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ENERGY NEEDS FOR ECONOMIC EXPANSION IN THE DEVELOPING WORLD: TRENDS IN THE ENERGY-DEVELOPMENT RELATIONSHIP

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ABSTRACT

Several studies of world commercial energy needs project significant increases in demand by developing countries, particularly for oil. (see,e.g., Goldemberg et al., 1987; and International Institute for Applied Systems Analysis, 1981). Sharp increases in oil prices, especially at the scale of the energy crises of the 1970s might have a severe effect on economic growth in developing countries, most of which are net energy importers and must finance their energy purchases from current accounts. This paper examines recent trends in the energy-development relationship among selected developing countries at comparable stages of development and with similar energy resource endowments. The growth rates and economic diversification of these countries are compared with changes in energy consumption to determine how different development groups were affected by high energy costs. The time span of the study is from 1967 to 1986 and is divided into three periods: 1967-1973--a pre-crisis period; 1973-1980--the energy crisis period; and 1980-1985--the post-crisis period. This paper concludes with an identification of potential energy-related development options which might be available for the year 2000.

INTRODUCTION

The role of energy in international economic development has recently attracted much attention. Several international studies have forecasted significant increases in developing country energy requirements. A 1981 study prepared at the International Institute for Applied Systems Analysis (IIASA) predicted that energy needs for developing countries would nearly triple in forty years, increasing from 3.3 terawatts in 1980 to over 9.2 terawatts in 2020 (see IIASA,1981, mid-range projections). A more recent World Resources Institute study concluded that energy consumption in developing countries may only double between 1980 and 2020, but even so this would mean an increase of 4.1 terawatts, or roughly 40 percent of existing world energy use (Goldemberg,et al., 1987). Substantial increases in oil prices during the 1970s and the prospect of still higher prices in the future have led some researchers to project an economic slowdown or even worse, particularly in the developing world (OPEC Special Fund, 1979; and OECD, 1982). Some analysts regard such fears as unduly pessimistic, neglecting or understating the likely contributions of energy efficiency and renewable fuel-based technologies (e.g., Flavin, 1986). Several studies have explored the causal relationships between economic development and aggregate energy consumption from an international perspective in an effort to resolve this issue (Kraft and Kraft, 1978; Akarca and Long, 1980; Yu and Choi, 1980; Yu and Hwang 1984; and Siddayao, 1986). The evidence from these studies, however, appears to be inconclusive. The relationship between energy and development seems to vary among countries, and empirical results are sensitive to the size and composition of the country samples used for the analysis. In this context, an important drawback of available research is the failure to compare energy requirements for development by country income level.

Studies of industrialized countries indicate that increases in energy prices need not have a strong effect on long-run growth because of the substantial capacity for substituting other inputs when energy prices rise. However, some studies point out that a similar change in energy costs in developing countries might have a more severe effect on economic growth. (National Academy of Sciences, 1978; Dunkerly et al., 1981). It is suggested that further sharp increases in oil prices beyond those of

1973-1974 and 1978-1979 might have different effects on national economic growth depending upon the development stage of the country, its gross domestic product(GDP) level, its development and energy strategies, and its relation to and competitiveness in world markets. Curiously, while speculation of this kind is present in the research literature, no systematic empirical study has been conducted to compare the actual impact of energy events of the 1970s on development of countries by income group. Moreover, there is no comprehensive empirical study estimating the energy-development relation by stage of development and level of oil dependency.

This paper offers a comparative framework for analyzing the energy requirements for economic growth by income/development group, and the distributional implications for world development of reduced fossil energy supplies. It should be noted that the impact of energy on economic growth is only one dimension of the world energy transition. Social, political, cultural and technological considerations must be examined if a complete analysis of the energy-development relation is to be achieved. The analysis and results provided here are intended as modest contributions to a much larger and more complete investigation of the energy-development relation.

