE	38.1	37.6	38.3	38.4	38.1	38.5	38.1
ITALY	39.3	38.5	38.5	39.1	38.9	39.6	38.9
TAIWAN	38.3	38.3	38.5	38.4	37.9	37.1	38.1
KOREA	38	39	40	41	41	43	40.3
SINGAPORE	33	33	37	36	32	39	35
GREECE	35	35.3	34.6	33.9	33.6	33.5	34.3
SPAIN	37.3	35.5	36.5	36.1	35.9	36.3	36.2
INDIA	25	27	24	24	24	23	24.5
PHILIPP.	33	33	37	37	38	31	34.5

Source: Ref.[12]-[14].

For comparing the saturation level between developed and developing countries as well as the convenience of data collection, 9 developed and developing countries from the 14 selected countries have been redesignated as new sample countries in this chapter. Among them USA, UK, Germany, Japan, France, and Italy were regarded as developed countries; while Greece, Spain, and Taiwan as less-developed countries or developing countries.

4.2.Electricity and Energies

The years between 1960 and 1985 can be considered as being the quarter century with the strongest structural changes in the world energy balance. From a heavy reliance on oil, a new approach to energy consumption was adopted during the 1970s. Figure 4-2 and 4-3 show the overall development of fuel shares in the selected countries for that period.

The share of oil still remains dominant in all the selected countries, but has clearly been decreased in most countries since the mid-1970s. In 1985 it was more than 50% in USA, Germany, France, and Italy; 60% in Japan, Spain, and Taiwan; 70% in Greece; and only 43.7% in UK. The share of gas ranked second in the secondary energy use in the western countries.

The greatest reductions in fuel share were observed for coal. In 1960 it was more than 50% in UK, Germany, Japan, France, and Spain, but then it was reduced respectively to 11.3%, 11.9%, 14.3%, 8.9%, and 10% in 1985. Another notable feature is that the secondary energy share of electricity steadily increased in all the selected countries.

The fuels which substituted for oil and coal were electricity in all countries since the 1970s, and gas in most developed European countries: UK, Germany, France, and Italy, etc. This pattern was partly the result of the increasing real price of oil and relatively stable real prices of electricity and the available supply of gas in these countries since the early 1970s.

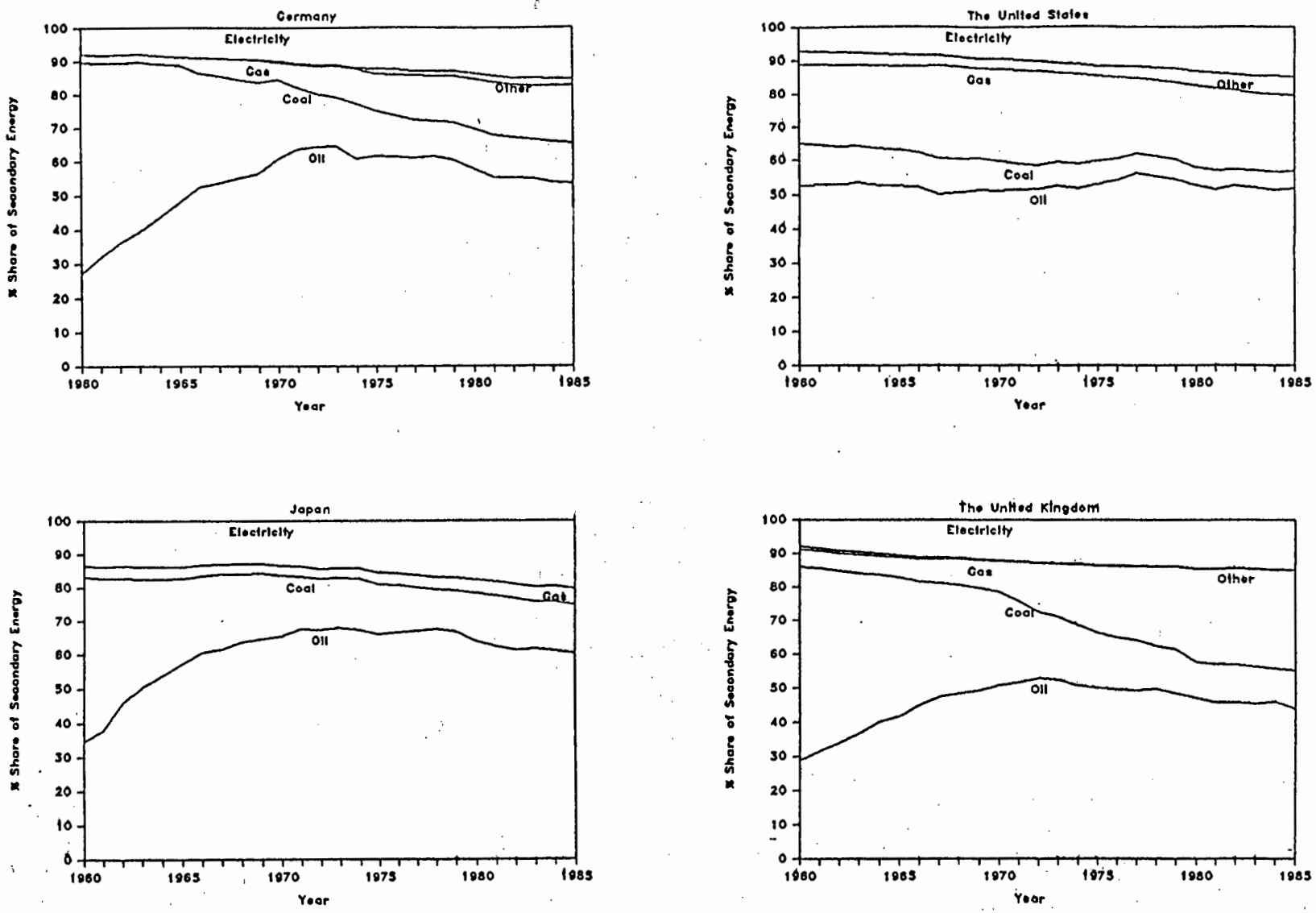


Figure 4-2 (a). The development of the Fuel Shares in each of the Selected Countries.

Source: Ref.[12],[13].

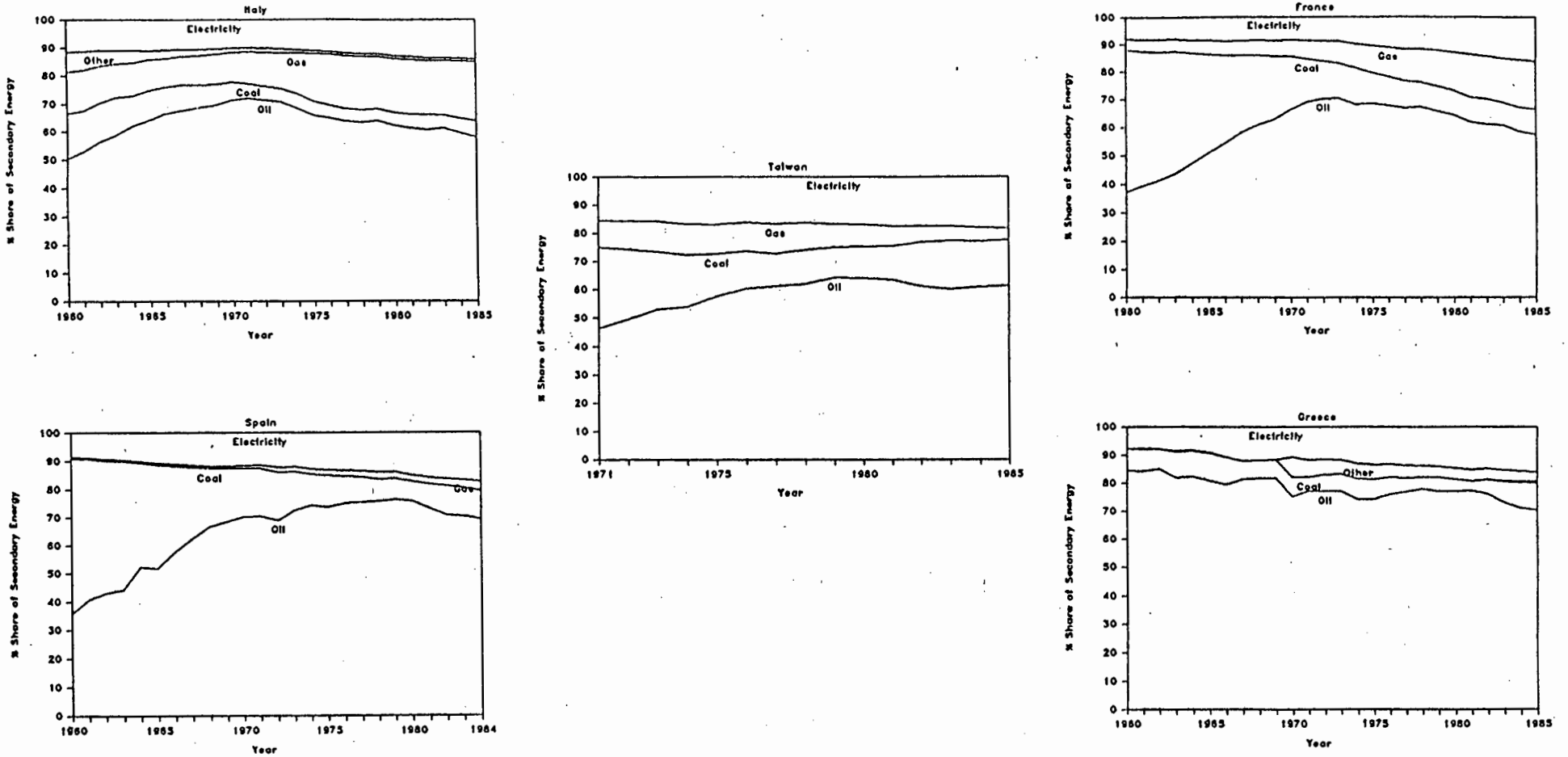

Italy
Electricity
Other
Gas
Coal
Oil
% Share of Secondary Energy
Year
Taiwan
Electricity
Gas
Coal
Oil
% Share of Secondary Energy
Year
France
Electricity
Gas
Coal
Oil
% Share of Secondary Energy
Year
Spain
Electricity
Coal
Gas
Oil
% Share of Secondary Energy
Year
Greece
Electricity
Other
Coal
Oil
% Share of Secondary Energy
Year

Figure 4-2 (b).

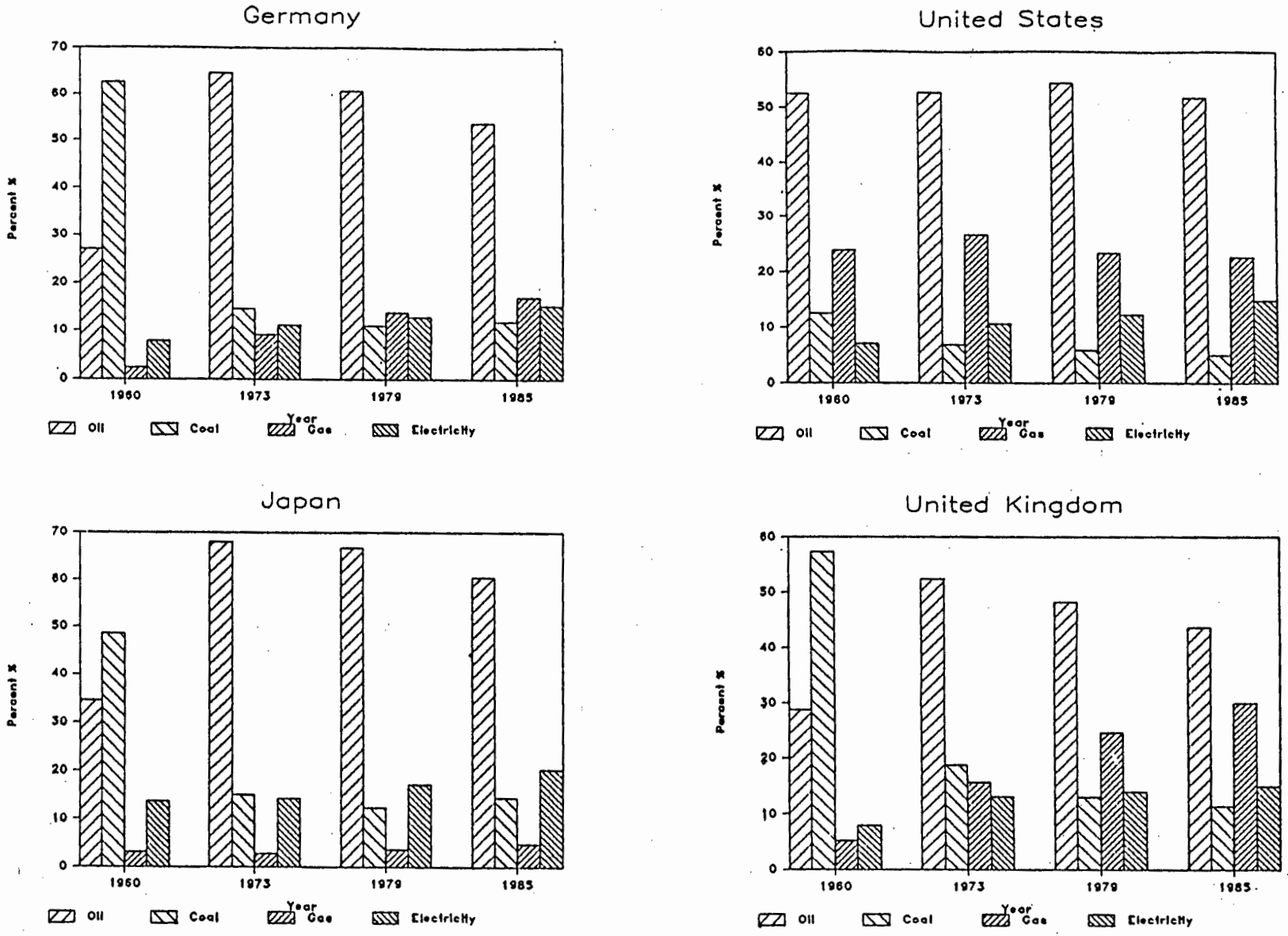


Figure 4-3 (a). Fuel Shares in the Selected Countries for the Years of 1960, 1973, 1979, and 1985.

Source: Ref.[12],[13].

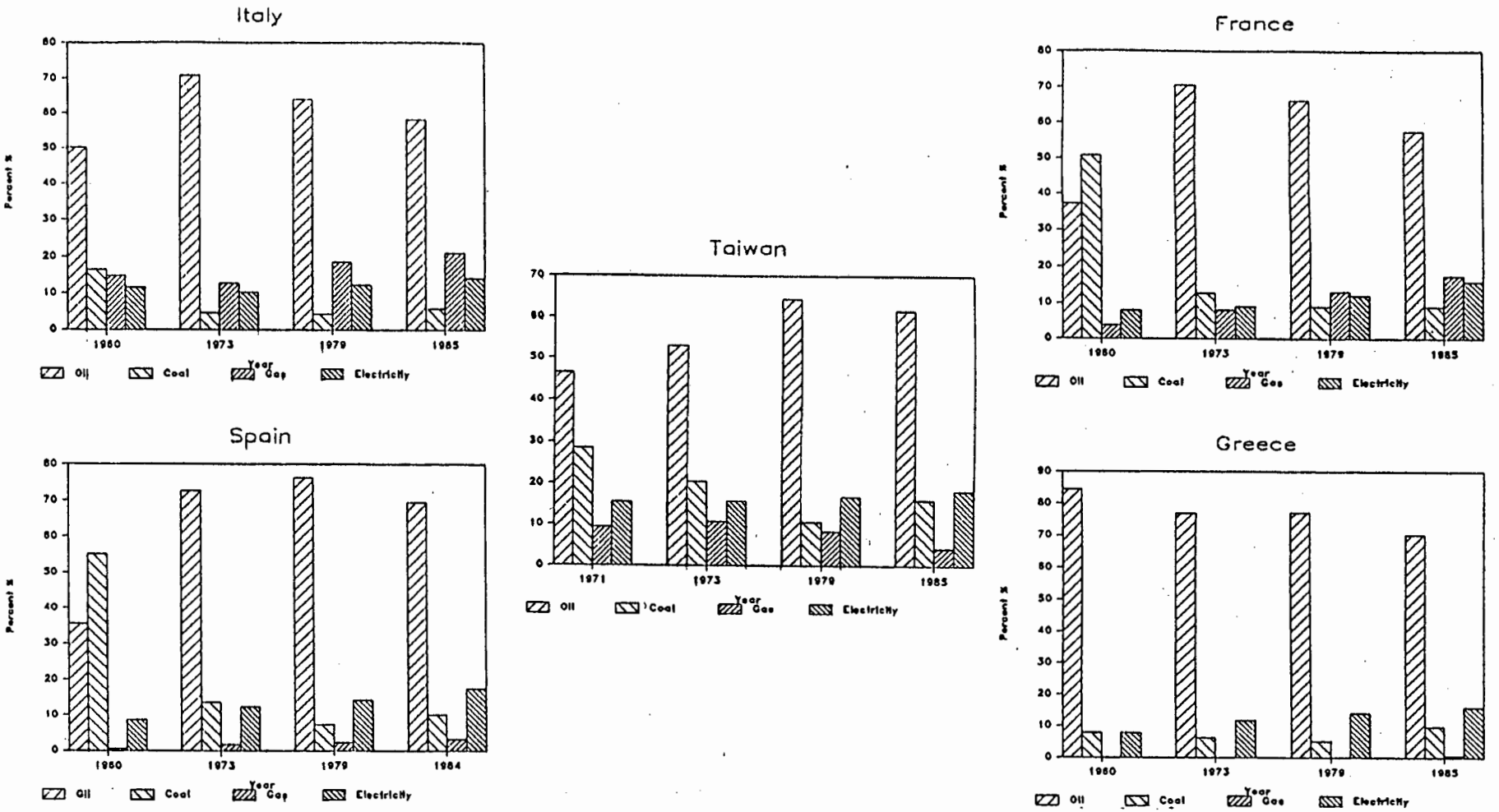

Italy
Spain
Taiwan
France
Greece
Percent %
Year
1960
1971
1973
1979
1984
1985
Oil
Coal
Gas
Electricity

Figure 4-3 (b).

Figure 4-4 shows the annual average growth rates of GDP, the secondary energy, and energy mix in the selected countries for the various subperiods between 1960-1985. In USA electricity has grown faster than GDP and other fuels in each subperiod. The consumption of coal has decreased since 1960, while oil and gas have declined since the mid-1970s.

Due to the development of the North Sea gas since the late-1960s, the growth of gas in UK has kept a significant high rate during the 1960s and 1970s, but has declined in the 1980s. Electricity demand decreased in the past few years.The consumption of oil and coal has decreased since the 1970s and the 1960s.

The energy consumption paths were similar for France and Germany. Eatrada and Fugleberg[34] have examined the interfuel competition for France and Germany, and pointed out that the total energy consumption decrease in these two countries due to the dual effect of improved energy efficiency and low economic activity. France and Germany have been moving away from coal since the 1960s, and moving away from oil more recently during the late 1970s. Electricity and gas have grown faster than the economy, and the growth rate of gas was higher than that of electricity in each subperiod.

Japan is the only country where the growth of the economy is faster than that of fuel consumptions. It is probably a result of the changing composition of the Japan economy that has successfully adjusted from energy intensive industries to less

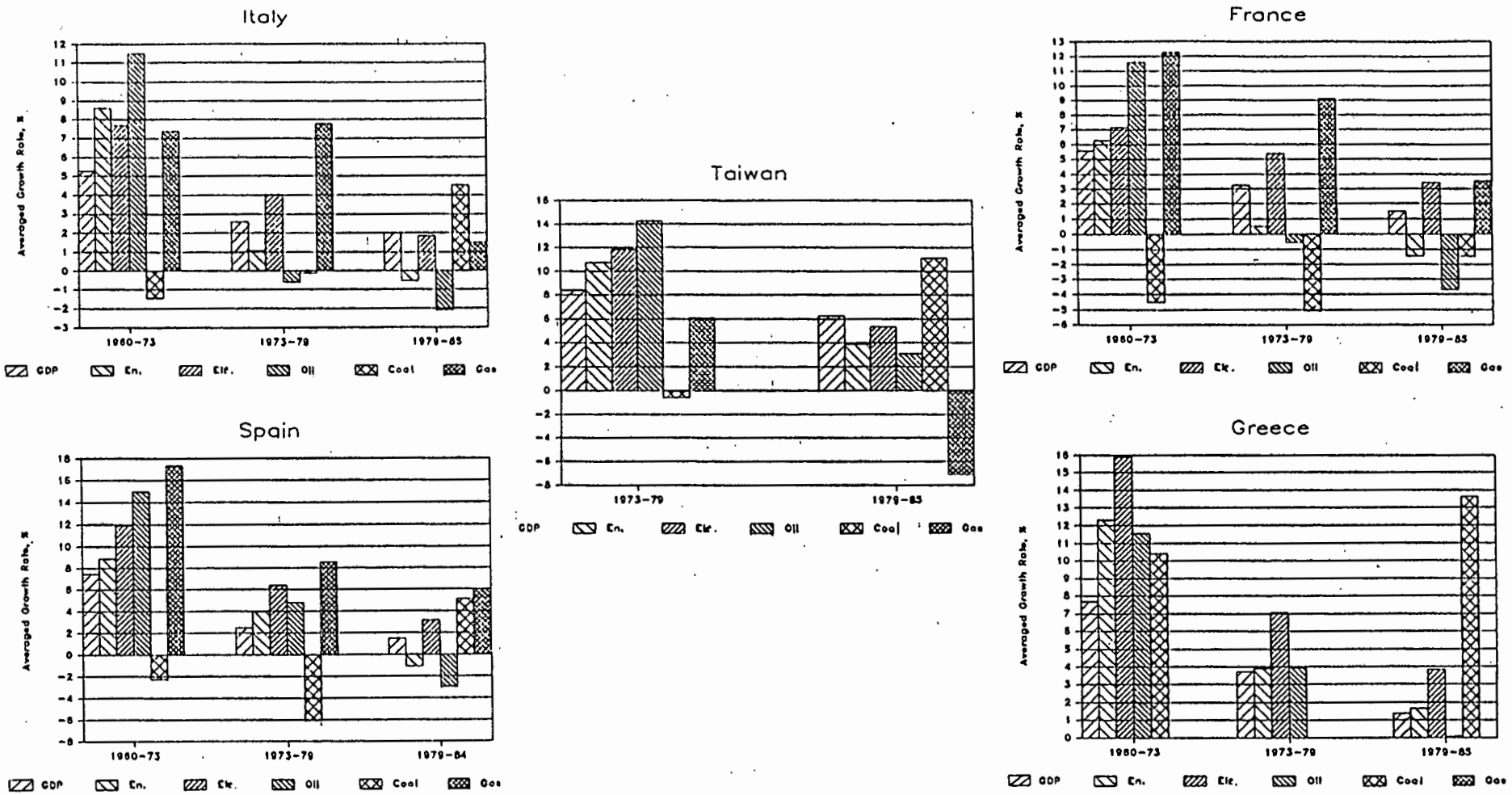

Italy
Averaged Growth Rate, %
1960-73
1973-79
1979-85
GDP
En.
Elc.
Oil
Coal
Gas
Taiwan
1973-79
1979-85
France
Spain
1960-73
1973-79
1979-84
Greece

Figure 4-4 (b).

energy use manufacturing and service industries. Greece also is the only country where the consumption of energy fuels has been increasing all the time, and electricity has grown faster than other fuels, except coal, in each sub-period.

The growths of fuel consumption were similar for Italy and Spain in the 1979-1985 period. Though the consumption of electricity, coal, and gas has increased, the total secondary energy use has decreased. Taiwan is the only country where oil growth has been faster than other fuels in the period between the two oil crises. This is as a result of postponing the reflection of the real oil costs controlled by the government in order to maintain economic growth.

4.3. The S Curve of Electricity Share

The share of electricity in secondary energy usage has been steadily increasing over the last 25 years in all the selected countries(See Figure 4-2). The rising trend is partly because of electricity's unique properties which have been mentioned in the previous section. But the development of electricity also has its disadvantages. For example, as a secondary fuel it is produced mainly from fossil fuels at a low thermal efficiency(around 30 per cent), and, in general, it can not be stored; the electricity industry is highly capital-intensive; and there is the limited substitution for petroleum products in the transport sector, and no substitution of petrochemical feedstock in the industrial sector etc. All of these

might impede the growth of the share of electricity and limit the share at a saturated level.

Therefore, it is to be expected that the increasing trend of the proportion of electricity in the total final energy consumption will be along an "S" shape saturation curve. That is, the growth of the electricity share is initially slow, then increases and finally flattens out to an asymptote, or the final value, i.e., the asymptote of the S curve is the saturation point of the electricity share curve. Figure 4-5 displays the general shape of the S curve.

Figure 4-6 shows the changes of the share of electricity in the secondary energy in the selected countries for the period of 1960-1985.The obvious point is that large differences of electricity share existed not only in each individual country but also across countries. For example, in Japan the share was 13.7% in 1960 and 20.3% in 1985, but in Italy it was only 11% and 14%. This is partly the result of the changing composition of the output, the price competition between fuels, and the household behavior, etc. Each country shown in Figure 4-6 has a high growth rate of electricity share with a steep slope of the share curve and a slow growth with a shallow gradient.

Compared with other countries the growth of electricity's share in UK was relatively low between 1970 and 1985. It is probably a result of the increasing share of gas, since gas substituted mainly for oil and coal, in the UK fuel market.

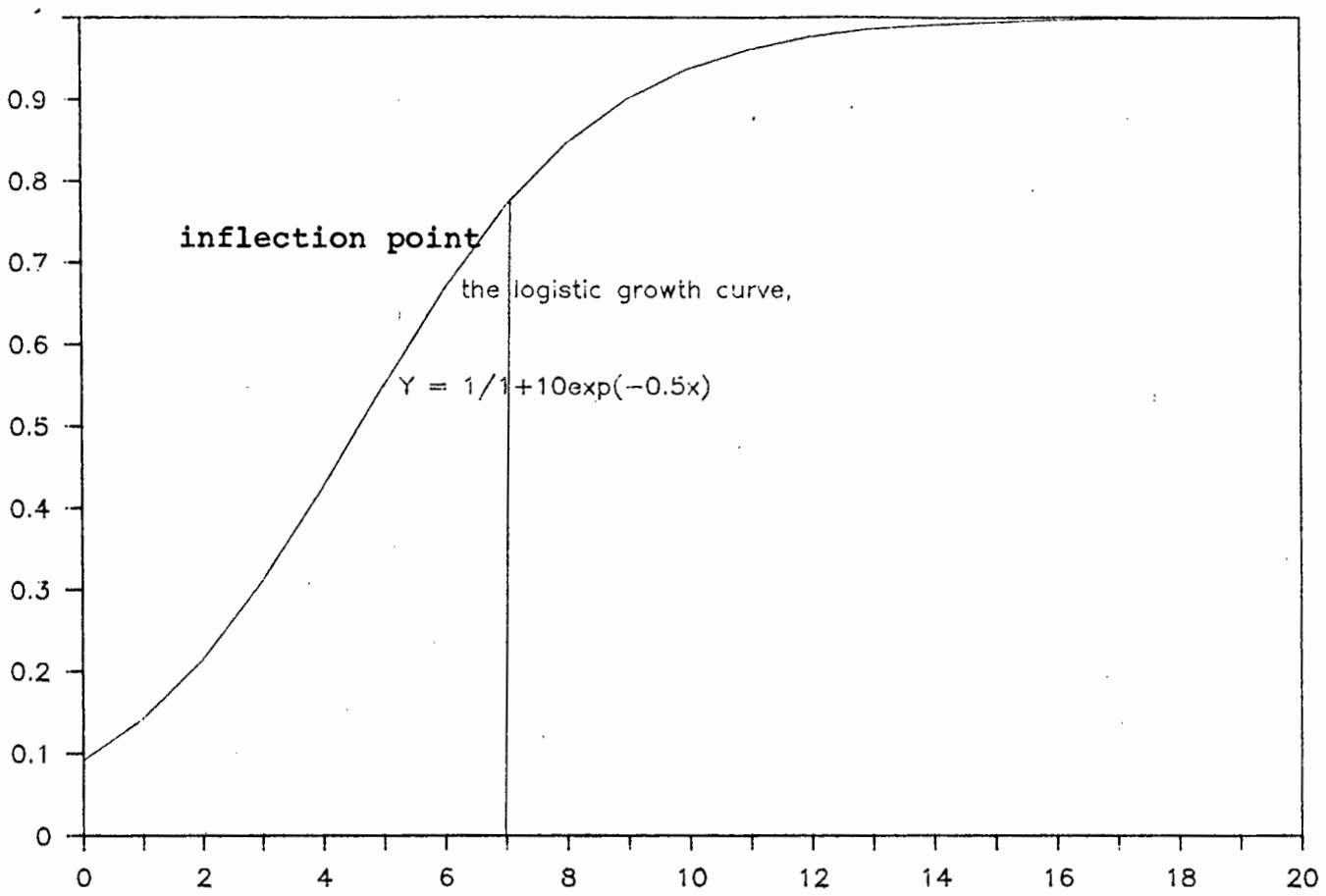
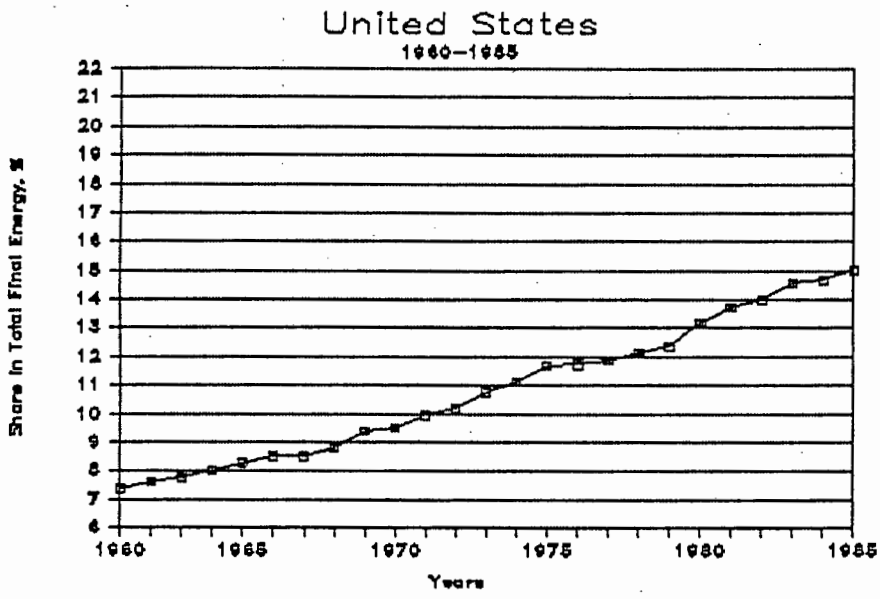
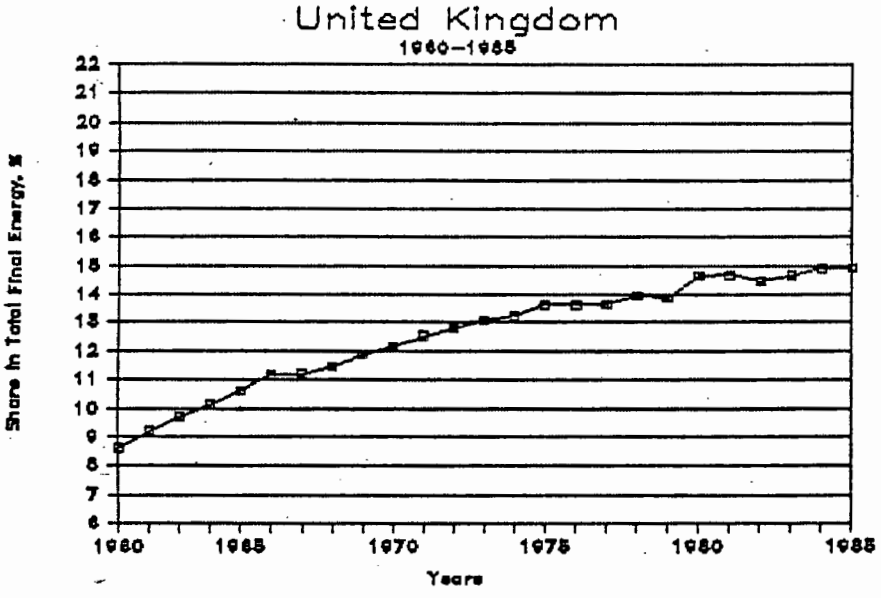


Figure 4-5. The General Shape of S Curve.





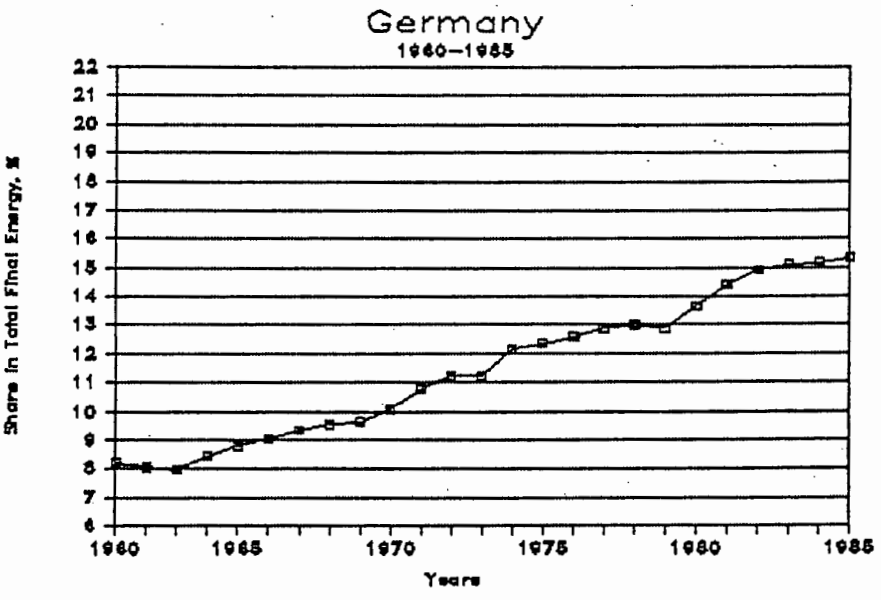
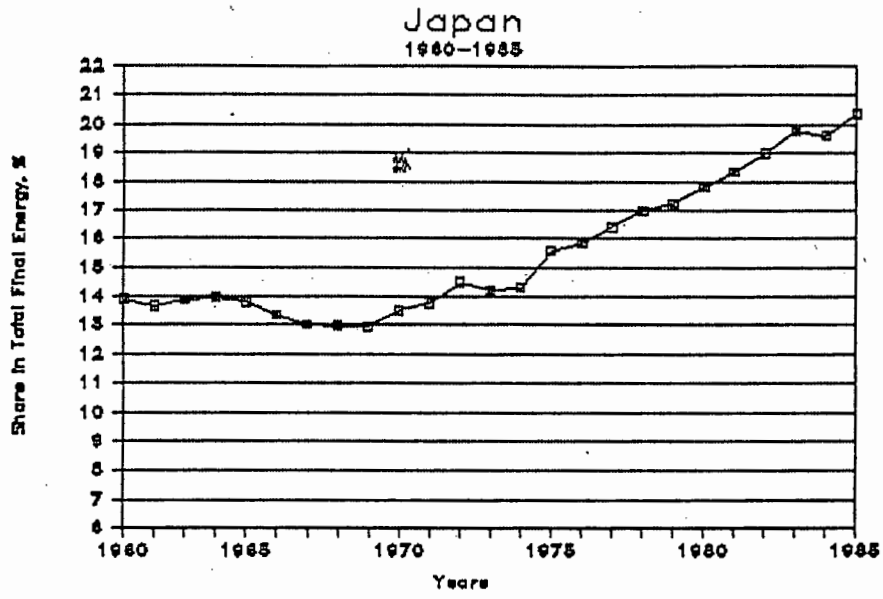


Figure 4-6 (a).

The Shares of electricity in the Secondary Energy Usage for the 9 Selected Countries for 1960-1985.

Source: Ref.[12],[13].


Japan
1960-1985
Share in Total Final Energy, %
Years
1960
1965
1970
1975
1980
1985

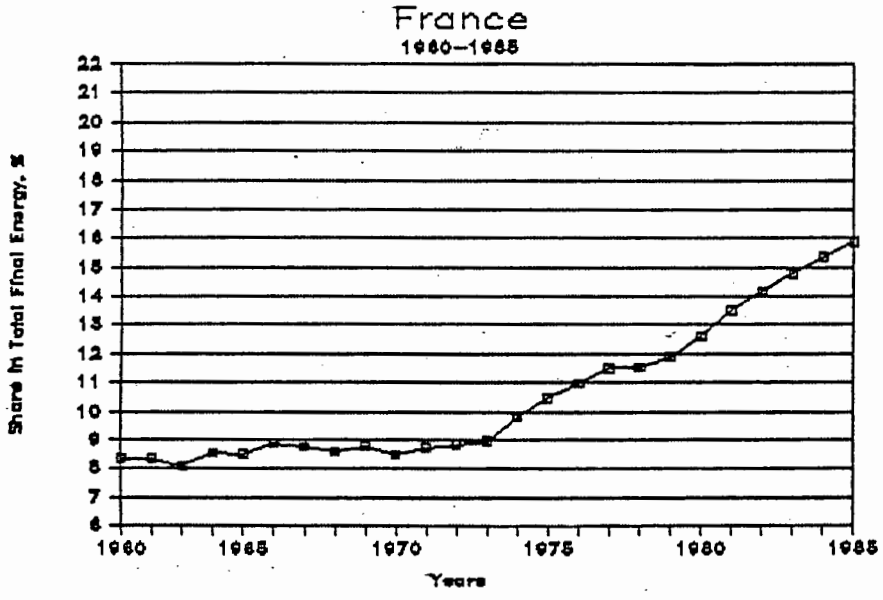

France
1960-1985
Share in Total Final Energy, %
Years
1960
1965
1970
1975
1980
1985

Figure 4-6 (b).


Greece
1960-1985
Share in Total Final Energy, %
Years
1960
1965
1970
1975
1980
1985

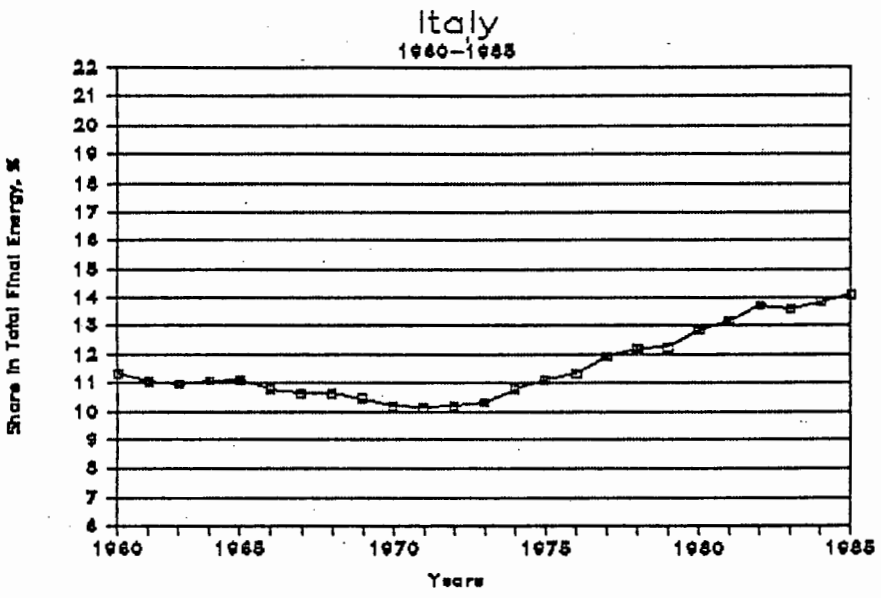
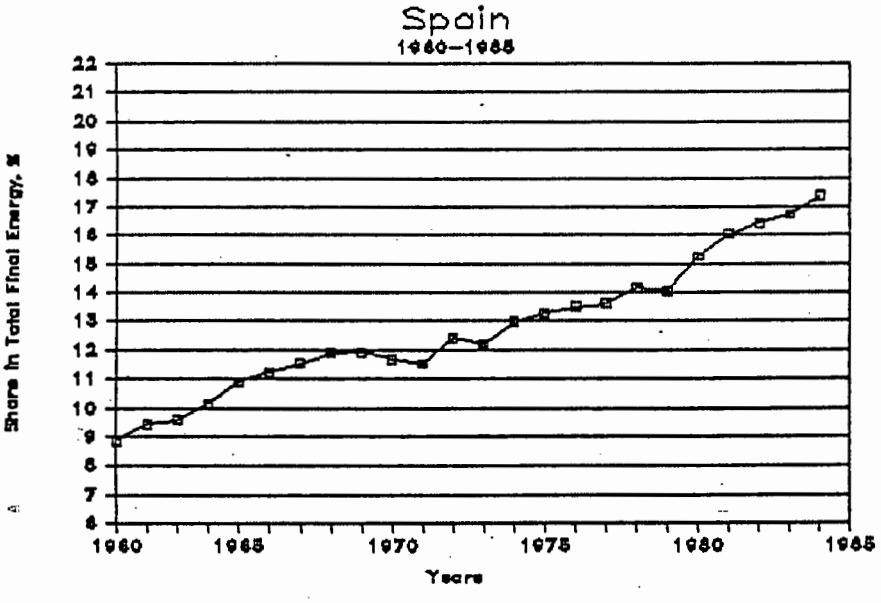
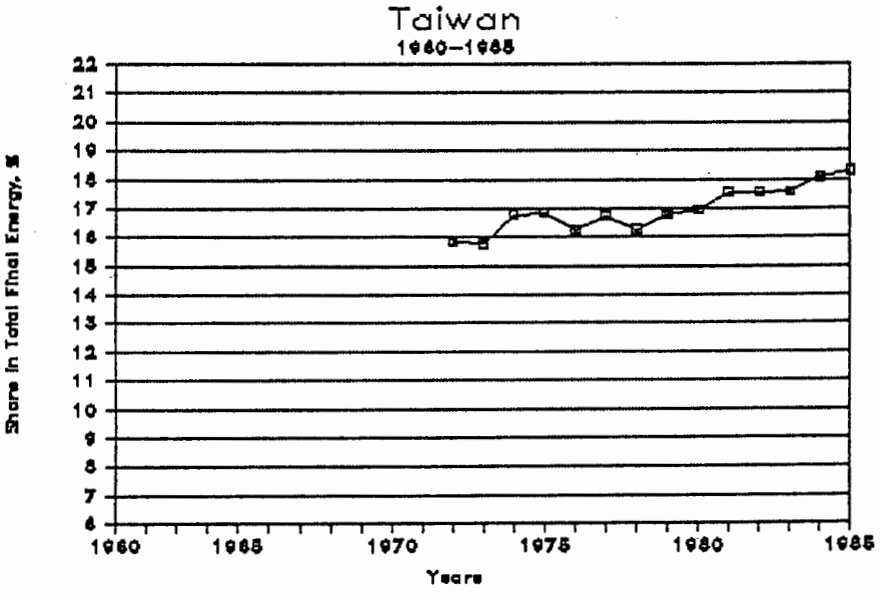

Italy
1960-1985
Share in Total Final Energy, %
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1960
1965
1970
1975
1980
1985
Years

Figure 4-6 (c).