DATA AND MEASUREMENT

Twenty-four countries were selected for this study (see Table 1). Using World Bank categories, countries were first classified into four income/development groups: low-income countries, lower-middle-income countries, upper-middle-income countries and high-income (industrialized) countries (see, e.g., World Development Report, 1987:202-203). Within each group, six countries were chosen based on real GDP and the ratio of oil imports to total imports in 1967. An effort was made to divide each group into two sub-groups of three members: one to represent countries in that income classification whose ratios of oil imports to total imports were above the mean for all countries in the particular World Bank income category; and a second sub-group with a below-mean ratio. In this way, the sample was stratified to account for degree of oil dependency within each income group.[1] Data on per capita GDP were obtained from the International Financial Statistics Yearbook published by International Monetary Fund (IMF). For comparison purposes, the data presented in local currency were converted into U.S. dollars. The conversion of GDP was done using official exchange rates and proceeded in two steps. First, the constant per capita GDP of 1980 was converted into U.S. dollars using the World Bank formula.[2] Second, each country's per capita GDP in U.S. dollars for the years of 1967, 1973, 1974, 1979, and 1985 were estimated by applying the yearly growth rates during these years to the 1980 GDP. Annual GDP growth rates and 1980 GDP are reported in the International Financial Statistics Yearbook (IMF, 1987).

Data on commercial energy consumption were obtained from two sources. For 1965-1980, World Tables published by the World Bank (3rd edition,1983) was used. Data for 1985 were taken from World Development Report, published in 1987 by the World Bank. Other macroeconomic data including total imports, exports, private consumption, government expenditure, domestic investment, and value added for industry were obtained from three publications: International Financial Statistics Yearbook, World Tables, and World Development Reports.

The study is divided into three periods: 1967-1973, a pre-energy crisis period with relatively low oil prices ($2.00/Bbl); 1973-1980, the energy crisis period with much higher oil prices ($20.00/Bbl); and

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1 The sample was rank-ordered by GDP per capita for the years 1973, 1980 and 1985 to determine membership in the four-category income/development classification. Changes in membership (e.g., Brazil moved from the lower-middle-income group in 1973 to the higher-middle-income group in 1980) were few and are discussed in a later section of the paper. Because data on oil imports do not permit a distinction between petroleum imports for fuel and for use in the petrochemicals industry, these ratios may overestimate the dependency on imported oil (World Development Report, 1987: 274).

2 The formula is based on a three-year moving average of country currency-to-U.S. dollar exchange rates. Refer to technical notes of the 1987 World Development Report.

1980-1985, a post-crisis period with high but decreasing oil prices ($17.00/Bbl). Data for some variables were not available for corresponding years. For example, world energy consumption data are published on a quinquennial basis only, and thus 1965 energy data had to be paired with 1967 GDP estimates.

ANALYSIS

The analysis is conducted in several steps. First, trends in energy consumption and gross domestic product (GDP) during the three periods are examined for each of the 24 countries. Economic growth and commercial energy consumption growth among countries within the same income group are contrasted and, where appropriate, the influence of oil dependency is noted. The second stage of the analysis examines the aggregate growth trends of energy consumption and GDP among the four income/development groups. Differences in energy requirements and adjustments rates across the four groups are graphically depicted for each time period. In the final step, regression analysis is utilized to develop statistical estimates of the relationship between energy consumption and GDP by income group. Through this analysis, it is possible to examine the causal relationship between income and energy requirements in a controlled manner. Because of the simultaneous nature of the relationship between energy consumption and GDP, two-stage least squares regression approach is adopted to more accurately measure net effects. The analysis specifically examines differences among the four income groups in energy requirements after controlling for growth in GDP, oil imports, and industrial value-added.[3]

1. Country Trends in Per Capita Energy Consumption and GDP

Figures 1-A through 1-D and 2-A through 2-D present the country trends in economic and energy growth for 1967-1985. The discussion below is based on these figures.