Spain
1960-1985
Share in Total Final Energy, %
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1960
1965
1970
1975
1980
1985
Years


Taiwan
1960-1985
Share in Total Final Energy, %
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1960
1965
1970
1975
1980
1985
Years

To cope with the economic recessions resulting from two oil crises, Japan successfully diversified her energy sources in the 1970s. Therefore, the growth of electricity share was stable between 1970 and 1985 and the share curve had a steady gradient. Owing to the implementation of the nuclear energy policy, France had a relatively high electricity growth rate over the past 25 years, the rate being about 3.8 times higher than that of Taiwan and her share curve had a steep slope.

The growth rate of the electricity share has sharply risen in the 1980-1985 period in Spain whose industrial sector was moving fast toward advanced non-energy intensive processes in the late 1970s and the early 1980s[35], and the share curve had a steep gradient in the last 5 years. Taiwan had a relatively low growth rate of electricity's share in the past 20 years probably because of the continuing increase in the petrochemical production which consumed more oil than other fuels, but the slope of the curve was still shallow.

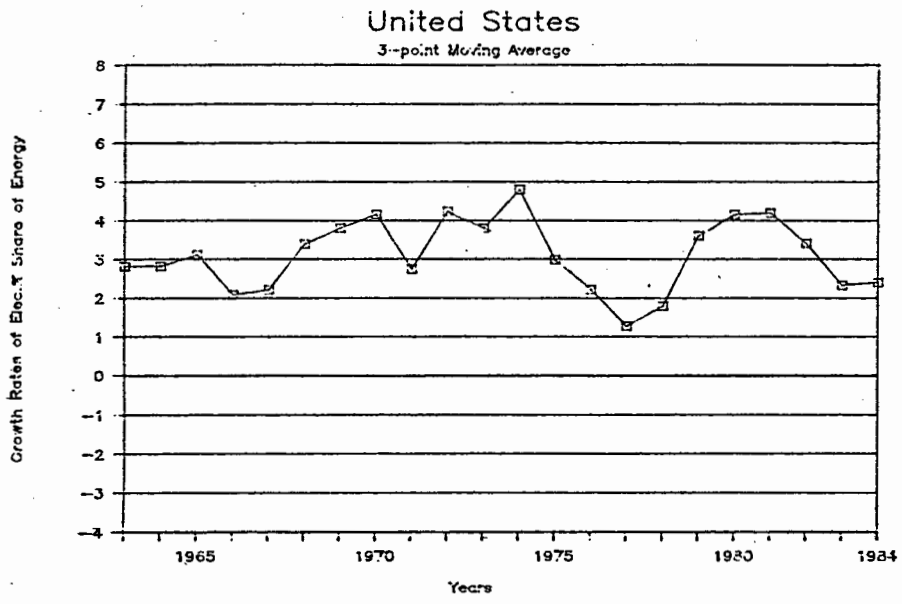
The growth rates of the rest of the selected countries, including USA, Germany, Greece, and Italy, declined in the last few years. The gradients of the share curve were initially high, and tended to decrease. It is partly the result of the changing composition of the economy away from energy-intensive industries toward high value-added manufacturing and service industries that leaded to the total energy consumption decreased as mentioned before in the study.

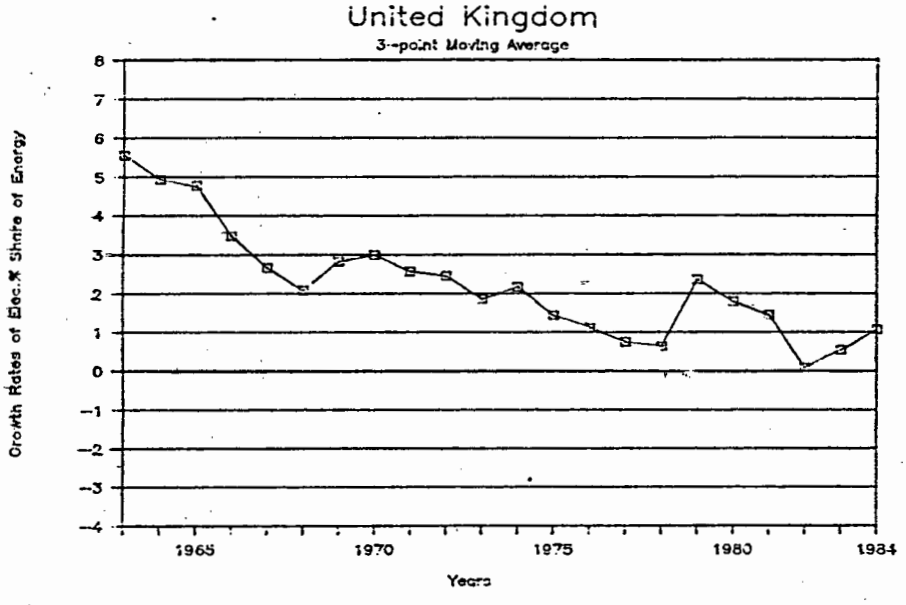
It would be interesting to determine whether the share

curve in the selected countries, especially in UK, was asymptotic to some value over the past 25 years. Figure 4-7 shows the 3-point moving average of the growth rates of electricity's share of the secondary energy usage in the selected countries over the past 25 years. If the electricity share had attained its saturation level, the growth rate should be zero.

In Figure 4-7 the growth curve of UK declined to zero around 1982, but it rose again thereafter. The curves of the other selected countries remained above zero during the past decade. There is no evidence to indicate that the saturation level has been reached in the selected countries. The UK and Greece are the only two countries where the growth of electricity share has consistently declined since 1960s. This tendency indicates that the present electricity share has gone beyond the inflection point of S curve and is tending towards the asymptote. However, for the UK and Greece the exact time which the inflection occurred is not available due to lack of relevant historical data.

The saturation level of the share of electricity in France and Japan might be relatively high, for their growth rates are higher than those of other fuels. The saturation level of the other countries will probably be lower than those two countries, as the growths of the share declined in recent years. Electricity might face the strong competition from gas in Italy and Germany, and the expansion speed of electricity in USA, Greece, and Taiwan might be slowed down due to the similar growth rate of other fuels occurred in the 1970s.





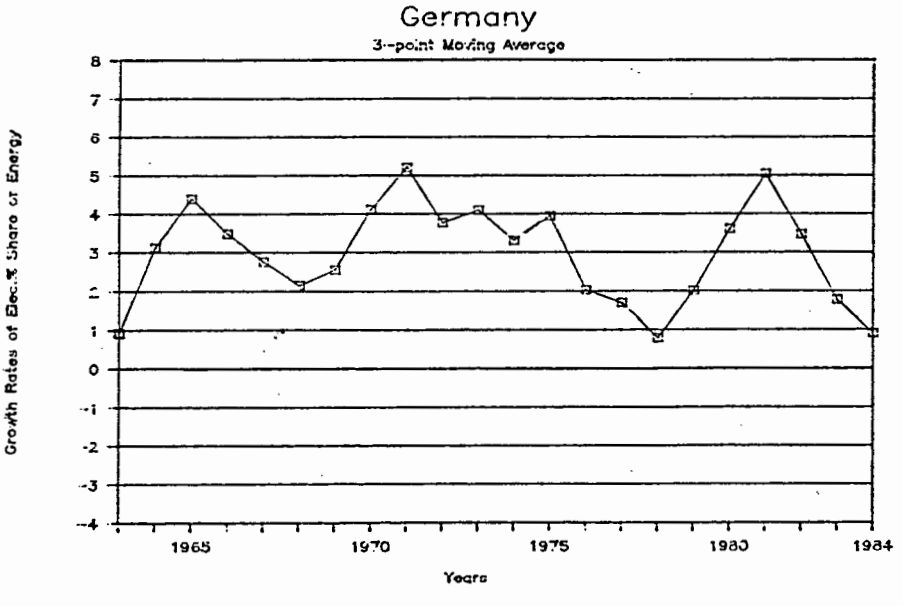


Figure 4-7 (a).

The Growth Rates of the Share of Electricity in the Secondary Energy Usage in the Selected Countries(3 Point Moving Average

Source: Ref.[12],[13].

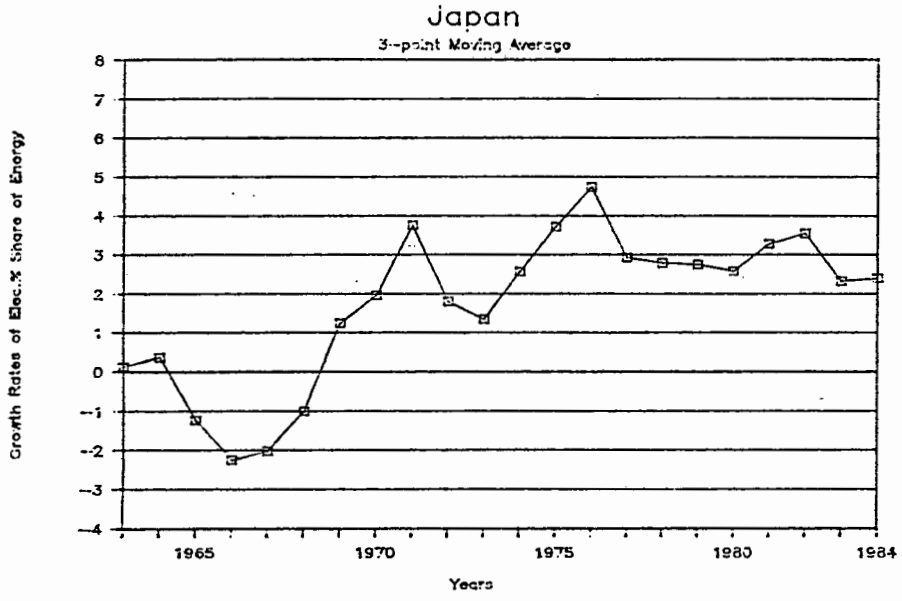
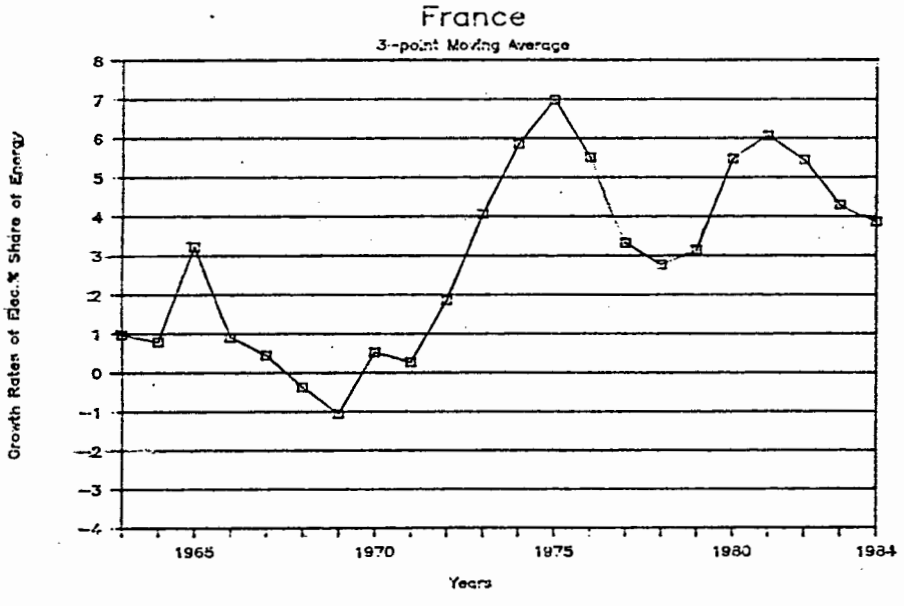
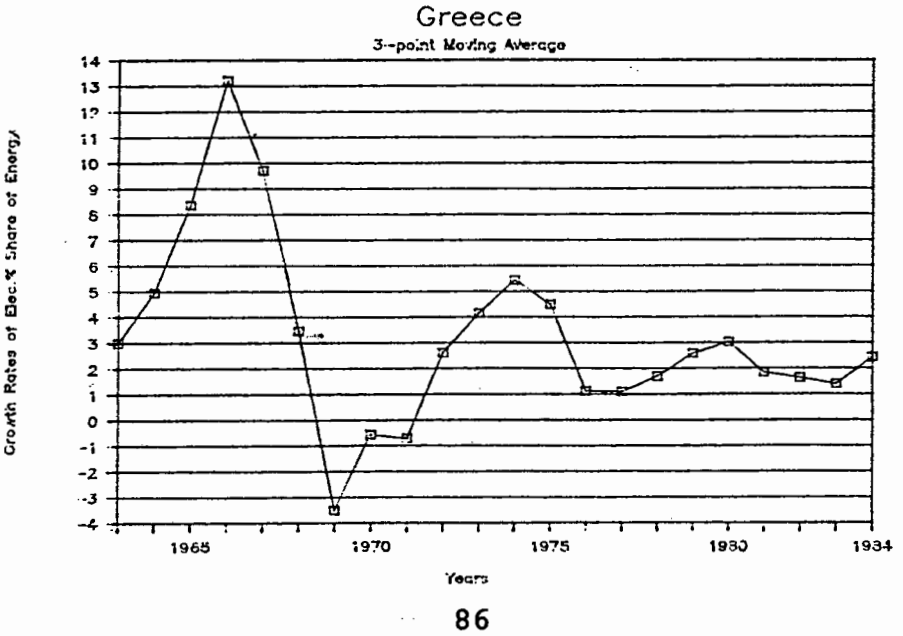

Japan
3-point Moving Average
Growth Rates of Elec.% Share of Energy
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
1965
1970
1975
1980
1984
Years

Figure 4-7 (b).


France
3-point Moving Average
Growth Rates of Elec.% Share of Energy
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
1965
1970
1975
1980
1984
Years


Greece
3-point Moving Average
Growth Rates of Elec.% Share of Energy
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
1965
1970
1975
1980
1984
Years

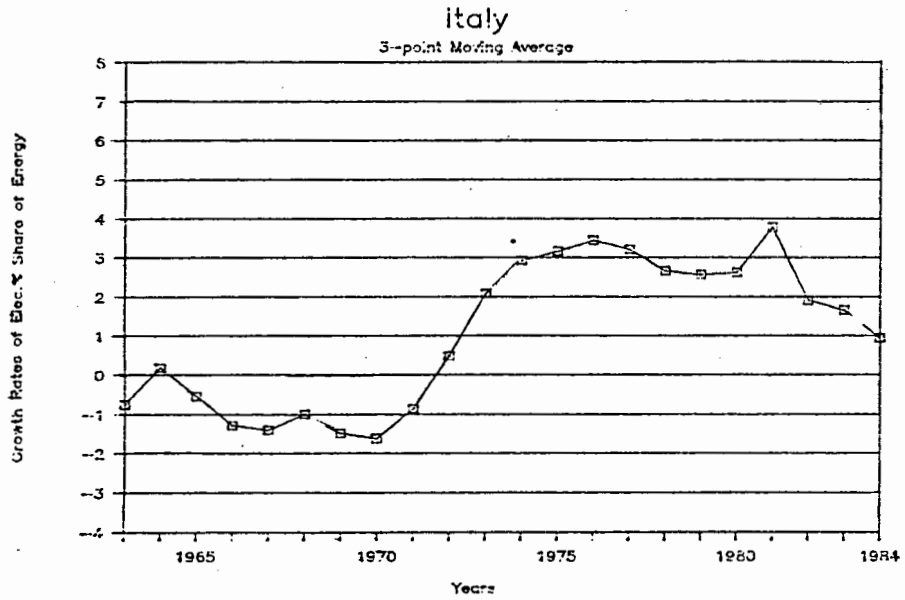
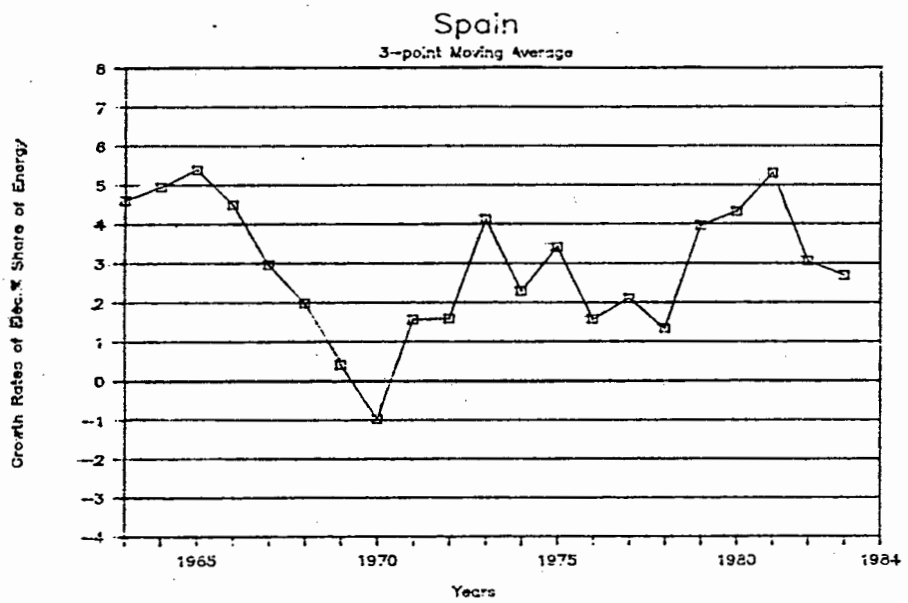
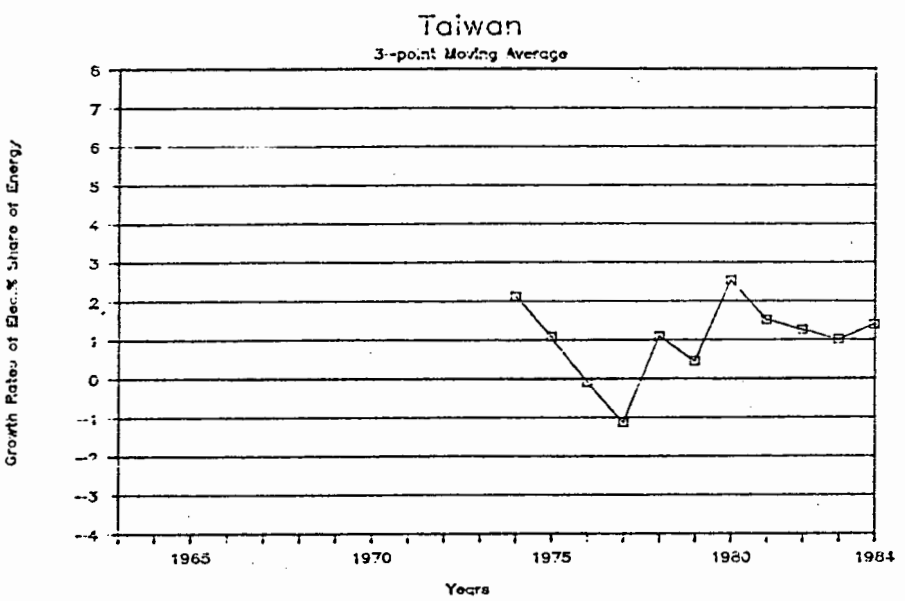

Italy
3-point Moving Average
Growth Rates of Elec.% Share of Energy
Years
1965
1970
1975
1980
1984

Figure 4-7 (c).


Spain
3-point Moving Average
Growth Rates of Elec.% Share of Energy
Years
1965
1970
1975
1980
1984


Taiwan
3-point Moving Average
Growth Rates of Elec.% Share of Energy
Years
1965
1970
1975
1980
1984

4.4. The Saturation level of the Electricity Share in the Total Final Energy Usage

The S curve, also called the logistic curve, has been used to describe the discovery and production of energy resource ([36]-[41]). The logistic equation is of the general form:

$$y = h / (1 + ae^{-bx}) \qquad (4\text{-}1)$$

where h, a, and b are parameters to be determined by the data, e is the base of natural logarithms, and x is time. Translating equation (4-1) into the logistic curve for the share of electricity in secondary energy gives

$$S_f = S_a / (1 + ae^{-bx}) \qquad (4\text{-}2)$$

in which S_a is the asymptotic value of the electricity's share of the total final energy consumption, S_f is the known value of the electricity share at time f. S_a can be determined by rearranging equation (4-2) as follows:

$$S_a / S_f - 1 = ae^{-bx} \qquad (4\text{-}3)$$

Taking the logarithm of both sides yields

$$\log ((S_a / S_f) - 1) = \log a - bx \log e \qquad (4\text{-}4)$$

A solution for equation (4-4) can be obtained by picking arbitrary likely value S_a and inserting the known value of S_f as a function of time. Then semi-logarithmic paper can use to

plot several estimates based on varying values of a, and the one that best approximates a straight line is the solution.