For low-income countries, the pattern of growth in GDP and energy consumption is similar during 1967-1973. With the exception of Nepal, per capita values for both variables tend to increase, although the rate of increase varies. The rapid increase in energy prices during 1973-1980 disrupts the generally positive trend as only China and the Philippines experience growth in GDP and energy consumption; the remainder have energy and economic growth rates near zero or negative. By the post-crisis period, a pattern of decline has set in for all but China, with the Philippines and Togo exhibiting sharp decreases in per capita GDP. For the low-income group, then, energy use and GDP tend to change in the same direction suggesting an energy-dependent basis of development. The impact of high energy prices and tight supplies is marked and appears to continue to adversely affect their development.

The lower-middle income countries (LMD) also exhibit a positive pattern of growth between GDP and energy consumption, but growth rates in both variables are typically much greater. Korea, Brazil and Malaysia experience rapid growth in GDP and energy consumption through 1980, carrying the former two into the ranks of the upper-middle-income group by the decade's end, and moving Malaysia to the top of the LMD group in terms of income. The other countries in this group show only slightly less rapid growth. Oil dependency seems to have little effect on GDP and energy consumption as the most dependent countries (Korea, Brazil and Malaysia) exhibit the highest growth. Moreover, the high energy prices of the 1970s appear to have little effect on growth either in terms of demand for energy or capacity for economic growth. Only after 1980 are growth tendencies moderated. For the LMD group, development and energy consumption are linked. However, unlike the low-income countries, high energy costs do not retard their growth, but only slow its pace.

With one exception, the upper-middle-income countries (UMD) countries display a quite different energy-development pattern. GDP growth for countries in this categories is moderate in all periods and near zero after 1980. Energy consumption increases modestly as well until 1980 when a majority of UMD countries reduce their per capita levels of use. Singapore and Jamaica are the notable exceptions to this pattern. Singapore exhibits rapid energy and economic growth through 1980, much like Korea

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[3] These were considered to be the major factors affecting energy consumption levels and rates.

and Malaysia. On the other hand, Jamaica's GDP per capita falls sufficiently to drop it to the LMD category after 1980. Singapore's experience is additionally important because of the visible decoupling of energy and economic growth since 1980. Other UMD countries do not appear to have found it possible to decouple development from energy use.[4] Yet, it should be noted that within the UMD group a great variety of GDP per capita levels and growth rates is supported by a relatively narrow band of energy use levels and growth rates, suggesting that development is not as energy-intensive as, for example, in the LMD group. Neither oil dependency (Singapore relies almost entirely on imported energy) nor the energy crisis of the 1970s dramatically altered energy and economic trends within this group, although all countries but Singapore have expanded their economies at a slower rate after 1980 than before.

In the high-income group, the capacity to sustain development without continued growth in per capita energy consumption is clearly established. Obviously, countries in this group have substantial technical and social infrastructures which enable them to reduce energy use and substitute non-energy resources into their production systems. Patterns of economic growth for those countries with domestic energy supplies (the U.S., Canada and U.K.) are not significantly different from those without such resources (Austria, Finland and Japan). All countries in this group had rapid energy consumption growth rates before 1973, but have moderated energy use since the advent of high energy prices while maintaining robust growth in GDP per capita.

In sum, a spectrum of energy-development relationships exists among the 24 countries with economic growth for the relatively poorer countries seemingly tied to greater energy use, while the richer countries appear to be capable of decoupling energy and economic growth. The turbulent period of 1973-80 exacerbated the problem of uneven development among countries, and this problem has worsened, especially for low-income countries, during the post-crisis interval.

2. Trends in Energy Consumption and GDP by Income Group

When country trends are aggregated into the four World Bank income groups, the divergence in energy-development relationships becomes clear. To permit this level of comparison, sample countries were categorized into the four income groups based on their GDP per capita rank order in 1973, 1980 and 1985. In this way, group membership was varied according to changes in the stages of development of individual countries. Aggregate values were computed as simple six-country averages. Figures 3-A and 3-B display the income group trends in energy and economic growth.