A more "precise" method of estimating the saturation level of the share of electricity is by statistical regression. By choosing several possible values of the saturation level, S_a, based on the trends, taking each of these possible value and inserting the historical value of the share of electricity, S_f, into the left-hand expression of equation (4-4) a time series set of data points will be derived, which can be used statistically to estimate values of the parameters a and b.

As an example, five possible values of S_a for the saturated share of electricity in the United States (which are presented in Appendix C) have been used to derive alternative data points for the period of 1970-1985. When each of these sets was regressed as a function of time, the one that yielded the highest value of the coefficient of determination, R squared, was $\log (34 / S_f) - 1$. The resultant equation is

$$\log (34 / S_f - 1) = 0.97547 - 0.04702 \text{ x}$$

$$R \text{ squared} = 0.987153$$

and the estimated saturation level of the share of electricity for the United States is 34%.

That 34% is the best estimate can be verified by putting the antilogarithm of intercept term a and the estimated value of saturation level, 34%, into the basic logistic equation (4-2).

Since the denominator of (4-2) will not be significantly different from 1, the numerator S_a represents the best estimate of the saturation level for the USA and will tend to be far more accurate than by plotting data points graphically.

It is possible to estimate not only the saturation level of the share of electricity in the secondary energy use but also how long it takes to reach the saturation level at current rates of the growth of the share.

As electricity intensity in most selected countries declined during the 1980s unlike the increases of the 1960s and 1970s --- electricity consumption has grown more slowly than the economy in the early 1980s. Two growth rates of the current share have been selected for the study: one is the annual average growth rate for 1970-1985 and the other is that for 1980-1985 so as to determine how long it takes to reach the saturation point. Thus, if the present share of electricity and the saturation level are S_o and S_a, in the following period (or year) it will be

$$S_a = S_o (1 + r)^t \qquad (4\text{-}5)$$

where r is the rate of growth. Rearranging the equation (4-5)

$$S_a / S_o = (1 + r)^t \qquad (4\text{-}6)$$

then taking the logarithm of both sides

$$\log (S_a / S_o) = t \log (1 + r) \qquad (4\text{-}7)$$

and solving for t

$$t = \log (S_a / S_o) / \log (1 + r) \qquad (4\text{-}8)$$

Following the above procedure, the estimates of the saturation level and the time it will take to reach the level at two current growth rates for the selected countries are shown in Table 4-2. The detailed computation of the saturation level of the share of electricity in the secondary energy use for the selected countries are shown in Appendix C.

Table 4-2. The Estimates of the Saturation Level and Time Needed to Reach the Level in the Selected Countries

	Saturation Level %	Annual Average Growth Rate of Electricity Share %		Time Needed to Reach the Saturation Level (year)	
		Rate 1 (1970-'85)	Rate 2 (1980-'85)	Rate 1	Rate 2
USA	34	3.089	2.615	26	31
UK	17	1.375	0.409	9	31
Germany	23	2.839	2.329	14	17
Japan	68	2.765	2.703	44	45
France	99	4.271	4.708	43	39
Italy	29	2.198	1.857	33	39
Taiwan	34	1.113	1.538	56	40
Greece	19	2.560	1.632	7	10
Spain	99	2.866	3.248	61	54

It is obvious from Table 4-2 that there is a large spread of saturation levels both amongst the developed countries, and amongst the developing countries. There does not appear to be any significant difference between the estimated saturation levels for these two groups of countries. The similar saturation levels between developed and developing countries can be seen in the estimation that USA and Taiwan have the same level of 34%; France and Spain have an almost completed electrification value of 99%; and UK's level is much the same as Greece's (17%:19%). Another notable point is that the saturation level of Japan is twice that of USA and Taiwan, but four times larger of the UK.

Although the growth of the electricity share has increased in the total final energy , the annual average growth rate of electricity share in the pre-1980s has declined in most selected countries with the exception of France, Spain, and Taiwan, whose annual average growth in the 1980-1985 period was higher than that of the 1970-1985 period. Japan is the only country where the rate had been kept at a stable ratio through the whole period.

As the structure of output is the major factor which affected the electricity consumption, the sectoral breakdown of GDP in the percentage share as well as the electricity and energy intensities are examined in Table 4-3. No uniform variations in the composition of the sectoral GDP and intensities between these groups of countries have been identified.

Table 4-3. Sectoral Production in Percentage Share of GDP as well as Electricity Intensity and Energy Intensity in the Selected Countries

Country	Year	Gross Domestic Product (%)				Electri. Intensity (Kwh / 1980 US$)	Energy Intensity (Kg CE / 1980 US$)
		Agr.	Ind.	Tras.	Services		
Japan	1960	13	43	9	35	0.502	0.543
	1973	6	44	6	44	0.571	0.541
	1979	5	41	7	47	0.581	0.462
	1983	3	42	7	48	0.531	0.389
USA	1960	4	39	7	50	0.594	1.057
	1973	3	37	6	54	0.841	1.097
	1979	3	35	6	56	0.858	0.958
	1983	2	32	6	60	0.855	0.824
Taiwan	1960	29	30	5	36	0.501	0.802
	1973	12	50	6	32	0.808	0.793
	1979	9	52	6	33	0.973	0.906
	1983	7	49	6	38	0.924	0.831
UK	1960	4	43	8	45	0.411	0.766
	1973	3	39	7	51	0.563	0.624
	1979	2	36	7	55	0.547	0.529
	1983	2	36	6	56	0.497	0.485
Greece	1960	23	22	6	49	0.187	0.314
	1973	17	30	6	47	0.468	0.583
	1979	14	28	7	51	0.564	0.511
	1983	16	26	7	51	0.596	0.524
France	1960	9	48	5	38	0.271	0.425
	1973	6	46	5	43	0.317	0.434
	1979	5	37	6	52	0.377	0.365
	1983	4	34	5	57	0.385	0.308
Spain	1960	22	33	6	39	0.261	0.325
	1973	12	33	6	49	0.413	0.384
	1979	7	35	6	52	0.501	0.426
	1980	7	34	7	52	0.532	0.391
Italy	1960	13	41	6	40	0.291	0.281
	1973	9	41	6	44	0.389	0.453
	1979	7	43	6	44	0.425	0.451
	1980	6	43	6	45	0.411	0.382
Germany	1960	6	53	13	28	0.305	0.517
	1973	3	46	6	45	0.441	0.517
	1979	2	45	6	47	0.462	0.481
	1983	2	38	9	51	0.465	0.436

Source: Ref. [20]-[22]

To estimate the saturation level of the fuel shares is a complicated task because the saturation value would vary from country to country. It is, however, necessary to discuss the reliability of the estimated saturation level here on the changes of the electricity share curve, the fuel shares and their growths See Figures 4-2, 4-3, 4-4,and 4-6) for each selected country:

-- USA: Electricity is the only energy that has been keeping the expansion of its share in the US fuel market since 1973. No particular factors should stunt the growth of the electricity share, and the estimated saturation level, 34%; might occur in the next 25 years.

--UK : Electricity faced strong competition from gas. Since the market share and growth of the share of the North Sea gas were larger than those of electricity, and the shape of UK electricity share curve seems to decline with time, 19% probably is the appropriate saturation level of the electricity share.

--Germany: The share of electricity has been maintaining the steady growth over the past 25 years, so it is only 1.7% behind the share of gas in 1985. Although the share of electricity has grown slower than gas since the early 1970s, it seems that the share of electricity can reach the estimate, 23%, in the next decade and a half.

--Japan: Oil still holds the largest share in the total fuel consumption. Moreover, the share has clearly decreased since the mid-1970s. Coal share has also decreased since the early 1960s. The fuels which substituted for oil and

coal were electricity and gas. As the share of electricity was 4 times larger than gas in 1985, it still kept the steady and relatively high growth rate over the past 25 years. The share curve of electricity might have a very high saturation point as the estimated value.

--France: The shares of electricity and gas were very close in 1985 (15.9% : 17.6%), and the annual average growths of the shares of these two fuels for 1980-1985 were also similarly high (4.71% : 4.93%). It is clear that the maximum share of electricity should be below 50%. The extremely high estimated value, 99%, is due to the fact that the small fluctuations over the last few current data points have an exaggerated effect in the logistic growth curve, and the rapid growth of the share over the last 5 years in France to cause this extremely high value.

--Greece: Oil occupies the majority of the fuel shares, with its rate at 70.3% in 1985. However, its share decreased slowly with time, and the annual average rate of reduction was only -0.44% over the last 15 years. Since the share of energy-intensive industries in industrial production has increased by 50%[42] that led to the slow reduction of the oil share in the Greek fuel market, the saturation level of the electricity share is not expected to be high(the estimated level being 19%).

--Italy: The growth of gas share was about two times faster than that of electricity over the past decade and a half, but they were almost equal in the last 5 years; the share of

electricity was two-thirds of the gas share in 1985(14% : 21%). With the slow decrease of oil share and coal share, the saturation level of electricity share is expectedly to reach the estimated value.

--Spain: Oil holds the largest share in the secondary energy use (69.4% in 1985). The reduction of oil was very slow in most recent years. The tremendous estimated saturation value of the electricity share, 99%, was due to the share points far away from the trend curve in the last five years, and the high slope existed at the rising part of the logistic growth curve to lead the estimated saturation point extremely high. Comparing the fuel shares in Spain with those in Greece, the shares of electricity and oil were similar in 1985, the growth of electricity share in Spain was faster than Greece but slower in oil share, and the saturation level might be above 30%.

--Taiwan: The share of electricity has been steadily increasing with time, oil has a declined tendency in recent years, gas has been losing its share since 1973, and the share of coal is still in varying. The share of electricity will be expected to continue its slow but steady growth in the future, and it might be possible to reach the estimated saturation level.

As UK is the only selected country discovered abundant indigenous energy, especially gas, in the oil crises. It is interested in the variation of the saturation level of the

electricity share of the total secondary energy without the North sea gas. Two electricity share S curves and their saturation levels, one is the present estimated saturation curve and the other is the possible saturation curve without the North Sea gas, are shown in Figure 4-8. It is found that the possible saturation level without the North Sea gas is almost the same as the present estimated saturation level. The reason for this result is the fact that the vacancy of the reduction of oil and coal consumptions created by energy crises was filled by the increase in gas consumption. Therefore, the estimation saturation curve and saturation level of the electricity share in the UK was not much affected by the increased share of gas.

The detailed data for the changes of fuel shares for the selected countries is presented in Appendix D.

The large saturation level differences between those above-mentioned countries can be explained by a number of things:

(a) Energy policies affected both the rate of energy growth and the proportion of the energies in the total energy.
(b) The degree of the cheapening of electricity relative to other forms of energy.
(c) The availability and ability to supply sufficient electric energy.
(d) The structures of various market sectors caused different demands of the individual energy.
(e) The degree of the penetration of electric appliances in the residential and commercial sector depended on income

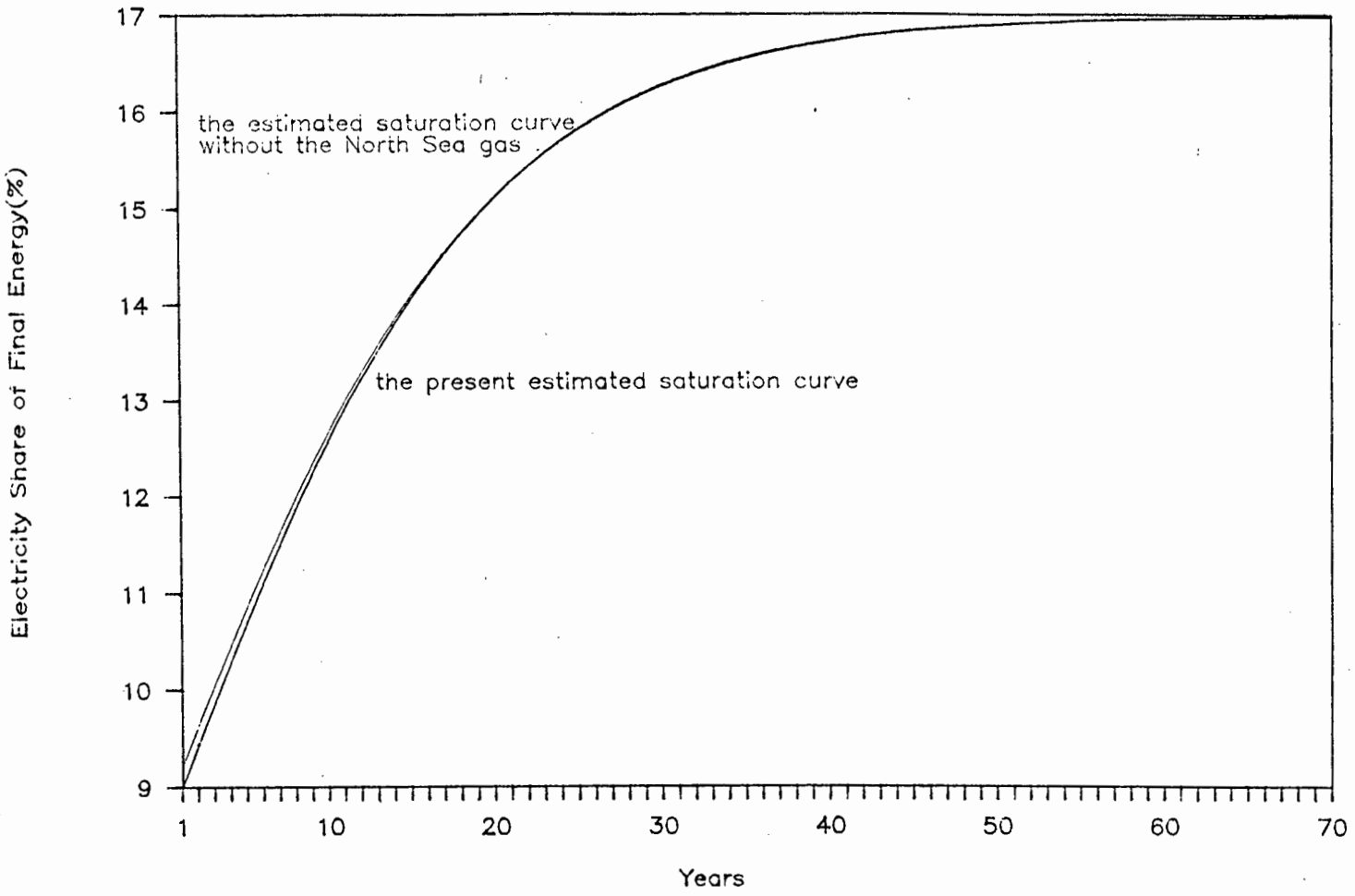


Figure 4-8. Two Estimated Saturation Curves for the UK.

Source: Ref. [13].

growth and household behavior.

It is found that the use of methods of the logistic growth curve and statistical regression can establish an estimated S shape electricity share curve for each country and also estimate their saturation levels. An attempt has been subsequently made to project the time it will take to reach the estimated saturation level based on two different growth scenarios. This framework might be useful for the projection of future electricity demand.

CHAPTER 5. CONCLUSIONS

Banks[44] indicated that economic development can be expressed in a simple equation: development = technology + energy. However, economic growth results from a more complicated interweaving of various factors of production -- capital, labor, materials, and energy -- whose relative contribution vary from time to time, and therefore the weight of each factor is hard to determine. No matter how the analysis of economic growth is attempted, energy is always an important determinant.

Historically, in the world in general, a close interrelationship exists between energy consumption and economic output. As economic output increases, so generally does energy consumption. But there is little evidence that energy consumption and economic growth move together in exactly the same proportions.

In the 1960s and early 1970s, the energy/GDP ratio of developed countries was approximately constant(Table 5-1). Thus, every percentage increase in GDP was met by an approximately equal percentage increase in energy consumption. With the increased price of oil after 1973, the developed countries were forced to seek financial redress by curtailing energy demand which led to the per capita energy consumption gradually decreasing(Table 2-1). But in the developing countries, although their economies were also affected by the sharply rising oil prices , the per capita energy consumption has steadily risen due to the fast industrialization and urbanization. However the growth rate of per

capita energy consumption has declined since 1973(Table 2-2).

Table 5-1. Energy Elasticities for Subperiods between 1960-1984

Period	World	Developed Country	Developing Country	Centrally Planned Country
1960-73	0.812	0.985	1.286	0.466
1973-79	-0.447	-0.478	0.774	0.011
1979-84	-2.751	-1.856	1.115	0.134

Source: Ref.[1]-[5].

In contrast to the marked reduction in per capita energy consumption, the per capita electricity consumption has increased in most countries, though its growth rate has declined since mid-1970s(Table 3-2 and 3-3). While the two oil price increases resulted in electricity price increases, industry responded by decreasing kWh demand(though the share of electricity in industrial energy consumption increased) due to decrease of electricity-intensive industries such as steel and aluminum. The residential and commercial sector electricity consumption increased due to increasing appliance penetration. The two effects roughly balance, so the trend of electricity consumption remained approximately constant.

From a statistical perspective, electricity consumption and GDP have been strongly correlated in most countries(Figure 3-8 and Table 3-5). It is found that the use of per capita GDP

explains about 90 per cent of the variation in per capita electricity use over the 1955-1985 period(section 3-7). One of the factors which serves to explain the major part of the remaining variations in electricity per capita use is lags in the response of electricity use to change in economic variables, including GDP. The lag effect of per capita electricity consumption reflects about 9 per cent of the variation in per capita electricity use(equation 3-4).

Since the electricity industry consumes more primary fuel than any other single industry, and usually accounts on average for about one third of the primary energy requirements of most countries, the increased penetration of electricity in the secondary energy market which occurred in most countries led to the rise in the electricity/primary energy ratio. i.e. electricity production per unit of primary energy consumption exhibits a increasing trend. It seems obvious that there is a relationship between electricity consumption and primary energy usage, but the use of per capita primary energy only serves to explain a small part of the variation in electricity per capita use over the 1955-1985 period(equation 3-5).

The strong correlation between electricity and GDP has been persistent even though its calculation ignores price change, structural change, technological progress, and other relevant factors which also affected electricity consumption. The relevant factors not explicitly included in the analysis are either collinear with one or more of the variables used or have effects

which largely cancel each other(Chapter 3). For instance, electricity price changes are not the sole determinants of electricity consumption growth, nor even the most important determinants. The important force in electrification has been identified as the cheapening of electricity relative to other forms of energy. This has accelerated the rate of technical change through innovations that have occurred throughout the whole range of economic activity. Therefore, the price variable has been left out of this analysis.

Electricity consumption and Gross Domestic Production have been, and probably will continue to be, strongly correlated. The strength of the effects of other relevant factors is not so great as to alter the fundamentally strong link between the growth in electricity use and the growths in GDP.

The relationship between electricity consumption and economic activities on a per capita basis has been investigated for various countries and at the aggregate level in Chapter 3. It is found that the use of per capita GDP, per capita primary energy, and time lagged variables establish a general form of relationship model of per capita electricity consumption. The excellent statistical results from the cross-country comparison reveal that these factors may explain the trends in the per capita electricity use and confirm the close tie between electricity consumption and economic activity.

The relative contribution of the different secondary fuels to the total secondary energy consumption in the selected

countries have been examined in Chapter 2 and Chapter 4. In spite of the exception noted, the basic historical trend is that of an increase in the use of electricity in most countries, an increase in the use of gas in the western countries, and a declining usage of coal and oil.

Various factors explain why the transformation of the energy market did not have the same impact on all sources of energy:

(a) The prices of the various energies changed at different rates owing to different cost developments and fixed-to-variable cost ratios.

(b) Demand developments were not uniform across the various market sectors, in which the individual energies play different roles.

(c) Environmental protection requirements affected the various sources of energy differently.

(e) Domestic fuel availability and the ability to finance sufficient energy imports.

In spite of the impact of the oil crises which resulted in a decrease of per capita energy consumption in many countries, the degree of the penetration of electricity has increased in most countries, owing to a number of reasons:

First of all, the high energy prices have resulted in an important electricity competitiveness, since the cost of fossil fuel inputs to electricity generation is only one component of retail electricity prices. Electricity has gained a substantial

cost advantage over other fuels since the first oil crisis.

Secondly, high energy prices have created a tendency in the structure of industrial sector of many countries to move towards less-energy intensive processes, and to industries dedicated to the fabrication of high value-added articles. These processes generally involve advanced technologies, which normally imply the consumption of electricity rather than other fuels.

Thirdly, electricity is versatile and efficient at the point of use, and it offers possibilities for programming, regulation and control which are difficult to achieve with other forms of energy.

The development of electricity also has its disadvantages. For instance, compared with other energies electricity it is produced mainly from fossil fuels at a low thermal efficiency, and, in general, cannot be stored; the electricity industry is highly capital-intensive, and consumes large quantities of coal and heavy fuel oil which suffer from environmental disadvantage; and there is the limited substitution for petroleum products in the transport sector, and no substitution for petrochemical feedstock in the industrial sector etc. All of these might impede the increased penetration of electricity into the energy market, and limit the share of electricity to a saturation level. Therefore, it is expected that the rising trend of the proportion of electricity in the total secondary energy consumption will be along an "S" shape saturation curve(Figure 4-5). The asymptote of this S curve is the

saturation level of the electricity share of the total secondary energy consumption.