In both economic and energy terms, the high-income group controls and absorbs far more of the world's resources than any of their three counterparts. In fact, GDP per capita in the high-income sample tends to be roughly twice that of the sum of the other three sample averages. High-income per capita energy use is approximately three times that of the summed averages of the low-income, LMD and UMD samples. Energy intensity among high-income countries and, to a lesser degree, upper-middle income countries, has slowed in the post-crisis period raising the possibility that economic growth in these groups will be accompanied by smaller energy consumption growth. The reverse appears to be the case for low- and lower-middle-income countries. These countries are likely to require continuous growth in energy consumption to sustain even modest levels of economic growth. As Figures 4-A and 4-B indicate, growth rates of energy consumption per capita were higher than GDP growth rates for all income groups during 1967-73. During the energy crisis period (1973-1980), the trend changed in two ways. First, overall growth of both energy and GDP slowed for all income groups. In addition, the growth hierarchy reversed for the upper-middle and high-income countries as the GDP growth rate exceeded the energy consumption rate. However, faster growth in energy consumption compared within GDP remained for low-income and lower-middle-income countries.

During the post-crisis period (1980-85), overall growth rates in both energy consumption and GDP are again reduced for all income groups. Importantly, both upper-middle and high-income countries have experienced negative rates of growth in energy consumption per capita while continuing to show

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[4] When Korea is counted in this group after 1980, changing categories with Jamaica, this phenomenon gains significance for UMD group.

positive growth in GDP per capita. On the other hand, low-income and lower-middle-income countries still exhibit positive growth rates in energy consumption; and for low-income countries, this increased energy need is present despite negative growth in GDP.

The unavailability of world energy consumption and GDP data after 1985 prevents us from examining the most recent pattern of energy-development growth by income group. Only data for the high-income countries could be obtained. With a substantial decrease in world oil prices after 1985 (from $27.60 per barrel in 1985 to $16.50 at the close of 1987), it might be expected that high-income countries would increase their consumption of this fuel. And indeed they did: in the U.S., consumption rose from 15.7 million barrels per day in 1985 to 16.6 million in 1987 (most of this increase coming from imports); and the European OECD countries lifted their use from 11.6 million barrels per day to 12.1 million. (EIA, 1988:116) However, per capita consumption continued to fall. Figures for primary energy consumption by high-income countries are available for 1986 only. While 1.03 percent higher than 1985, they are still 3.24 percent below 1980 levels. Computed on an annual basis, the high-income group exhibited a 0.55 percent decrease in primary energy consumption per capita for 1980-1986, while GDP per capita grew on an annualized basis at 1.99 percent. If energy prices continue to fall, these countries may eventually increase their annual energy consumption growth rates above those of the embargo period, but such growth would almost certainly not undo the structural change in the energy-development relationship found in this group since 1973.

Our aggregate analysis suggests that the impact of energy shortages and high prices during the 1970s fell disproportionately on the lower-middle and low-income countries. While worldwide economic growth has slowed since the energy crises of the 1970s, the richer country groups have fared comparatively better, maintaining continued economic growth with much slower energy growth. Lower-middle and low-income countries seem to have less flexibility in their ability to reduce energy consumption and as result have seen their situation worsen since the first oil embargo. These countries already face daunting challenges in their struggle for economic progress under conditions of rapidly increasing population, capital shortages, and economic and political underdevelopment produced by colonialism. Unless industrialized countries develop a shared concern regarding the energy plight of lower-middle and low-income countries, the economic situation of the poor nations is likely to become even more desperate.

3. Regression Results

Based on the above trend analyses, a regression model was specified to reflect the causal relationship between commercial energy consumption and economic growth. Empirical studies dealing with this subject are often inconclusive because they fail to account for the simultaneity in the relationship between energy and economic growth. Using a two-stage regression approach, we were able to overcome this problem and determine causal direction. Additionally, dummy variables representing the income classifications of 24 countries were included in the energy growth equation so that the effect of stages of development on energy requirements could be estimated.