The method of examining the asymptote of the electricity share curve is to investigate the growth curve of electricity share(section 4-3). In Chapter 4 it is shown that there is no significant evidence to indicate that the asymptote has been reached in the 9 selected developed and developing countries over the past 25 years. But the UK and Greece are the only two selected countries where the growth rate of electricity share has consistently declined since 1960s. This tendency indicates that the present electricity share has gone beyond the inflection point of S curve and is tending to the asymptote. However, for the UK and Greece the exact time at which the inflection point occurred is not available due to lack of adequate historical data.

In order to estimate the saturation level of the electricity share of the total secondary energy, the logistic growth curve and statistical regression have been used to establish an estimated S shape electricity share curve for each selected country, and their saturation levels are also estimated in section 4-4. An attempt has been subsequently made to project the time it will take to reach the estimated saturation level for the selected countries based on two different growth scenarios(Table 4-2).

Wide variation in the estimated saturation level can occur both in the developed countries and in the developing countries(Table 4-2). Variations such as these these can be

explained by a number of things, such as energy policy(i.e., to promote electricity as part of a national policy to reduce oil use), the price competition between fuels(i.e., the degree of the price decrease of electricity relative to other forms of energy), supply systems(i.e., the availability and ability to supply sufficient electric energy), the composition of output(i.e.,the structure of various market sectors caused different demands of the individual energies), and the household behavior(i.e., the degree of the increased penetration of electric space and water heating equipment as well as home appliances)etc. This framework of estimating the saturation level of electricity share of the total secondary energy consumption might be useful for the projection of future electricity demand.

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APPENDIX A. TABLES OF ECONOMIC STRUCTURES, SECTORAL ENERGIES USAGE AND ELECTRICITY CONSUMPTION AND FUEL SHARES.

Year	World	Developed Country	Developing Country	Centrally Planned Country		Annual Average Growth Rate: World	Developed	Developing	Centrally Planned
GDP:Index, 1975=100					GDP				
1960	48	53	42	39					
1973	98	100	90	90	1960-73	5.644036	5.004895	6.037875	6.644082
1979	119	117	125	119	1973-79	3.288859	2.651266	5.627722	4.765287
1984	130	124	145	147	1979-84	1.783944	1.168931	3.012896	4.316756
GDP/Capi.					GDP/Capita				
1960	64	62	59	45					
1973	102	102	94	92	1960-73	3.650352	3.903797	3.647702	5.655086
1979	111	113	115	115	1973-79	1.419267	1.721567	3.417729	3.789081
1984	114	117	120	135	1979-84	0.534789	0.698148	0.854825	3.258826
Energy					Energy				
1960	4242.8	2608.6	285.74	1348.54					
1973	7909.3	4884.8	712.5	2311.9	1960-73	4.907509	4.943820	7.281327	4.233685
1979	8593.6	4935.8	958.1	2700.5	1973-79	1.392581	0.173256	5.060064	2.623271
1984	8855.8	4603.8	1209.3	2985.5	1979-84	0.602907	-1.38300	4.767032	2.026873
Energy/Ca					Energy/Capita				
1960	1423	3995	211	1383					
1973	2080	6524	383	1940	1960-73	2.963054	3.844714	4.692757	2.637512
1979	2002	6208	448	1945	1973-79	-0.63499	-0.82406	2.647065	0.042909
1984	1859	5816	490	1988	1979-84	-1.47122	-1.29604	1.808400	0.438300
Electri.					Electricity				
1960	2300.9	1695.4	130.9	474.6					
1973	6073.6	4259.8	463.7	1350.1	1960-73	7.752363	7.344113	10.21828	8.374227
1979	7998				1973-79	4.694179			
1984	9304.6				1979-84	3.072607			
Elec./Cap					Electricity/Capita				
1960	772	2596	97	487					
1973	1597	5689	249	1133	1960-73	5.750800	6.220929	7.521281	6.710649
1979	1848				1973-79	2.462789			
1984	1950				1979-84	1.080301			

Proportions of Gross Domestic Product by Sector

Country	Year	GDP	Agricul.	Industry	Transport	Other (Services)
		Billions 1980 US Dollars		%		
U.S.A.	1960	1427.4	4	39	7	50
	1973	2352.1	3	37	6	54
	1979	2736.3	3	35	6	56
	1983	2809.5	2	32	6	60
U.K.	1960	334	4	43	8	45
	1973	501.22	3	39	7	51
	1979	547.7	2	36	7	55
	1983	554.4	2	36	6	56
GERMANY	1960	402.7	6	53	13	28
	1973	700.94	3	46	6	45
	1979	805.25	2	45	6	47
	1983	821.75	2	38	9	51
JAPAN	1960	221.96	13	43	9	35
	1973	819.98	6	44	6	44
	1979	1014.7	5	41	7	47
	1983	1167.43	3	42	7	48
TAIWAN	1960	6.474	29	30	5	36
	1973	23.405	12	50	6	32
	1979	38.057	9	52	6	33
	1983	47.98	7	49	6	38
KOREA	1960	11.44	37	20	5	38
	1973	37.46	24	29	5	42
	1979	64.17	20	39	6	35
	1983	76.94	14	39	8	39
SINGAPORE	1960	1.955	4	17	14	65
	1973	6.737	2	31	13	54
	1979	10.278	1	36	13	50
	1983	14.313	1	38	13	48
INDIA	1960	80.77	47	19	5	29
	1973	124.09	41	20	5	34
	1979	152.1	31	24	5	40
	1983	191.39	32	23	5	40
PHILIPPIN	1960	11.47	26	29	4	41
	1973	23.26	28	33	5	34
	1979	33.55	24	36	6	34
	1983	37.59	22	36	6	36

End-Use Energy Consumption by Energy Source (%)

Country	Year	Coal /Other	Oil	Gas	Electri.
		%			
U.S.A.	1960	16.53	52.45	0.24	7.11
	1973	9.80	52.69	0.27	10.76
	1979	9.89	54.26	0.23	12.38
	1983	9.97	52.16	0.23	14.59
U.K.	1960	58.12	28.71	0.05	7.99
	1973	18.84	52.36	0.16	13.07
	1979	13.08	48.31	0.25	13.88
	1983	11.05	45.23	0.29	14.65
GERMANY	1960	62.60	26.97	0.02	7.96
	1973	14.88	64.62	0.09	11.23
	1979	11.20	60.64	0.14	12.88
	1983	11.86	55.19	0.16	15.12
JAPAN	1960	48.66	34.47	0.03	13.73
	1973	15.03	67.88	0.03	14.23
	1979	12.33	66.78	0.04	17.21
	1983	13.90	61.81	0.05	19.77
TAIWAN	1973	20.37	53.10	0.11	15.77
	1979	10.67	64.25	0.08	16.76
	1983	17.09	60.16	0.05	17.57
KOREA	1981	35.91	53.78	0.00	9.97
	1983	37.19	51.57	0.00	10.91
SINGAPORE	1981	0.00	93.48	0.01	5.95
	1983	0.00	93.39	0.01	6.10
INDIA	1981	55.32	32.04	0.02	10.80
	1983	54.66	32.41	0.02	11.18
PHILIPPINES	1981	2.40	77.89	0.00	19.64
	1983	5.32	74.76	0.00	19.86

Energy Consuaption by Sector

Country	Year	Total	Industry	Commerce	Resident.	Transport	Industry	Commerce	Resident.	Transport
							%			
U.S.A.	1960	832.49	341.36			229.26	41.00	0.00	0.00	27.54
	1973	1332.15	470.93	137.96	245.94	411.14	35.35	10.36	18.46	30.86
	1979	1388.44	474.73	146.74	247.19	447.17	34.19	10.57	17.80	32.21
	1983	1222.41	373.84	137.64	228.39	426.92	30.58	11.26	18.68	34.92
	1960-1973	3.68	2.51			4.60				
	1973-1979	0.69	0.13	1.03	0.08	1.41				
	1979-1983	-3.13	-5.80	-1.59	-1.96	-1.15				
U.K.	1960	118.09	49.62			19.87	42.02	0.00	0.00	16.83
	1973	153.31	66.70	13.43	33.94	30.97	43.51	8.76	22.14	20.20
	1979	152.79	57.65	13.66	37.81	33.77	37.73	8.94	24.75	22.10
	1983	133.55	41.45	13.42	35.65	34.45	31.04	10.05	26.69	25.80
	1960-1973	2.03	2.30			3.47				
	1973-1979	-0.06	-2.40	0.28	1.82	1.45				
	1979-1983	-3.31	-7.92	-0.44	-1.46	0.50				
GERMANY	1960	104.22	52.19			16.78	50.08	0.00	0.00	16.10
	1973	196.88	74.76	5.25	62.52	33.70	37.97	2.67	31.76	17.12
	1979	212.92	76.43	24.00	42.85	40.91	35.90	11.27	20.12	19.21
	1983	185.11	66.48	16.61	33.22	41.57	35.91	8.97	17.95	22.46
	1960-1973	5.01	2.80			5.51				
	1973-1979	1.31	0.37	28.83	-6.10	3.28				
	1979-1983	-3.44	-3.43	-8.79	-6.17	0.40				
JAPAN	1960	59.56	37.55			11.54	63.05	0.00	0.00	19.38
	1973	250.82	149.44	14.95	21.10	40.86	59.58	5.96	8.41	16.29
	1979	260.72	137.71	19.23	26.78	53.53	52.82	7.38	10.27	20.53
	1983	237.84	113.41	19.88	28.04	54.54	47.68	8.36	11.79	22.93
	1960-1973	11.69	11.21			10.21				
	1973-1979	0.65	-1.35	4.29	4.05	4.60				
	1979-1983	-2.27	-4.74	0.83	1.16	0.47				
TAIWAN	1973	103106.90	51591.10	10484.60	7716.50	12318.50	50.04	10.17	7.48	11.95
	1979	190055.70	88350.70	13615.80	15537.30	27105.40	46.49	7.16	8.18	14.26
	1983	217188.70	96058.10	17425.50	19140.90	34029.30	44.23	8.02	8.81	15.67
	1973-1979	10.73	9.38	4.45	12.37	14.05				
	1979-1983	3.39	2.11	6.36	5.35	5.85				
KOREA	1981	1385944.00	661955.00	43367.00	432615.00	229071.00	47.76	3.13	31.21	16.53
	1983	1520475.00	661401.00	69530.00	498425.00	244075.00	43.50	4.57	32.78	16.05
	1981-1983	4.74	-0.04	26.62	7.34	3.22				
SINGAPORE	1981	354645.00	98366.00	9709.00	72780.00	144340.00	27.74	2.74	20.52	40.70
	1983	401851.00	137965.00	8480.00	68028.00	158990.00	34.33	2.11	16.93	39.56
	1981-1983	6.45	18.43	-6.54	-3.32	4.95				
INDIA	1981	3247579.00	1930780.00	63594.00	400616.00	789855.00	59.45	1.96	12.34	24.32
	1983	3579727.00	2184526.00	72515.00	396614.00	853727.00	61.02	2.03	11.08	23.85
	1981-1983	4.99	6.37	6.78	-0.50	3.96				
PHILIP.	1981	344258.00	129396.00	30078.00	69733.00	69122.00	37.59	8.74	20.26	20.08
	1983	355039.00	128166.00	30084.00	72212.00	72496.00	36.10	8.47	20.34	20.42
	1981-1983	1.55	-0.48	0.01	1.76	2.41				

Electricity Consumption by Sector (%)

Country	Year	Industry	Transport	Residual	(Agricul.	Commerce	Resident.)
U.S.A.	1960	47.08	0.79	52.12	0.00	0.00	0.00
	1973	38.73	0.26	0.00	0.86	25.40	34.74
	1979	38.50	0.15	0.01	0.00	27.18	34.16
	1983	33.68	0.12	0.00	0.00	29.98	36.22
U.K.	1960	49.47	2.01	48.52	0.00	0.00	0.00
	1973	39.17	1.10	0.00	1.70	18.86	39.17
	1979	39.09	1.18	0.05	1.65	21.69	36.35
	1983	34.95	1.28	0.00	1.64	25.70	36.43
GERMANY	1960	67.35	3.98	28.67	0.00	0.00	0.00
	1973	55.22	3.44	0.00	2.35	15.60	23.38
	1979	50.49	3.28	0.00	2.26	17.86	26.10
	1983	47.18	3.18	0.00	2.25	19.69	27.70
JAPAN	1960	77.26	5.26	17.48	0.00	0.00	0.00
	1973	70.20	3.19	0.00	0.28	7.25	19.08
	1979	64.59	2.94	0.00	0.27	10.00	22.19
	1983	60.18	2.94	0.00	0.26	12.30	24.34
TAIWAN	1973	60.48	0.18	8.02	1.53	11.22	18.58
	1979	60.26	0.72	7.29	1.67	11.08	18.98
	1983	55.38	0.80	7.13	1.85	14.58	20.26
KOREA	1981	70.44	1.20	0.00	0.67	12.22	15.48
	1983	68.00	1.12	0.00	0.91	13.14	16.82
SINGAPORE	1981	38.99	0.00	0.00	0.00	42.34	18.66
	1983	49.41	0.00	0.00	0.00	31.28	19.31
INDIA	1981	61.78	2.57	0.00	9.29	15.62	10.73
	1983	59.93	2.39	0.00	16.40	9.37	11.92
PHILIPPINES	1981	44.33	0.00	0.00	6.96	31.76	16.95
	1983	34.62	0.00	0.08	15.06	30.52	19.72

Industrial Fuel Mix (%)

Country	Year	Coal	Oil	Gas	Electri.
U.S.A.	1960	28.20	34.29	29.35	8.16
	1973	22.91	27.16	38.14	11.79
	1979	22.06	33.89	30.11	13.94
	1983	23.85	27.78	32.31	16.06
U.K.	1960	57.48	29.02	4.09	9.41
	1973	23.64	49.12	15.47	11.77
	1979	18.72	42.38	24.53	14.38
	1983	18.21	33.75	31.53	16.50
GERMANY	1960	69.44	18.03	1.82	10.71
	1973	23.83	44.68	15.16	16.33
	1979	22.89	38.53	20.46	18.12
	1983	25.84	33.49	20.80	19.87
JAPAN	1960	55.13	26.07	1.97	16.83
	1973	23.93	57.89	1.41	16.77
	1979	22.83	54.17	1.95	21.05
	1983	28.77	43.75	2.53	24.94
TAIWAN	1973	34.53	33.56	12.84	19.07
	1979	21.32	50.63	6.32	21.73
	1983	37.37	37.94	2.68	22.00
KOREA	1981	25.10	59.60	0.60	14.70
	1983	29.89	52.53	0.53	17.06
SINGAPORE	1981	0.01	91.51	0.12	8.36
	1983	0.00	91.17	0.05	8.78
INDIA	1981	74.48	12.01	2.29	11.22
	1983	75.81	11.20	2.02	10.98
PHILIPPINES	1981	6.38	70.46	0.00	23.16
	1983	14.74	66.19	0.00	19.07

Residential Fuel Mix (%)

Country	Year	Coal	Oil	Gas	Electri.
U.S.A.	1973	4.89	27.95	46.90	20.26
	1979	8.28	20.58	47.39	23.76
	1983	10.57	15.46	45.69	28.28
U.K.	1973	32.44	11.64	32.79	23.13
	1979	20.50	8.83	50.28	20.39
	1983	16.49	6.00	57.50	20.00
GERMANY	1973	12.81	78.07	0.85	8.27
	1979	10.32	71.90	1.07	16.71
	1983	10.20	65.53	0.93	23.33
JAPAN	1973	8.29	41.99	17.44	32.27
	1979	2.61	39.84	20.35	37.19
	1983	1.53	35.59	22.08	40.80
TAIWAN	1973	4.96	47.81	8.06	39.17
	1979	0.99	44.70	15.39	38.93
	1983	0.22	43.99	15.40	40.39
KOREA	1981	74.29	20.63	0.13	4.94
	1983	73.26	20.83	0.31	5.60
SINGAPORE	1981	0.00	93.03	1.56	5.41
	1983	0.00	91.34	1.70	6.96
INDIA	1981	20.04	70.56	0.00	9.39
	1983	13.04	74.94	0.00	12.02
PHILIPPINES	1981	0.00	83.47	0.09	16.43
	1983	0.00	80.66	0.06	19.28

Commercial / Public Services Fuel Mix (%)

Country	Year	Coal	Oil	Gas	Electri.
U.S.A.	1973	2.48	26.70	44.42	26.40
	1979	1.99	21.38	44.79	31.84
	1983	3.32	15.74	42.10	38.83
U.K.	1973	14.67	44.15	13.03	28.15
	1979	10.76	40.41	15.15	33.67
	1983	9.76	34.65	18.11	37.48
GERMANY	1973	29.71	0.00	4.57	65.71
	1979	3.71	74.88	1.00	20.42
	1983	3.11	63.39	1.06	32.44
JAPAN	1973	0.07	73.91	8.70	17.32
	1979	0.05	69.16	7.44	23.35
	1983	0.00	62.58	8.35	29.07
TAIWAN	1973	11.18	70.37	1.05	17.41
	1979	6.70	64.27	3.10	25.93
	1983	5.62	57.41	5.05	31.92
KOREA	1981	23.41	37.66	0.00	38.93
	1983	3.55	65.00	0.09	31.36
SINGAPORE	1981	0.00	0.00	7.92	92.08
	1983	0.00	0.00	9.59	90.41
INDIA	1981	0.00	24.99	23.79	51.22
	1983	0.00	22.89	25.42	51.68
PHILIPPINES	1981	0.00	27.99	0.62	71.39
	1983	0.00	27.97	0.44	71.60

Elasticities of Commercial/Public Services Fuels

Country	Year	Total	Coal	Oil	Gas	Electri.
U.S.A.	1973-1979	Ø.38	-Ø.45	-Ø.98	Ø.44	1.57
	1979-1983	-1.54	Ø.49	-8.58	-3.Ø1	3.32
U.K.	1973-1979	Ø.2Ø	-3.5Ø	-Ø.85	2.Ø4	2.39
	1979-1983	-1.52	-9.22	-14.47	14.1Ø	7.79
GERMANY	1973-1979	1Ø.68	-3.31		Ø.ØØ	2.23
	1979-1983	-25.Ø4	-31.57	-33.19	-21.45	7.73
JAPAN	1973-1979	1.19		Ø.87	Ø.45	2.67
	1979-1983	Ø.25		-Ø.5Ø	1.14	1.95
TAIWAN	1973-1979	Ø.53	-Ø.49	Ø.34	2.99	1.38
	1979-1983	1.Ø7	Ø.3Ø	Ø.57	3.39	2.Ø2
KOREA	1981-1983	1.54	-2.93	3.84		Ø.79
SINGAPORE	1981-1983	-Ø.89			Ø.38	-1.ØØ
INDIA	1981-1983	-4.ØØ		-1.3Ø	-6.14	-4.29
PHILIPPINES	1981-1983					

Elasticities of Residential Fuels

Country	Year	Total	Coal /Other	Oil	Gas	Electri.
U.S.A.	1973-1979	Ø.Ø3	3.36	-1.78	Ø.Ø9	1.Ø1
	1979-1983	-Ø.7Ø	1.51	-3.12	-1.Ø2	Ø.86
U.K.	1973-1979	1.27	-3.98	-1.93	6.54	-Ø.21
	1979-1983	-3.82	-17.54	-27.57	4.99	-5.Ø7
GERMANY	1973-1979	-1.83	-2.82	-2.21	-Ø.7Ø	1.67
	1979-1983	-9.93	-1Ø.33	-13.39	-15.13	3.22
JAPAN	1973-1979	Ø.81	-2.8Ø	Ø.63	1.35	1.31
	1979-1983	Ø.28	-2.69	-Ø.4Ø	Ø.77	Ø.84
TAIWAN	1973-1979	1.55	-1.78	1.4Ø	3.16	1.54
	1979-1983	Ø.72	-3.74	Ø.66	Ø.72	Ø.85

APPENDIX B

Correlation Results of the Electricity-Economy Relationship Test for 14 Selected Countries
(USA,UK,Germany,Japan,Taiwan,Korea,Singapore,India, the Philippines, Brazil,France,Greece,Italy,Spain,etc.)