Equations for energy consumption and GDP growth during 1967-1973, 1973-1980, and 1980-1985 were first separately and then simultaneously estimated using an instrumental variables approach. In the two-stage estimations, all the exogenous variables in both equations were used as instrumental variables. Variable specification followed conventional practice with the growth of energy consumption assumed to be a function of GDP growth and growth of oil imports (as a percent of GDP). A new variable vector addressing the impact of development stage was also added. GDP growth was assumed to be a function of the growth in energy consumption, exports and investment.[5]

The estimated two-stage versions of the model for energy consumption growth and GDP growth are shown in Table 2. Our analysis indicates that energy consumption growth only moderately affects

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[5] The GDP growth equation is consistent with standard macro-economic theory in which economic growth is determined by net exports, consumer spending, investment, and government expenditure. Because of incomplete data on three countries, it was not possible to include customer spending and government expenditures.

economic growth; however, the reverse relationship is statistically quite strong. Thus, particularly during the energy shortage and post-shortage periods, growth in GDP significantly affected energy consumption growth. Understandably, no significant relationship between the two was identified in the pre-shortage period.

The bottom of Table 2 shows the annual growth rates of energy consumption by income category. These rates were derived from the coefficients of the dummy variables representing low-income, lower-middle income, upper-middle income, and high-income countries (the latter was represented by the y-intercept value in the equation). These rates estimate annual growth in energy consumption under the assumption of constant GDP and oil-to-GDP growth.

The regressions indicate an inverse relation between country income and energy requirements for development. Thus, low-income and lower-middle-income countries in every time period require higher energy consumption per capita than the higher income countries to achieve the same rate of GDP growth. This energy requirement was highest during the pre-shortage period of 1967-1973 when low-income countries needed roughly six times the growth in energy consumption of high-income countries (12.84 vs. 1.67) in order to secure the same GDP growth rate. During the energy crisis period of 1973-1980, countries in all income groups sought to reduce energy requirements, resulting in negative energy requirement coefficients. Even here, though, the lower-income countries were at a relative disadvantage; their conservation rates for the same GDP growth rate were comparatively smaller (e.g., -1.25 vs. -10.10). In the post-shortage period, upper-middle and high-income countries have continued a process of GDP growth without increases in energy requirements. Capacities for conservation continue to be high, especially for the richest countries in the sample. In contrast, poor countries still require increases in energy consumption in order to grow, although the rate of increase has fallen substantially compared to the pre-shortage levels. In sum, our regression results support the conclusions of the earlier trend analysis and provide a quantitative estimate of energy requirements by development stage. These estimates reinforce the premise that the energy-development relation is leading to uneven growth opportunities among the rich and poor countries of the world.

CONCLUSION

As conventional supplies diminish and the price of remaining stocks increase, the impact of energy on world development patterns and opportunities is likely to grow. In the wake of the 1970s energy shortages, our analysis suggests that a disturbing polarity may be emerging between rich countries who are reducing their economic requirements for increasingly costly energy, and poor countries who are unable to develop economically without additional growth in energy use. For those who would emphasize the advantages of energy efficiency and renewable sources of energy supply, it is essential that such emphasis is translated soon into practical strategies which address the energy-development problem of lower income countries. For those who would emphasize the energy basis of economic growth, it is past due for supporting change in an energy distribution system which continually denies those societies most in need of energy services the capacity to meet those needs. The year 2000 may be too late to respond.