*on a per capita basis

Y	X	period	R square
ln(electricity)	ln(GDP) ln(energy)	1956 - 1985	0.999352
	ln(electricity)_1 ln(GDP)_1 ln(energy)_1	1956 - 1973 1974 - 1985	0.998997 0.999257
	ln(GDP) ln(energy)	1960 - 1973	0.995488
	ln(electricity)_5 ln(GDP)_5 ln(energy)_5	1960 - 1985 1974 - 1985	0.995536 0.995037
	ln(GDP) ln(energy)	1965 - 1985	0.990316
	ln(electricity)_10 ln(GDP)_10 ln(energy)_10	1965 - 1973 1974 - 1985	0.991504 0.990069
	ln(GDP) ln(electricity)_1 ln(energy)_1	1956 - 1985	0.998956
	ln(GDP) ln(electricity)_1	1956 - 1985	0.998934
	ln(GDP) ln(electricity)_5 ln(energy)_5	1960 - 1985	0.988379
	ln(GDP) ln(electricity)_5	1960 - 1985	0.988273
	ln(GDP) ln(electricity)_10 ln(energy)_10	1960 - 1985	0.971348
	ln(GDP)	1955 - 1985 1955 - 1973 1974 - 1985	0.9065 0.9153 0.9502

	ln(Energy)	1955 - 1985	0.9321
		1955 - 1973	0.9391
		1974 - 1985	0.9514
	GDP	1955 - 1985	0.7552
		1955 - 1973	0.8046
		1974 - 1985	0.7547
	energy	1955 - 1985	0.6269
		1955 - 1973	0.6318
		1974 - 1985	0.6477
	ln(GDP)	1955 - 1985	0.9452
	ln(energy)	1955 - 1973	0.9540
		1974 - 1985	0.9756
	GDP	1955 - 1985	0.7677
	energy	1955 - 1973	0.8047
		1974 - 1985	0.7849
	ln(GDP)	1955 - 1985	0.9208
	energy	1955 - 1973	0.9313
		1974 - 1985	0.9673
	ln(energy)	1955 - 1985	0.9328
	GDP	1955 - 1973	0.9395
		1974 - 1985	0.9550
electricity	GDP	1955 - 1985	0.8023
		1955 - 1973	0.8082
		1974 - 1985	0.7738
	GDP	1955 - 1985	0.8951
	except USA, Taiwan	1955 - 1973	0.8740
	India	1974 - 1985	0.9191
	energy	1955 - 1985	0.8818
		1955 - 1973	0.9316
		1974 - 1985	0.9226
	energy	1955 - 1985	0.8287
	except USA, Taiwan	1955 - 1973	0.8906
	India	1974- -1985	0.8234
	GDP	1955 - 1985	0.9198
	energy	1955 - 1973	0.9461
		1974 - 1985	0.9532
	GDP & energy	1955 - 1985	0.9124
	except USA, Taiwan	1955- -1973	0.9109
	India	1974- -1985	0.9446

ln(GDP)	1955 - 1985	0.7183
ln(energy)	1955 - 1973	0.7743
	1974 - 1985	0.7422
ln(GDP)	1955 - 1985	0.8941
energy	1955 - 1973	0.9416
	1974 - 1985	0.9389
ln(energy)	1955 - 1985	0.8137
GDP	1955 - 1973	0.8136
	1974 - 1985	0.8141

Correlation Results of the Electricity-Economy Relationship Test for 9 Selected Countries
(USA, UK, Germany, Japan, Taiwan, Korea, Singapore, India, the philippines, etc.)

*on a per capita basis

Y	X	period	R square
Electricity	GDP	1955 - 1985	0.8538
		1955 - 1973	0.8652
		1974 - 1985	0.8369
	USA, Taiwan, India	1955 - 1985	0.9631
		1955 - 1973	0.9621
		1974 - 1985	0.9992
	except: USA, Taiwan India	1955 - 1985	0.9426
		1955 - 1973	0.9191
		1974 - 1985	0.9732
	Energy	1955 - 1985	0.8899
		1955 - 1973	0.8652
		1974 - 1985	0.8369
	USA, Taiwan, India	1955 - 1985	0.9244
		1955 - 1973	0.9689
		1974 - 1985	0.9816
	except: USA, Taiwan India	1955 - 1985	0.8329
		1955 - 1973	0.8861
		1974 - 1985	0.8185
	GDP & Energy	1955 - 1985	0.9278
		1955 - 1973	0.9479
		1974 - 1985	0.9609
	USA, Taiwan, India	1955 - 1985	0.9693
		1955 - 1973	0.9717
		1974 - 1985	0.9993
	except: USA, Taiwan India	1955 - 1985	0.9437
		1955 - 1973	0.9213
		1974 - 1985	0.9784
	Industrial Production	1960 - 1983	0.8709
		1960 - 1973	0.9311
		1974 - 1983	0.8599
	USA, Taiwan, India	1960 - 1983	0.9622
	Other Countries	1960 - 1983	0.7058

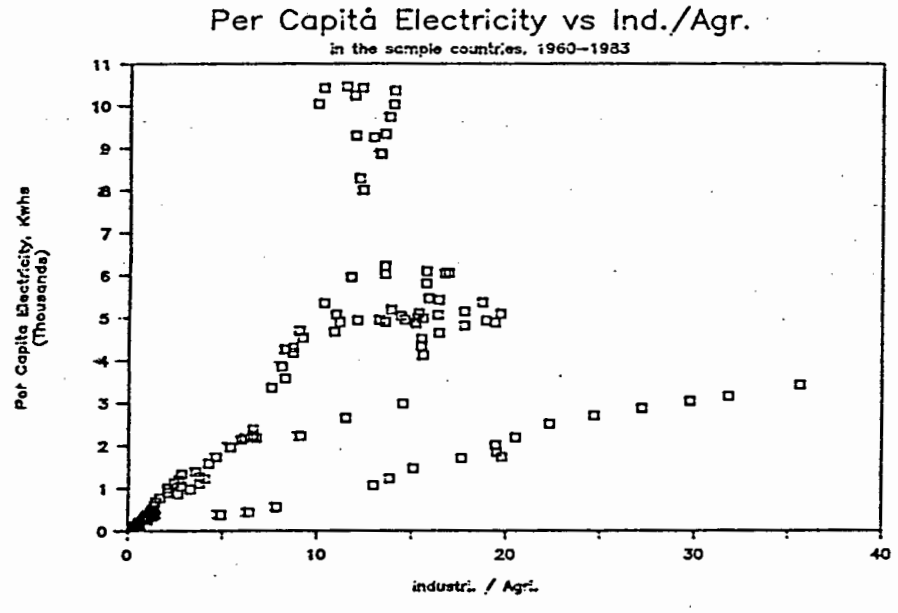
	Industry/Agriculture	1960 - 1983	0.3430
	Industry/Services	1960 - 1983	0.0006
	Population	1960 - 1983	0
Electricity/GDP	Electricity	1955 - 1985	0.1986
	GDP	1955 - 1985	0.0499
	Industrial Production	1955 - 1985	0.0943
	(>100 billion US $)	1955 - 1985	0.7643
	(<100 billion US $)	1955 - 1985	0.0427
	Industry/Agriculture	1960 - 1983	0.0002
	Industry/services	1960 - 1983	0.0303
	Population	1955 - 1985	0.0709

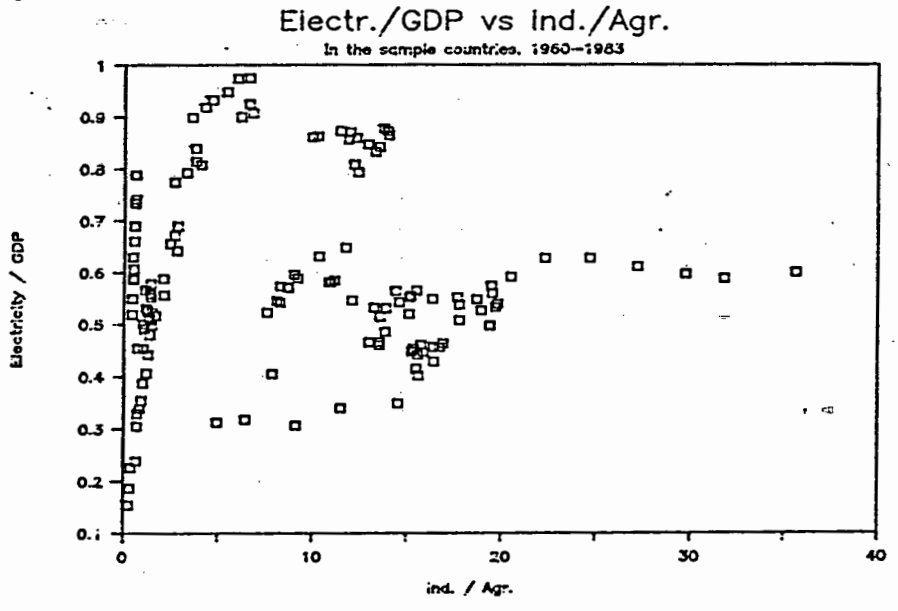
Correlation Results of the Electricity-Economy Relationship Test for 8 OECD Countries
(USA, UK, Germany, Japan, France, Greece, Italy, Spain.)

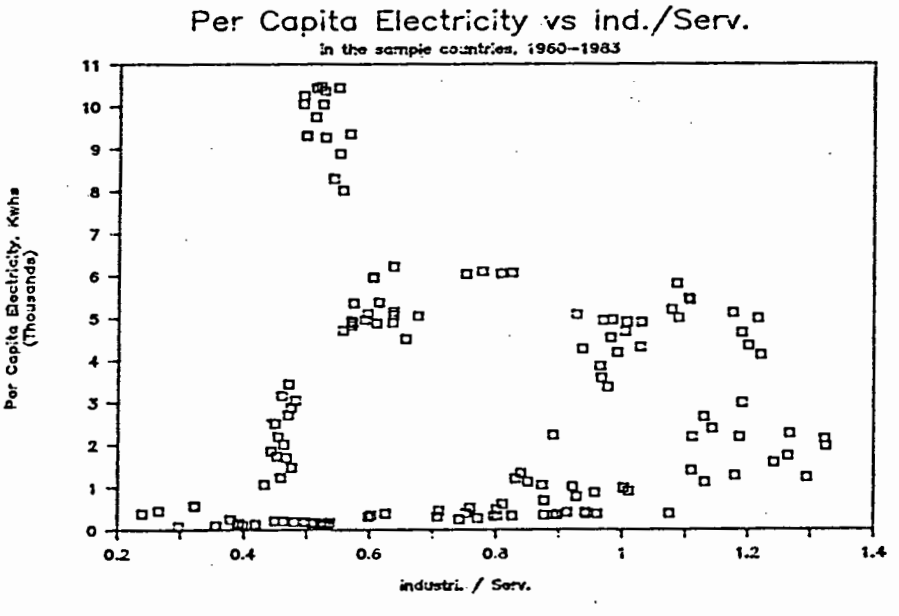
*on a per capita basis

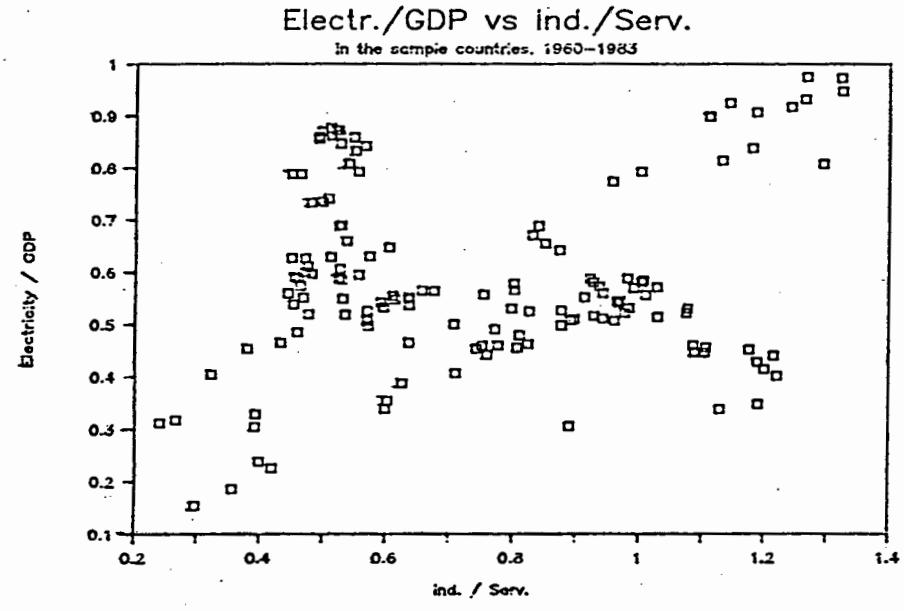
Y	X	period	R square
Electricity	GDP	1960 - 1985	0.6751
		1960 - 1973	0.7001
		1974 - 1985	0.5355
	except USA	1960 - 1985	0.8237
		1960 - 1973	0.7699
		1974 - 1985	0.8025
	Energy	1960 - 1985	0.8566
		1960 - 1973	0.9309
		1974 - 1985	0.9340
	except USA	1960 - 1985	0.8121
		1960 - 1973	0.8919
		1974 - 1985	
	Oil	1960 - 1985	0.8376
		1960 - 1973	0.8947
		1974 - 1985	0.8509
	except USA	1960 - 1985	0.7216
		1960 - 1973	0.7637
		1974 - 1985	0.5534
	Coal	1960 - 1985	0.0367
		1960 - 1973	0.1587
		1974 - 1985	0.4449
	Energy & Oil	1960 - 1985	0.8623
		1960 - 1973	0.9335
		1974 - 1985	0.9460
	except USA	1960 - 1985	0.8190
		1960 - 1973	0.8975
		1974 - 1985	0.8468
	GDP & Energy	1960 - 1985	0.8924
		1960 - 1973	0.9345
		1974 - 1985	0.9405
	except USA	1960 - 1985	0.8447
		1960 - 1973	0.9128
		1974 - 1985	0.8390

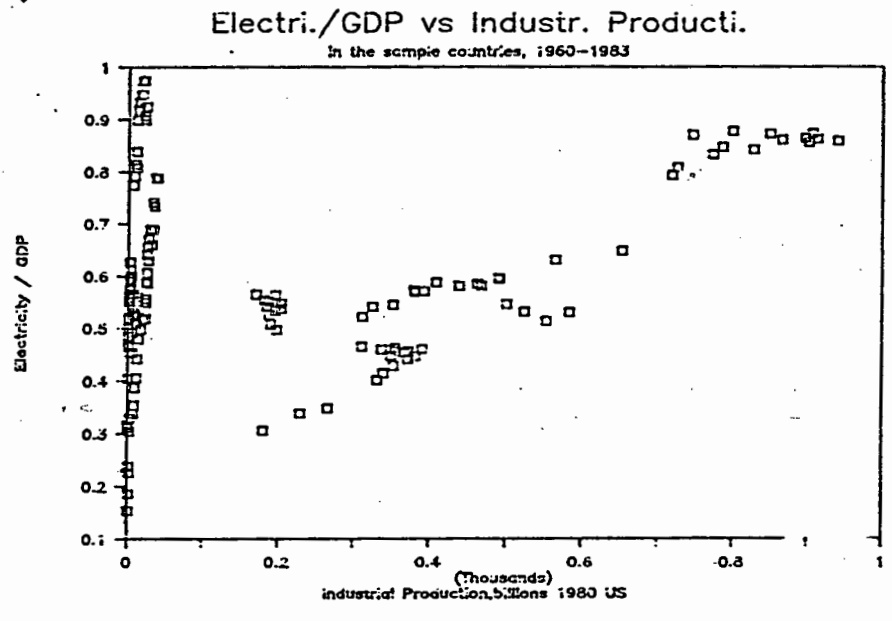
GDP, Energy and Oil	1960 - 1985	0.8934
	1960 - 1973	0.9361
	1974 - 1985	0.9515
except USA	1960 - 1985	0.8459
	1960 - 1973	0.9323
	1974 - 1985	0.8735

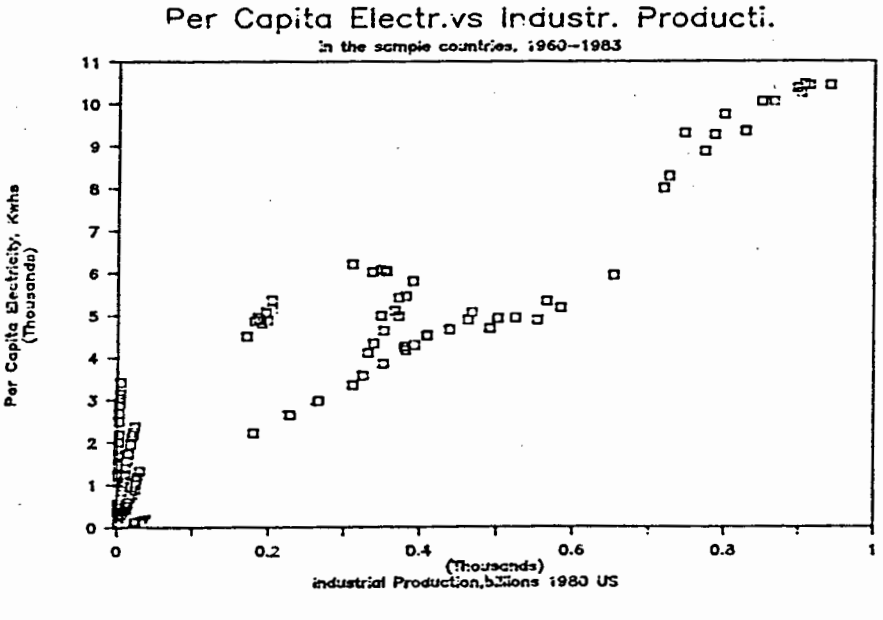

Per Capita Electricity vs Ind./Agr.
In the sample countries, 1960–1983
Per Capita Electricity, Kwhs (Thousands)
industri. / Agri.

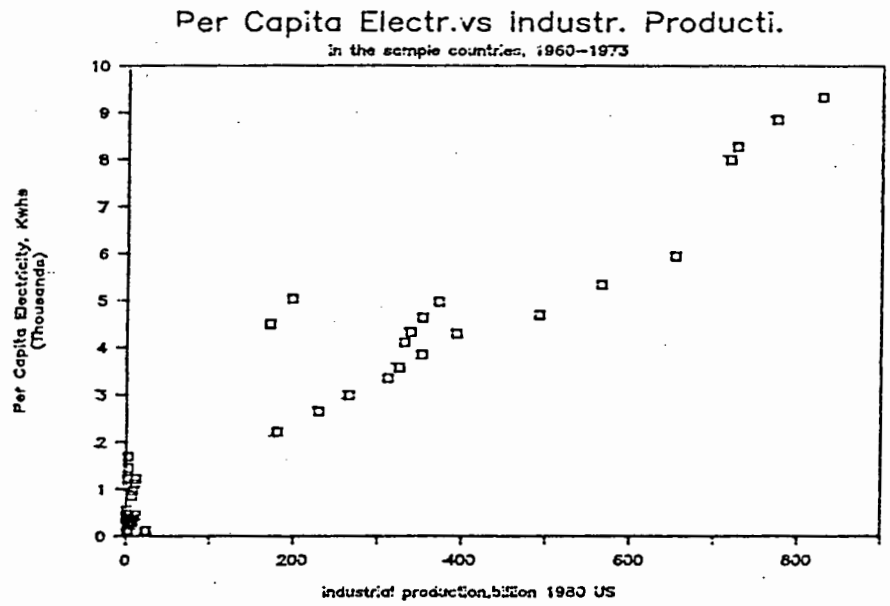

Electr./GDP vs Ind./Agr.
In the sample countries, 1960–1983
Electricity / GDP
ind. / Agr.

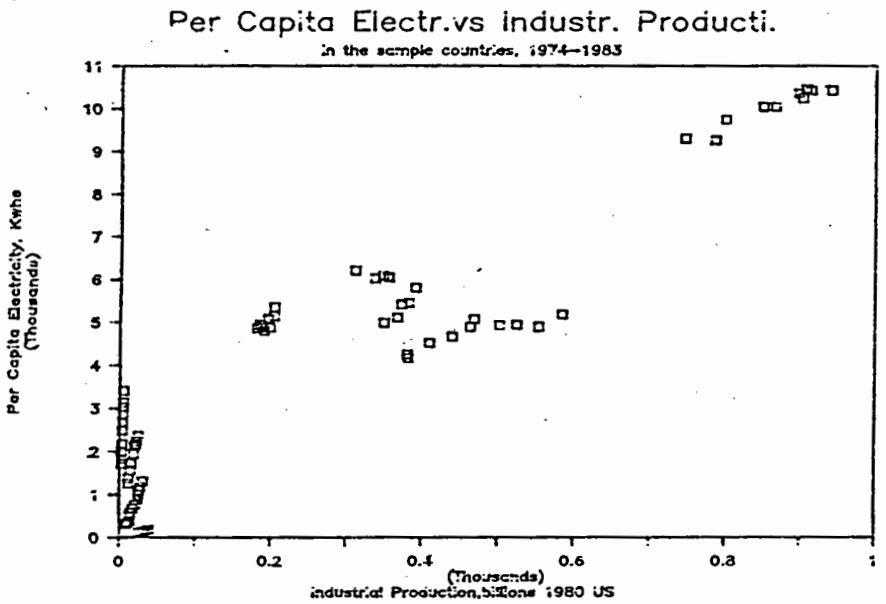

Per Capita Electricity vs Ind./Serv.
In the sample countries, 1960–1983
Per Capita Electricity, Kwhs (Thousands)
industri. / Serv.

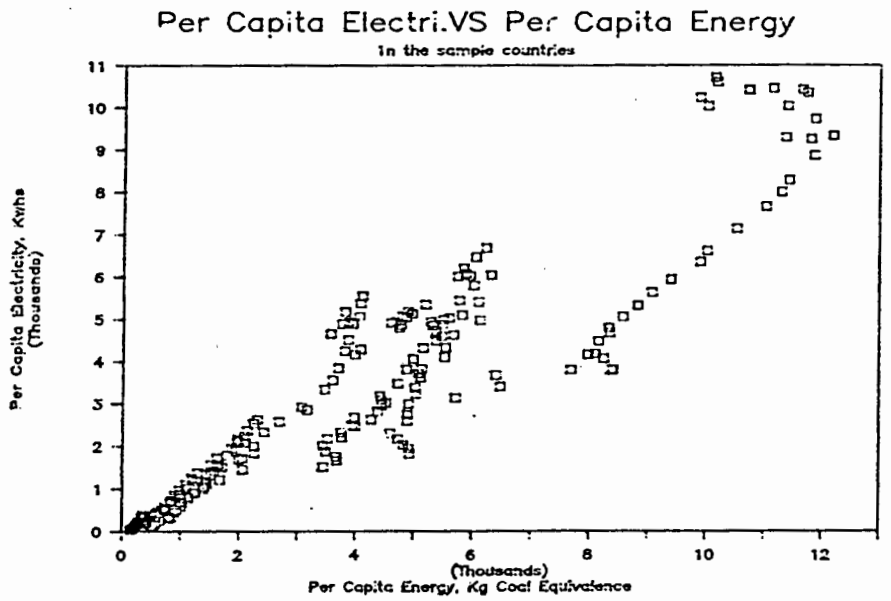

Electr./GDP vs Ind./Serv.
In the sample countries, 1960-1983
Electricity / GDP
ind. / Serv.


Electri./GDP vs Industr. Producti.
In the sample countries, 1960-1983
Electricity / GDP
(Thousands)
Industrial Production,billions 1980 US


Per Capita Electr.vs Industr. Producti.
In the sample countries, 1960-1983
Per Capita Electricity, Kwhs (Thousands)
(Thousands)
Industrial Production,billions 1980 US


Per Capita Electr.vs Industr. Producti.
In the sample countries, 1960-1973
Per Capita Electricity, Kwhs (Thousands)
0
1
2
3
4
5
6
7
8
9
10
0
200
400
600
800
Industrial production,billion 1980 US


Per Capita Electr.vs Industr. Producti.
In the sample countries, 1974-1983
Per Capita Electricity, Kwhs (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
0
0.2
0.4
0.6
0.8
1
(Thousands)
Industrial Production,billions 1980 US


Per Capita Electri.VS Per Capita Energy
In the sample countries
Per Capita Electricity, Kwhs (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
0
2
4
6
8
10
12
(Thousands)
Per Capita Energy, Kg Coal Equivalence

APPENDIX C

* Estimation of the saturation level of the share of electricity in secondary energy for the United States, 1970-1985

Electricity Share in Final energy — log (a / S - 1) — a : asyatote

		S, %					
USA			a=30	a=32	a=33	a=34	a=35
1970	1	9.512551	0.767200	0.860345	0.903854	0.945548	0.985573
1971	2	9.964593	0.698462	0.793612	0.837994	0.880489	0.921252
1972	3	10.18334	0.665768	0.761919	0.806736	0.849631	0.890761
1973	4	10.76380	0.580604	0.679518	0.725532	0.769522	0.811658
1974	5	11.13524	0.527180	0.627946	0.674760	0.719481	0.762287
1975	6	11.71032	0.445865	0.549640	0.597750	0.643652	0.687538
1976	7	11.74394	0.441158	0.545115	0.593303	0.639275	0.683227
1977	8	11.87831	0.422394	0.527083	0.575585	0.621843	0.666056
1978	9	12.15414	0.384101	0.490324	0.539484	0.586341	0.631099
1979	10	12.37936	0.353040	0.460551	0.510261	0.557617	0.602832
1980	11	13.19611	0.241688	0.354141	0.405956	0.455217	0.502166
1981	12	13.71751	0.171416	0.287269	0.340523	0.391083	0.439210
1982	13	13.99376	0.134366	0.252105	0.306154	0.357431	0.406207
1983	14	14.58512	0.055331	0.177322	0.233156	0.286037	0.336261
1984	15	14.68691	0.041751	0.164505	0.220659	0.273826	0.324308
1985	16	15.01412	-0.00188	0.123390	0.180595	0.234703	0.286034
R squared			0.987088	0.98714	0.98715	0.987153	0.98715

UK			a=16	a=17	a=18	a=20
1970	1	12.16262	-1.15358	-0.92199	-0.73408	-0.43946
1971	2	12.52085	-1.28060	-1.02796	-0.82644	-0.51527
1972	3	12.79620	-1.38481	-1.11316	-0.89976	-0.57454
1973	4	13.07155	-1.49596	-1.20219	-0.97541	-0.63480
1974	5	13.22431	-1.56116	-1.25347	-1.01852	-0.66871
1975	6	13.63796	-1.75333	-1.40031	-1.13991	-0.76251
1976	7	13.63099	-1.74987	-1.39772	-1.13781	-0.76090
1977	8	13.65840	-1.76352	-1.40790	-1.14611	-0.76722
1978	9	13.93931	-1.91167	-1.51607	-1.23336	-0.83288
1979	10	13.88179	-1.88001	-1.49332	-1.21516	-0.81931
1980	11	14.62688	-2.36578	-1.81865	-1.46702	-1.00145
1981	12	14.68032	-2.40912	-1.84508	-1.48664	-1.01509
1982	13	14.46856	-2.24577	-1.74319	-1.41027	-0.96153
1983	14	14.65368	-2.38732	-1.83184	-1.47683	-1.00828
1984	15	14.90854	-2.61442	-1.96407	-1.57329	-1.07437
1985	16	14.92879	-2.63450	-1.97515	-1.58122	-1.07971
R Squared			0.958944	0.961619	0.9607	0.958157

Gersany		a=22	a=23	a=24	a=26
1970	1	10.06753	0.169947	0.250425	0.324906	0.459043
1971	2	10.78191	0.039656	0.125046	0.203715	0.344614
1972	3	11.22443	-0.04081	0.047933	0.129441	0.274881
1973	4	11.23019	-0.04185	0.046931	0.128477	0.273979
1974	5	12.13934	-0.20789	-0.11130	-0.02322	0.132603
1975	6	12.34943	-0.24659	-0.14799	-0.05825	0.100171
1976	7	12.59297	-0.29168	-0.19065	-0.09891	0.062639
1977	8	12.88702	-0.34652	-0.24240	-0.14810	0.017381
1978	9	12.98290	-0.36451	-0.25934	-0.16418	0.002629
1979	10	12.88277	-0.34572	-0.24165	-0.14739	0.018035
1980	11	13.65561	-0.49256	-0.37937	-0.27770	-0.10095
1981	12	14.41201	-0.64149	-0.51769	-0.40755	-0.21809
1982	13	14.92178	-0.74579	-0.61365	-0.49694	-0.29784
1983	14	15.11533	-0.78641	-0.65079	-0.53138	-0.32835
1984	15	15.18153	-0.80044	-0.66359	-0.54323	-0.33882
1985	16	15.32151	-0.83036	-0.69083	-0.56841	-0.36102
R Squared			0.972642	0.972726	0.972688	0.972441

Japan		a=65	a=67	a=68	a=69	a=70
1970	1	13.51134	1.337831	1.375940	1.394462	1.412649	1.430510
1971	2	13.75775	1.314961	1.353249	1.371857	1.390125	1.408065
1972	3	14.47192	1.250318	1.289136	1.307995	1.326504	1.344677
1973	4	14.23331	1.271655	1.310294	1.329068	1.347496	1.365591
1974	5	14.30137	1.265543	1.304233	1.323031	1.341483	1.359600
1975	6	15.56919	1.155279	1.194942	1.214199	1.233093	1.251635
1976	7	15.85316	1.131443	1.171331	1.190694	1.209689	1.228330
1977	8	16.41307	1.085275	1.125614	1.145189	1.164388	1.183226
1978	9	16.97438	1.040028	1.080829	1.100621	1.120030	1.139069
1979	10	17.21386	1.021020	1.062021	1.081907	1.101406	1.120533
1980	11	17.80269	0.974987	1.016489	1.036611	1.056337	1.075681
1981	12	18.32079	0.935261	0.977214	0.997549	1.017478	1.037018
1982	13	18.96381	0.886894	0.929421	0.950025	0.970213	0.990001
1983	14	19.76538	0.827930	0.871194	0.892144	0.912664	0.932771
1984	15	19.60846	0.839364	0.882482	0.903363	0.923817	0.943861
1985	16	20.34324	0.786256	0.830068	0.851275	0.872041	0.892385
R Squared			0.984876	0.984877	0.984878	0.984877	0.984877

France		a=70	a=80	a=90	a=99	a=95
1970	1	8.482548	1.981310	2.131930	2.262806	2.367531	2.322335
1971	2	8.722566	1.949498	2.100666	2.231954	2.336974	2.291654
1972	3	8.843588	1.933741	2.085187	2.216685	2.321853	2.276471
1973	4	8.959517	1.918820	2.070533	2.202232	2.307543	2.262101
1974	5	9.806057	1.814571	1.968261	2.101447	2.207812	2.161929
1975	6	10.47265	1.737667	1.892952	2.027332	2.134543	2.088306
1976	7	10.96481	1.683442	1.839924	1.975201	2.083045	2.036544
1977	8	11.51420	1.625202	1.783044	1.919335	2.027894	1.981094
1978	9	11.54060	1.622461	1.780369	1.916709	2.025303	1.978488
1979	10	11.89115	1.586522	1.745312	1.882308	1.991363	1.944356
1980	11	12.62115	1.514301	1.674956	1.813339	1.923368	1.875954
1981	12	13.53332	1.428495	1.591545	1.731699	1.842971	1.795038
1982	13	14.18145	1.370171	1.534966	1.676407	1.788579	1.740271
1983	14	14.79006	1.317186	1.483655	1.626327	1.739356	1.690691
1984	15	15.34806	1.269995	1.438028	1.581847	1.695675	1.646676
1985	16	15.88549	1.225695	1.395264	1.540204	1.654812	1.605489
R Squared			0.989132	0.989222	0.989281	0.989319	0.989304

Greece		a=16	a=18	a=20	a=19
1970	1	10.89258	-0.75738	-0.42694	-0.17899	-0.29530
1971	2	11.69188	-0.99839	-0.61705	-0.34166	-0.46990
1972	3	11.51079	-0.94160	-0.57314	-0.30448	-0.42982
1973	4	11.74568	-1.01555	-0.63021	-0.35275	-0.48189
1974	5	13.15165	-1.52981	-0.99791	-0.65254	-0.81038
1975	6	13.45496	-1.66520	-1.08531	-0.72064	-0.88644
1976	7	13.34702	-1.61561	-1.05378	-0.69622	-0.85911
1977	8	13.59605	-1.73267	-1.12728	-0.75286	-0.92265
1978	9	13.90374	-1.89200	-1.22208	-0.82448	-1.00365
1979	10	14.04109	-1.96960	-1.26602	-0.85710	-1.04080
1980	11	14.67811	-2.40729	-1.48582	-1.01452	-1.22266
1981	12	15.2	-2.94443	-1.69167	-1.15267	-1.38629
1982	13	14.81164	-2.52284	-1.53590	-1.04899	-1.26310
1983	14	15.39101	-3.22974	-1.77482	-1.20577	-1.45035
1984	15	15.82733	-4.51815	-1.98578	-1.33318	-1.60716
1985	16	15.91614	-5.24604	-2.03311	-1.36029	-1.64115
R Squared			0.838157	0.967918	0.966798	0.968177

Italy		a=32	a=28	a=27	a=29	a=30
1970	1	10.17628	0.762937	0.560470	0.502729	0.615057	0.666819
1971	2	10.12949	0.769686	0.567699	0.510114	0.622147	0.673784
1972	3	10.17982	0.762426	0.559923	0.502171	0.614521	0.666292
1973	4	10.32497	0.741595	0.537587	0.479346	0.592621	0.644784
1974	5	10.77315	0.678209	0.469411	0.409609	0.525838	0.579250
1975	6	11.10195	0.632534	0.420076	0.359074	0.477570	0.531937
1976	7	11.33832	0.600091	0.384922	0.323027	0.443208	0.498283
1977	8	11.92427	0.520934	0.298733	0.234509	0.359081	0.415993
1978	9	12.20729	0.483279	0.257514	0.192100	0.318911	0.376755
1979	10	12.26320	0.475881	0.249398	0.183744	0.311006	0.369038
1980	11	12.86155	0.397456	0.162994	0.094654	0.226961	0.287081
1981	12	13.18787	0.355203	0.116148	0.046249	0.181479	0.242802
1982	13	13.70919	0.288331	0.041549	-0.03099	0.109184	0.172533
1983	14	13.60678	0.301413	0.056188	-0.01582	0.123358	0.186299
1984	15	13.85009	0.270372	0.021415	-0.05187	0.089701	0.153621
1985	16	14.10099	0.238500	-0.01442	-0.08909	0.055049	0.120011
R Squared			0.979519	0.979536	0.979527	0.979538	0.979535

Spain		a=70	a=80	a=90	a=99	a=98
1970	1	11.68588	1.607462	1.765734	1.902346	2.011130	1.999611
1971	2	11.54064	1.622456	1.780364	1.916705	2.025298	2.013798
1972	3	12.43862	1.532045	1.692229	1.830262	1.940047	1.928427
1973	4	12.21741	1.553825	1.713443	1.851055	1.960543	1.948953
1974	5	12.99572	1.478411	1.640043	1.779150	1.889687	1.877992
1975	6	13.29479	1.450493	1.612910	1.752596	1.863540	1.851804
1976	7	13.50301	1.431273	1.594243	1.734337	1.845567	1.833802
1977	8	13.61924	1.420643	1.583923	1.724246	1.835536	1.823855
1978	9	14.15094	1.372871	1.537583	1.678963	1.791092	1.779236
1979	10	14.04612	1.382181	1.546609	1.687779	1.799762	1.787921
1980	11	15.27502	1.276100	1.443927	1.587594	1.701317	1.689302
1981	12	16.03116	1.213872	1.383861	1.529109	1.643930	1.631804
1982	13	16.38830	1.185198	1.356229	1.502235	1.617582	1.605404
1983	14	16.71411	1.159418	1.331409	1.478114	1.593946	1.581719
1984	15	17.35887	1.109394	1.283318	1.431427	1.548229	1.535905
R Squared			0.96912	0.969461	0.969705	0.969873	0.969856

Taiwan			a=32	a=34	a=33	a=35
1971	1	15.65162	0.043553	0.158965	0.102923	0.212033
1972	2	15.84699	0.019126	0.135856	0.079193	0.189479
1973	3	15.77109	0.028614	0.144829	0.088409	0.198235
1974	4	16.78781	-0.09855	0.024963	-0.03489	0.081437
1975	5	16.85126	-0.10650	0.017498	-0.04258	0.074175
1976	6	16.24817	-0.03102	0.088507	0.030526	0.143310
1977	7	16.72159	-0.09026	0.032756	-0.02686	0.089018
1978	8	16.26482	-0.03310	0.086545	0.028508	0.141398
1979	9	16.76842	-0.09612	0.027246	-0.03253	0.083657
1980	10	16.93372	-0.11684	0.007796	-0.05258	0.064739
1981	11	17.53112	-0.19197	-0.06250	-0.12514	-0.00355
1982	12	17.53689	-0.19270	-0.06318	-0.12585	-0.00421
1983	13	17.56986	-0.19686	-0.06706	-0.12986	-0.00798
1984	14	18.06184	-0.25917	-0.12508	-0.18988	-0.06423
1985	15	18.27672	-0.28653	-0.15048	-0.21619	-0.08882
R Squared			0.852169	0.852176	0.852174	0.852174

APPENDIX D

* The Changes of Fuel Shares in the Selected Countries

Year	GDP	Sec.Ener	Popula.	Electri.	Oil	Coal	Gas	Electri.	Oil	Coal	Gas
Unit	Billions 1980 USDollars	Million Tons OE	Millions	Millions Tons OE	Millions Tons OE	Millions Tons OE	Millions Tons OE		%		
USA											
60	1427.4	832.49	180.68	59.17	436.66	104.3	199.01	7.107592	52.45228	12.52867	23.90539
	1464.6	841.9	183.69	62.09	445.01	98.53	203.68	7.374985	52.85782	11.70329	24.19289
	1542.4	878.55	186.54	66.91	465.61	97.76	215.54	7.615958	52.99755	11.12742	24.53360
	1605.7	922.06	189.24	71.64	492.76	99.57	224.78	7.769559	53.44120	10.79864	24.37802
	1691.4	962.01	191.89	77.06	507.92	102.24	241.14	8.010311	52.79778	10.62774	25.06626
	1789.4	991.5	194.3	82.04	521.87	104.48	249.55	8.274331	52.63439	10.53756	25.16893
	1892.9	1045.33	196.56	89.01	546.26	106.3	269.35	8.515014	52.25718	10.16903	25.76698
	1946.9	1110	198.71	94.51	558.43	114.68	308.68	8.514414	50.30900	10.33153	27.80900
	2027.7	1171.99	200.71	103.46	594.1	112.8	325.96	8.827720	50.69155	9.624655	27.81252
	2077.1	1202.53	202.68	113	618.45	110.6	324.26	9.396854	51.42907	9.197275	26.96481
70	2071.1	1218.18	205.05	115.88	623.86	106.32	336.15	9.512551	51.21246	8.727774	27.59444
	2129.9	1242.7	207.66	123.83	641.24	93.21	348.41	9.964593	51.60054	7.500603	28.03653
	2235.9	1314.99	209.9	133.91	680.36	91.43	371.51	10.18334	51.73879	6.952904	28.25192
	2352.1	1332.15	211.91	143.39	701.95	92.14	356.22	10.76380	52.69301	6.916638	26.74023
	2339.5	1289.15	213.85	143.55	671.66	90.27	344.95	11.13524	52.10099	7.002288	26.75794
	2310.1	1245.14	215.97	145.81	662.66	81.68	317.28	11.71032	53.21971	6.559904	25.48147
	2422.9	1317.7	218.04	154.75	713.03	82.65	324.17	11.74394	54.11170	6.272292	24.60119
	2536.1	1365.85	220.24	162.24	766.68	78.76	311.97	11.87831	56.13207	5.766372	22.84072
	2670.2	1382.08	222.59	167.98	764.82	81.13	316.89	12.15414	55.33833	5.870137	22.92848
	2736.3	1388.44	225.06	171.88	753.38	83.25	325.83	12.37936	54.26089	5.995937	23.46734
80	2732	1320.01	227.74	174.19	697.19	67.8	324.96	13.19611	52.81702	5.136324	24.61799
	2784.7	1301.11	230.04	178.48	670.41	74.48	321.42	13.71751	51.52600	5.724343	24.70352
	2713.8	1235.55	232.35	172.9	650.97	58.05	296.45	13.99376	52.68665	4.698312	23.99336
	2809.5	1222.41	234.54	178.29	637.59	61.11	283.1	14.58512	52.15844	4.999141	23.15916
	2993.2	1291.49	236.68	189.68	664.54	65.97	301.61	14.68691	51.45529	5.108053	23.35364
1985	3060.1	1281.26	239.28	192.37	663.36	64.97	292.27	15.01412	51.77403	5.070789	22.81113
60	333.9868	118.09	52.35	9.44	33.9	67.66	6.13	7.993902	28.70691	57.29528	5.190956
UK	344.9437	117.25	52.81	10.1	36.94	63.3	6.08	8.614072	31.50533	53.98720	5.185501
	348.5262	121.08	53.27	11.13	41.19	61.42	6.38	9.192269	34.01883	50.72679	5.269243
	363.2052	125.17	53.54	12.16	45.89	59.39	6.79	9.714787	36.66213	47.44747	5.424622
	382.2343	126.08	53.85	12.76	50.5	55.03	7.03	10.12055	40.05393	43.64689	5.575824
	391.1673	129.3	54.18	13.72	53.82	53.27	7.76	10.61098	41.62412	41.19876	6.001546
	398.7278	127.26	54.5	14.21	57.21	46.5	8.56	11.16611	44.95520	36.53936	6.726386
	409.8940	130.77	54.8	14.64	61.88	44.31	9.26	11.19522	47.31972	33.88391	7.081134
	427.2715	137.25	55.05	15.74	66.42	44.23	10.32	11.46812	48.39344	32.22586	7.519125
	433.0640	141.91	55.27	16.84	69.86	43.22	11.55	11.86667	49.22838	30.45592	8.138961
70	442.6018	144.87	55.42	17.62	73.67	39.9	13.3	12.16262	50.85248	27.54193	9.180644
	454.3961	143.84	55.61	18.01	74.3	34.42	16.87	12.52085	51.65461	23.92936	11.72830
	464.4225	145.59	55.78	18.63	76.96	28.53	21.3	12.79620	52.86077	19.59612	14.63012
	501.2245	153.31	55.91	20.04	80.28	28.71	24.09	13.07155	52.36449	18.72676	15.71326
	495.5949	147.38	55.92	19.49	74.64	26.25	26.88	13.22431	50.64459	17.81110	18.23856
	490.9656	141.59	55.9	19.31	70.92	22.82	28.45	13.63796	50.08828	16.11695	20.09322
	510.8322	144.01	55.89	19.63	71.17	22.22	30.73	13.63099	49.42017	15.42948	21.33879
	516.0198	146.43	55.85	20	72.19	21.6	32.39	13.65840	49.30000	14.75107	22.11978
	535.7701	145.99	55.84	20.35	72.55	18.43	34.47	13.93931	49.69518	12.62415	23.61120