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Table 1
CLASSIFICATION OF SAMPLE BY INCOME GROUP
(IN GDP PER CAPITA RANK ORDER)

	1967-1973	1973-1980	1980-1985
Low Income Countries:	Nepal Ethiopia* China India* Togo Philippines*	Ethiopia Nepal India China Togo Philippines	Ethiopia Nepal India Togo China Philippines
Lower-Middle Income Countries:	People's Rep. of Congo Colombia Rep. of Korea* Turkey* Malaysia Brazil*	People's Rep. of Congo Colombia Jamaica Turkey Rep. of Korea Malaysia	Jamaica Colombia People's Rep. of Congo Turkey Malaysia Brazil
Upper-Middle Income Countries:	Jamaica* Mexico Yugoslavia Uruguay* Singapore* Argentina	Brazil Mexico Yugoslavia Uruguay Argentina Singapore	Mexico Uruguay Rep. of Korea Yugoslavia Argentina Singapore
High Income Countries:	United Kingdom Japan* Finland* Canada U.S.A.*	United Kingdom Japan Finland Canada U.S.A.	United Kingdom Austria Japan Canada U.S.A.

* Above-average oil dependency (caculated as the ratio of oil imports to to total imports) in respective income category.

Table 2
Regression Estimates of Annual Growth Rates of Energy Consumption and GDP per Capita, using Two-stage Least Squares Procedure

Variables	Pre-Shortage (1967-73) ENG	Pre-Shortage (1967-73) GDP	Energy Shortage (1973-80) ENG	Energy Shortage (1973-80) GDP	Post-Shortage (1980-85) ENG	Post-Shortage (1980-85) GDP
ENG	---	-0.13	---	-0.22	---	-0.08
GDP	0.97	---	4.73*	---	1.04*	---
OTP	0.06	---	0.07	---	0.02	---
EXP	---	0.25*	---	0.25*	---	0.32
INV	---	0.06	---	0.10	---	0.14*
Income Category						
Low Income	12.84		-1.25		0.12	
Lower-Middle Income	11.00		-3.36		0.12	
Upper-Middle Income	11.49		-14.57		-0.05	
High Income	1.67		-10.10		-2.32	
R-square	0.33	0.60	0.62	0.27	0.59	0.61
Standard Error	7.38	1.95	4.69	2.26	2.54	2.21

Note: ENG: Annual growth rate of energy consumption
GDP: Annual growth rate of GDP
OTP: Annual growth rate of oil imports to GDP
EXP: Annual growth rate of exports
INV: Annual growth rate of investment
LOW: Dummy variable for low income countries
LMD: Dummy variable for lower-middle income countries
UMD: Dummy variable for upper-middle income countries

* Statistically significant at 0.05 level.

FIGURE 1-A
TREND IN GDP PER CAPITA:
LOW INCOME COUNTRIES
(1980 U.S. $)

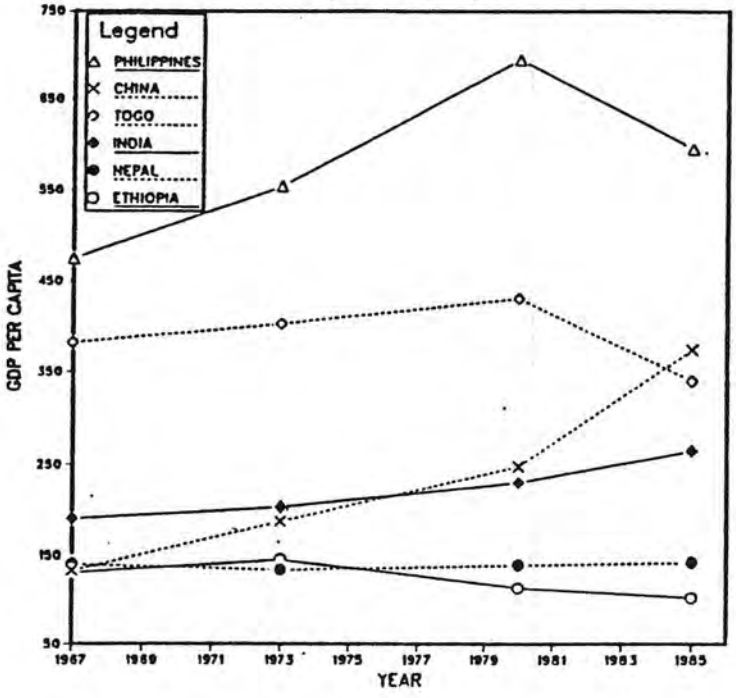

FIGURE 2-A
TREND IN ENERGY CONSUMPTION PER CAPITA:
LOW INCOME COUNTRIES
(K-GRAMS OF COAL EQUIVALENT)

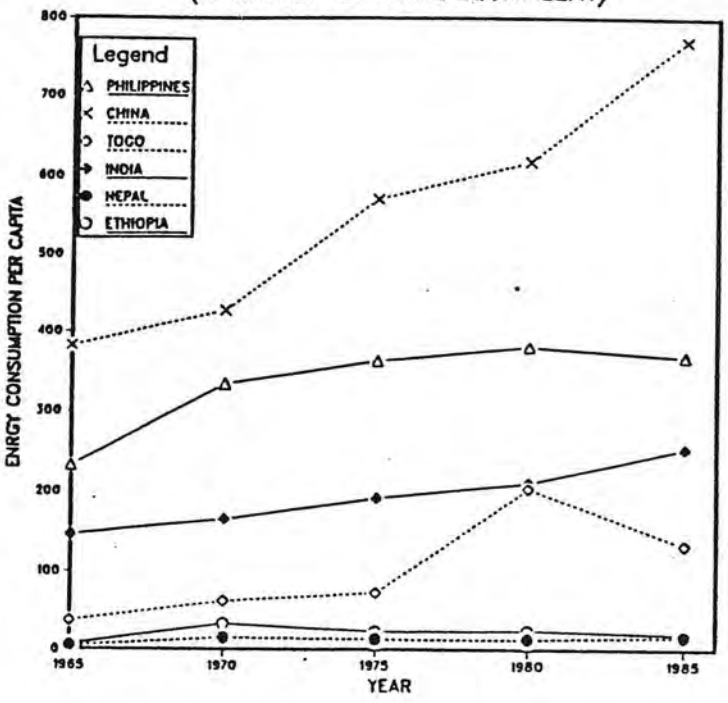

FIGURE 1-B
TREND IN GDP PER CAPITA:
LOWER-MIDDLE INCOME COUNTRIES
(1980 U.S. $)

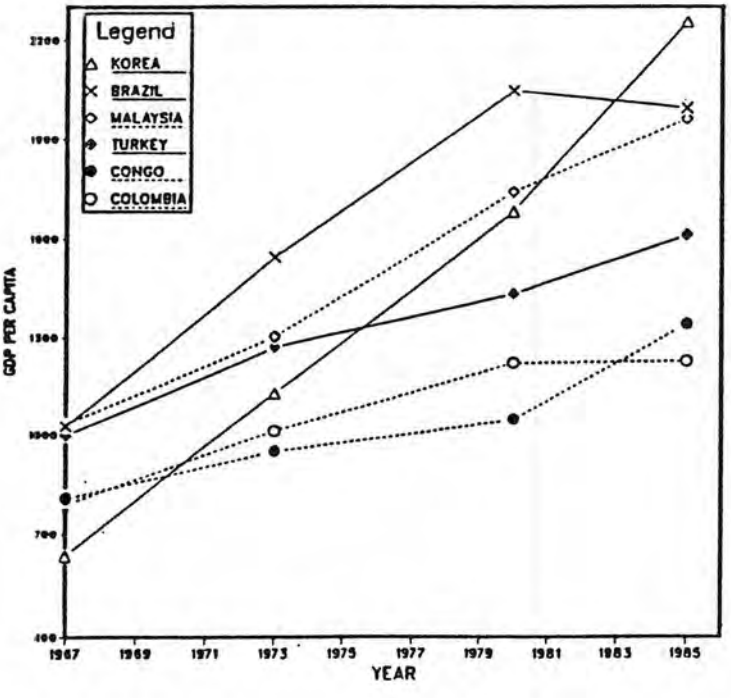

FIGURE 2-B
TREND IN ENERGY CONSUMPTION PER CAPITA:
LOWER-MIDDLE INCOME COUNTRIES
(K-GRAMS OF COAL EQUIVALENT)