	547.7040	152.79	55.88	21.21	73.81	19.93	37.69	13.88179	48.30813	13.04404	24.66784
80	535.0722	137.76	55.95	20.15	64.61	14.81	38.03	14.62688	46.90040	10.75058	27.60598
	528.5353	134.67	56.35	19.77	61.43	15.2	38.2	14.68032	45.61520	11.28684	28.36563
	535.1187	133.6	56.34	19.33	60.93	14.91	38.36	14.46856	45.60628	11.16017	28.71257
	554.4038	133.55	56.38	19.57	60.41	14.74	38.79	14.65368	45.23399	11.03706	29.04530
	565.4304	133.95	56.49	19.97	61.3	13.18	39.47	14.90854	45.76334	9.839492	29.46621
1985	562.4124	139.73	56.62	20.86	61.05	15.85	41.93	14.92879	43.69140	11.34330	30.00787
60	402.7067	104.22	55.43	8.3	28.11	65.24	2.57	7.963922	26.97179	62.59834	2.465937
Germany	420.2563	107.97	56.18	8.88	34.46	62	2.62	8.224506	31.91627	57.42335	2.426599
	440.0616	118.24	56.94	9.52	42.73	63.05	2.94	8.051420	36.13836	53.32374	2.486468
	452.2198	129.39	57.59	10.3	50.88	65.16	3.05	7.960429	39.32297	50.35937	2.357214
	481.8726	132.92	58.27	11.21	58.16	60.22	3.34	8.433644	43.75564	45.30544	2.512789
	507.6195	137.37	59.01	12.11	66.14	55.56	3.57	8.815607	48.14733	40.44551	2.598820
	522.6935	142.41	59.5	12.89	74.76	48.23	6.52	9.051330	52.49631	33.86700	4.578330
	522.3634	143.35	59.87	13.39	76.89	45.79	7.28	9.340774	53.63794	31.94279	5.078479
	552.5664	154.76	60.17	14.8	85.55	44.97	9.44	9.563194	55.27914	29.05789	6.099767
	594.0474	169.42	60.44	16.34	96.08	45.78	11.23	9.644670	56.71113	27.02160	6.628497
70	623.9753	176.21	60.71	17.74	107.25	41.49	9.17	10.06753	60.86487	23.54576	5.204017
	642.6252	175.85	61.29	18.96	111.84	32.44	12.07	10.78191	63.59965	18.44754	6.863804
	669.5824	184.33	61.67	20.69	118.63	29.02	15.5	11.22443	64.35740	15.74350	8.408831
	700.9407	196.88	61.97	22.11	127.22	28.86	18.26	11.23019	64.61804	14.65867	9.274685
	702.2610	188.89	62.04	22.93	115.14	30.76	19.71	12.13934	60.95611	16.28461	10.43464
	692.1384	180.98	61.83	22.35	111.85	24.26	19.83	12.34943	61.80240	13.40479	10.95701
	730.7586	192.25	61.51	24.21	118.34	23.71	23.07	12.59297	61.55526	12.33289	12
	750.1237	193.14	61.4	24.89	119	21.93	25.52	12.88702	61.09557	11.35445	13.21321
	774.6052	202.42	61.31	26.28	124.87	21.25	26.94	12.98290	61.68856	10.49797	13.36896
	805.2483	212.92	61.44	27.43	129.11	23.66	29.55	12.88277	60.63779	11.11215	13.87845
80	817.1315	200.65	61.56	27.4	116.1	23.99	29.84	13.65561	57.86194	11.95614	14.87166
	817.1865	191.16	61.67	27.55	105.88	23.7	30.43	14.41201	55.38815	12.39799	15.91860
	809.3194	182.82	61.64	27.28	101.35	21.84	28.56	14.92178	55.43704	11.94617	15.62192
	821.7527	185.11	61.42	27.98	102.17	21.25	29.78	15.11533	55.19420	11.47966	16.08773
	846.6743	192.8	61.18	29.27	104.29	22.9	32.38	15.18153	54.09232	11.87759	16.79460
1985	867.0847	196.26	61.02	30.07	105.52	23.36	33.53	15.32151	53.76541	11.90257	17.08447
60	221.9590	59.56	94.11	8.18	20.53	28.98	1.87	13.73404	34.46944	48.65681	3.139691
Japan	254.0883	68.06	94.95	9.47	25.72	30.55	2.33	13.91419	37.79018	44.88686	3.423449
	271.9291	73.74	95.83	10.08	33.75	27.24	2.67	13.66965	45.76891	36.94060	3.620829
	300.3836	84.12	96.81	11.68	42.38	26.99	3.08	13.88492	50.38040	32.08511	3.661436
	339.8606	94.44	97.83	13.18	50.87	27.02	3.37	13.95595	53.86488	28.61075	3.568403
	398.5754	102.43	98.88	14.15	58.72	25.91	3.65	13.81431	57.32695	25.29532	3.563409
	440.3854	119.49	99.73	15.97	72.43	27.25	3.85	13.36513	60.61595	22.80525	3.222026
	486.1824	140.07	100.83	18.25	86.31	31.27	4.24	13.02919	61.61919	22.32455	3.027057
	547.0847	157.24	101.96	20.42	100.27	31.98	4.57	12.98651	63.76876	20.33833	2.906385
	613.2795	183.27	103.17	23.75	118.59	35.78	5.15	12.95902	64.70780	19.52310	2.810061
70	671.2887	199.24	104.34	26.92	130.21	36.46	5.65	13.51134	65.35334	18.29953	2.835775
	700.2161	212.68	105.71	29.26	143.45	33.64	6.32	13.75775	67.44874	15.81719	2.971600
	759.9805	224.78	107.19	32.53	151.58	34.1	6.57	14.47192	67.43482	15.17038	2.922857
	819.9832	250.82	108.71	35.7	170.25	37.71	7.16	14.23331	67.87736	15.03468	2.854636
	808.3487	246.34	110.16	35.23	165.6	37.84	7.66	14.30137	67.22416	15.36088	3.109523
	829.9770	232.96	111.57	36.27	153.68	35.09	7.92	15.56919	65.96840	15.06267	3.399725
	869.7847	245.44	112.77	38.91	163.57	34.52	8.44	15.85316	66.64357	14.06453	3.438722
	916.1947	247.12	113.86	40.56	165.27	32.3	9	16.41307	66.87843	13.07057	3.641955
	963.8881	251.85	114.9	42.75	170.25	29.93	8.91	16.97438	67.59976	11.88405	3.537820
	1014.704	260.72	115.87	44.88	174.11	32.15	9.58	17.21386	66.78045	12.33123	3.674440
80	1059.257	247.94	116.78	44.14	158.33	35.57	9.9	17.80269	63.85819	14.34621	3.992901
	1096.965	242.02	117.65	44.34	150.84	36.55	10.29	18.32079	62.32542	15.10205	4.251714

	1130.788	233.55	118.45	44.29	143.24	35.7	10.32	18.96381	61.33162	15.28580	4.418754
	1167.434	237.84	119.26	47.01	147.02	33.06	10.74	19.76538	61.81466	13.90010	4.515640
	1226.598	251.83	120.02	47.38	154.26	36.35	11.84	19.60846	61.25560	14.43434	4.701584
1985	1283.580	250.55	120.79	50.97	151.63	35.9	12.05	20.34324	60.51885	14.32847	4.809419
France	265.5717	64.63	45.68	5.19	24.11	32.81	2.53	8.030326	37.30465	50.76589	3.914590
1961	280.1968	67.2	46.16	5.59	26.39	32.35	2.87	8.318452	39.27083	48.13988	4.270833
1962	298.9397	72.63	47	6.04	29.98	33.3	3.31	8.316122	41.27770	45.84882	4.557345
1963	314.8665	80.72	47.82	6.53	35.21	35.36	3.62	8.089692	43.61992	43.80574	4.484638
1964	335.3843	83.32	48.31	7.12	39.44	32.82	3.93	8.545367	47.33557	39.39030	4.716754
1965	353.1806	86.97	48.76	7.39	44.33	30.81	4.44	8.497182	50.97159	35.42600	5.105208
1966	371.5921	88.66	49.16	7.88	48.3	27.84	4.64	8.887886	54.47778	31.40085	5.233476
1967	389.0098	94.32	49.55	8.27	54.97	26.06	5.02	8.768023	58.28032	27.62934	5.322307
1968	405.5992	101.06	49.91	8.69	61.59	25.31	5.46	8.598852	60.94399	25.04452	5.402731
1969	433.9265	108.84	50.32	9.56	68.48	24.67	6.13	8.783535	62.91804	22.66629	5.632120
1970	458.7750	121.19	50.77	10.28	80.37	23.35	7.19	8.482548	66.31735	19.26726	5.932832
1971	483.6472	124.39	51.25	10.85	85.82	19.45	8.26	8.722566	68.99268	15.63630	6.640405
1972	512.1402	131.96	51.7	11.67	92.76	17.88	9.65	8.843588	70.29402	13.54956	7.312822
1973	539.6393	142.53	52.13	12.77	100.34	18.03	11.38	8.959517	70.39921	12.64996	7.984284
1974	557.1043	137.67	52.49	13.5	93.9	18.38	11.89	9.806057	68.20658	13.35076	8.636594
1975	558.0982	129.48	52.79	13.56	88.83	14.58	12.51	10.47265	68.60518	11.26042	9.661725
1976	586.9935	134.43	52.91	14.74	91.16	14.16	14.38	10.96481	67.81224	10.53336	10.69701
1977	612.9070	134.79	53.15	15.52	90.5	13.27	15.5	11.51420	67.14147	9.844943	11.49936
1978	633.4248	143.84	53.38	16.6	97.13	12.9	17.21	11.54060	67.52641	8.968298	11.96468
1979	653.9663	147	53.61	17.48	97.13	13.18	19.22	11.89115	66.07482	8.965986	13.07482
1980	664.5920	142.38	53.88	17.97	92.04	12.67	19.69	12.62115	64.64391	8.898721	13.82918
1981	672.4015	133.67	54.18	18.09	83.04	11.81	20.73	13.53332	62.12313	8.835191	15.50834
1982	689.5352	130.17	54.48	18.46	80.02	11.58	20.11	14.18145	61.47345	8.896058	15.44902
1983	694.3156	131.71	54.73	19.48	80.28	10.72	21.22	14.79006	60.95209	8.139093	16.11115
1984	703.9710	132.59	54.95	20.35	77.92	11.45	22.87	15.34806	58.76762	8.635643	17.24866
1985	715.7090	134.84	55.17	21.42	77.62	12.08	23.72	15.88549	57.56452	8.958765	17.59121
Greece	12.15946	2.05	8.33	0.16	1.73	0.16	0	7.804878	84.39024	7.804878	0
1961	13.51573	2.34	8.4	0.18	1.97	0.18	0	7.692307	84.18803	7.692307	0
1962	13.71987	2.52	8.45	0.2	2.14	0.18	0	7.936507	84.92063	7.142857	0
1963	15.10899	2.7	8.48	0.23	2.21	0.25	0	8.518518	81.85185	9.259259	0
1964	16.36436	3.22	8.51	0.27	2.65	0.29	0	8.385093	82.29813	9.006211	0
1965	17.89192	3.5	8.55	0.32	2.83	0.34	0	9.142857	80.85714	9.714285	0
1966	18.98538	4	8.61	0.43	3.18	0.39	0	10.75	79.5	9.75	0
1967	20.02721	4.28	8.72	0.52	3.48	0.28	0	12.14953	81.30841	6.542056	0
1968	21.35767	4.68	8.74	0.56	3.82	0.3	0	11.96581	81.62393	6.410256	0
1969	23.47889	5.41	8.77	0.64	4.42	0.35	0	11.82994	81.70055	6.469500	0
1970	25.34434	6.61	8.79	0.72	4.97	0.46	0	10.89258	75.18910	6.959152	0
1971	27.14879	7.27	8.83	0.85	5.61	0.36	0	11.69188	77.16643	4.951856	0
1972	29.55862	8.34	8.89	0.96	6.43	0.5	0	11.51079	77.09832	5.995203	0
1973	31.71973	9.28	8.93	1.09	7.15	0.58	0	11.74568	77.04741	6.25	0
1974	30.56761	8.44	8.96	1.11	6.27	0.61	0	13.15165	74.28909	7.227488	0
1975	32.42368	8.77	9.05	1.18	6.51	0.63	0	13.45496	74.23033	7.183580	0
1976	34.48389	9.74	9.17	1.3	7.4	0.59	0	13.34702	75.97535	6.057494	0
1977	35.67121	10.15	9.27	1.38	7.81	0.5	0	13.59605	76.94581	4.926108	0
1978	38.05288	11.22	9.36	1.56	8.74	0.47	0	13.90374	77.89661	4.188948	0
1979	39.46077	11.68	9.45	1.64	9.01	0.58	0	14.04109	77.14041	4.965753	0
1980	40.14829	11.65	9.64	1.71	8.97	0.51	0	14.67811	76.99570	4.377682	0
1981	40.17410	11.25	9.73	1.71	8.7	0.38	0	15.2	77.33333	3.377777	0
1982	40.33366	11.68	9.79	1.73	8.9	0.57	0.03	14.81164	76.19863	4.880136	0.256849
1983	40.49557	12.02	9.85	1.85	8.79	0.89	0.03	15.39101	73.12811	7.404326	0.249584
1984	41.60780	12.51	9.9	1.98	8.91	1.12	0.05	15.82733	71.22302	8.952837	0.399680

1985	42.85379	12.88	9.93	2.05	9.06	1.25	0.06	15.91614	70.34161	9.704968	0.465838
Italy	192.3225	34.99	49.64	4.03	17.57	5.74	5.15	11.51757	50.21434	16.40468	14.71849
1961	208.1048	38.4	49.9	4.35	20.35	5.61	5.51	11.32812	52.99479	14.60937	14.34895
1962	221.0158	42.92	50.24	4.74	24.18	6.02	5.63	11.04380	56.33737	14.02609	13.11742
1963	233.4154	48.65	51.18	5.33	28.62	6.56	5.77	10.95580	58.82836	13.48406	11.86022
1964	239.9427	51.4	51.57	5.69	31.94	5.58	5.92	11.07003	62.14007	10.85603	11.51750
1965	242.9915	55.29	51.99	6.14	35.5	5.91	6	11.10508	64.20690	10.68909	10.85187
1966	266.1198	62.1	52.33	6.69	41.32	5.87	6.33	10.77294	66.53784	9.452495	10.19323
1967	281.4677	67.64	52.67	7.2	45.75	6.14	6.83	10.64458	67.63749	9.077468	10.09757
1968	299.8890	72.92	52.99	7.76	50.08	5.79	7.68	10.64179	68.67800	7.940208	10.53208
1969	318.1760	79.22	53.32	8.28	55.22	5.68	8.57	10.45190	69.70462	7.169906	10.81797
1970	335.0735	87.36	53.66	8.89	62.33	5.57	9.27	10.17628	71.34844	6.375915	10.61126
1971	340.5780	91.12	54.01	9.23	65.51	4.81	10.25	10.12949	71.89420	5.278753	11.24890
1972	351.4852	96.76	54.41	9.85	69.06	4.7	11.64	10.17982	71.37246	4.857379	12.02976
1973	376.1992	102.47	54.8	10.58	72.45	4.74	12.98	10.32497	70.70362	4.625744	12.66712
1974	391.7795	101.92	55.1	10.98	69.75	5.3	14.72	10.77315	68.43602	5.200156	14.44270
1975	377.5361	97.1	55.4	10.78	64.16	4.67	16.38	11.10195	66.07621	4.809474	16.86920
1976	399.7034	104.16	55.7	11.81	67.8	4.71	18.75	11.33832	65.09216	4.521899	18.00115
1977	407.2909	102.48	55.93	12.22	65.39	4.67	19.24	11.92427	63.80757	4.556986	18.77439
1978	418.2251	104.2	56.13	12.72	66.21	4.64	19.79	12.20729	63.54126	4.452975	18.99232
1979	438.7342	109.27	56.29	13.4	69.91	4.71	20.36	12.26320	63.97913	4.310423	18.63274
1980	455.8979	106.83	56.42	13.74	66.67	4.87	20.55	12.86155	62.40756	4.558644	19.23616
1981	461.0824	103.58	56.5	13.66	63.58	5.24	20.05	13.18787	61.38250	5.058891	19.35701
1982	462.1999	101.1	56.64	13.86	61.43	5.51	19.31	13.70919	60.76162	5.450049	19.09990
1983	464.4079	101.42	56.84	13.8	62.19	4.76	19.66	13.60678	61.31926	4.693354	19.38473
1984	480.7823	105.27	56.98	14.58	62.77	5.5	21.37	13.85009	59.62762	5.224660	20.30918
1985	494.0028	105.95	57.13	14.94	61.6	6.14	22.29	14.10099	58.14063	5.795186	21.03822
Spain	70.80892	13.75	30.45	1.18	4.9	7.57	0.09	8.581818	35.63636	55.05454	0.654545
1961	79.19107	14.9	30.76	1.32	6.05	7.43	0.09	8.859060	40.60402	49.86577	0.604026
1962	86.55509	15.8	31.07	1.49	6.78	7.43	0.1	9.430379	42.91139	47.02531	0.632911
1963	94.14225	17.09	31.39	1.64	7.53	7.8	0.11	9.596255	44.06085	45.64072	0.643651
1964	102.1757	18.16	31.72	1.84	9.5	6.69	0.12	10.13215	52.31277	36.83920	0.660792
1965	108.6471	19.1	32.06	2.08	9.89	6.99	0.14	10.89005	51.78010	36.59685	0.732984
1966	116.3040	21.2	32.39	2.38	12.2	6.46	0.16	11.22641	57.54716	30.47169	0.754716
1967	121.3389	23.03	32.73	2.66	14.31	5.87	0.18	11.55015	62.13634	25.46849	0.781589
1968	129.5536	25.24	33.08	3	16.84	5.2	0.2	11.88589	66.71949	20.60221	0.792393
1969	141.1436	28.48	33.43	3.39	19.52	5.34	0.23	11.90308	68.53932	18.75	0.807564
1970	146.9037	32.09	33.78	3.75	22.53	5.49	0.31	11.68588	70.20878	17.10813	0.966033
1971	154.1701	35.18	34.13	4.06	24.77	5.93	0.42	11.54064	70.40932	16.85616	1.193860
1972	166.7224	36.66	34.49	4.56	25.28	6.26	0.57	12.43862	68.95799	17.07583	1.554928
1973	179.8186	41.58	34.86	5.08	30.17	5.62	0.72	12.21741	72.55892	13.51611	1.731601
1974	190.0976	42.78	35.22	5.56	31.78	4.67	0.77	12.99672	74.28705	10.91631	1.799906
1975	192.1896	43.25	35.6	5.75	31.85	4.78	0.86	13.29479	73.64161	11.05202	1.988439
1976	197.9776	46.36	35.97	6.26	34.77	4.37	0.96	13.50301	75	9.426229	2.070750
1977	204.5048	47.8	36.35	6.51	36.03	4.2	1.06	13.61924	75.37656	8.786610	2.217573
1978	208.1729	48.76	36.67	6.9	36.99	3.68	1.18	14.15094	75.86136	7.547169	2.420016
1979	208.5634	52.47	36.99	7.37	40.05	3.87	1.18	14.04612	76.32933	7.375643	2.248904
1980	211.7852	50.54	37.54	7.72	38.26	3.49	1.07	15.27502	75.70241	6.905421	2.117134
1981	212.4546	48.78	37.76	7.82	35.63	4.25	1.09	16.03116	73.04223	8.712587	2.234522
1982	214.6025	47.9	37.98	7.85	33.91	4.95	1.19	16.38830	70.79331	10.33402	2.484342
1983	219.8605	49.18	38.17	8.22	34.62	4.98	1.36	16.71411	70.39446	10.12606	2.765351
1984	224.9511	49.6	38.34	8.61	34.45	4.97	1.58	17.35887	69.45564	10.02016	3.185483
Taiwan	18.31175	7.98	14.84	1.249	3.713	2.27	0.748	15.65162	46.52882	28.44611	9.373433
1972	20.73706	9.15	15.14	1.45	4.523	2.274	0.901	15.84699	49.43169	24.85245	9.846994
1973	23.40566	10.31	15.42	1.626	5.475	2.1	1.109	15.77109	53.10378	20.36857	10.75654

1974	23.66956	10.18	15.71	1.709	5.511	1.846	1.113	16.78781	54.13555	18.13359	10.93320
1975	24.80406	11.376	16	1.917	6.565	1.709	1.186	16.85126	57.70921	15.02285	10.42545
1976	28.19166	13.7	16.33	2.226	8.276	1.804	1.394	16.24817	60.40875	13.16788	10.17518
1977	31.00619	14.867	16.66	2.486	9.098	1.708	1.575	16.72159	61.19593	11.48853	10.59393
1978	35.18520	17.627	16.97	2.867	10.911	2.152	1.697	16.26482	61.89935	12.20854	9.627276
1979	38.05736	19	17.31	3.186	12.211	2.027	1.581	16.76842	64.26842	10.66842	8.321052
1980	40.84292	20.22	17.64	3.424	12.969	2.255	1.573	16.93372	64.13946	11.15232	7.779426
1981	43.35035	19.28	17.97	3.38	12.224	2.302	1.377	17.53112	63.40248	11.93983	7.142116
1982	44.54963	19.65	18.3	3.446	12.011	3.085	1.108	17.53689	61.12468	15.69974	5.638676
1983	47.98000	21.719	18.6	3.816	13.066	3.711	1.125	17.56986	60.15930	17.08642	5.179796
1984	52.56658	22.96	18.87	4.147	14	3.678	1.139	18.06184	60.97560	16.01916	4.960801
1985	54.82827	23.85	19.13	4.359	14.653	3.821	1.018	18.27672	61.43815	16.02096	4.268343