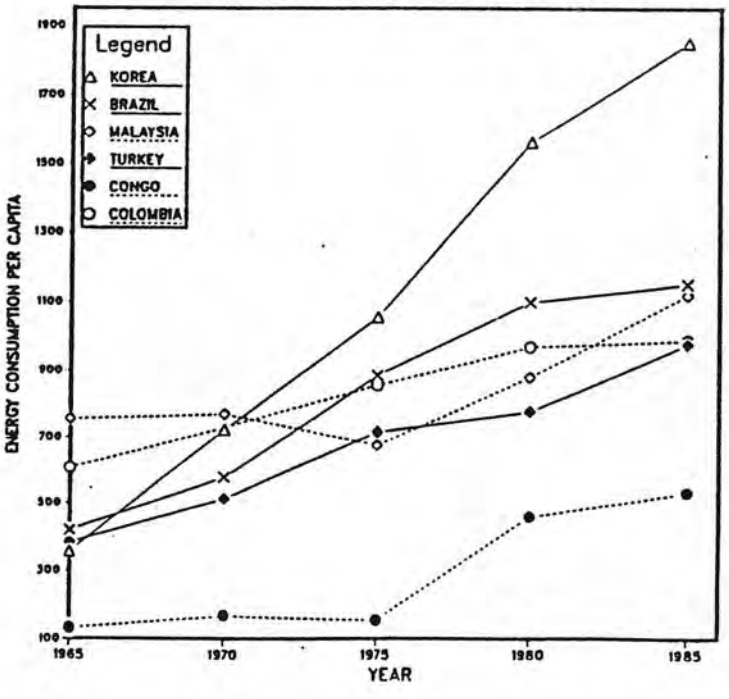

FIGURE 1–C
TREND IN GDP PER CAPITA:
UPPER–MIDDLE INCOME COUNTRIES
(1980 U.S. $)

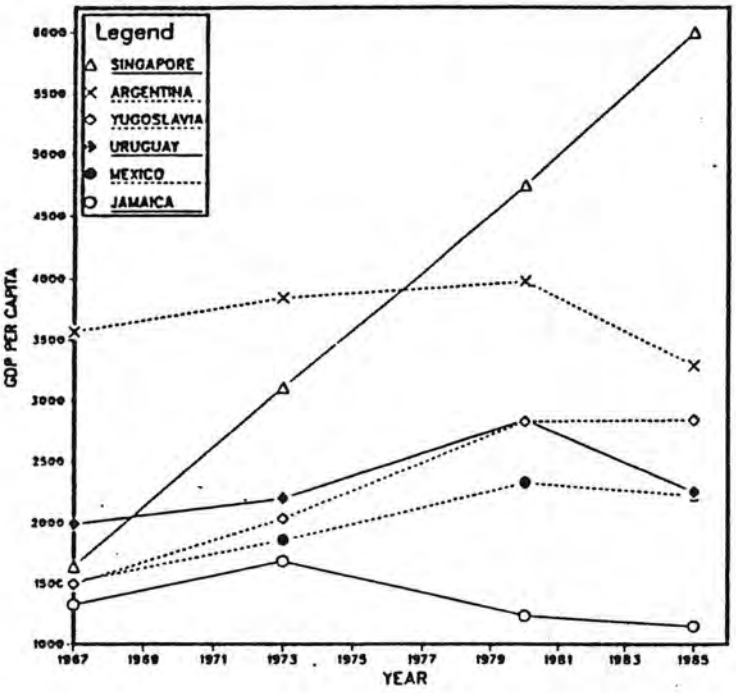

FIGURE 2–C
TREND IN ENERGY CONSUMPTION PER CAPITA:
UPPER–MIDDLE INCOME COUNTRIES
(K–GRAMS OF COAL EQUIVALENT)

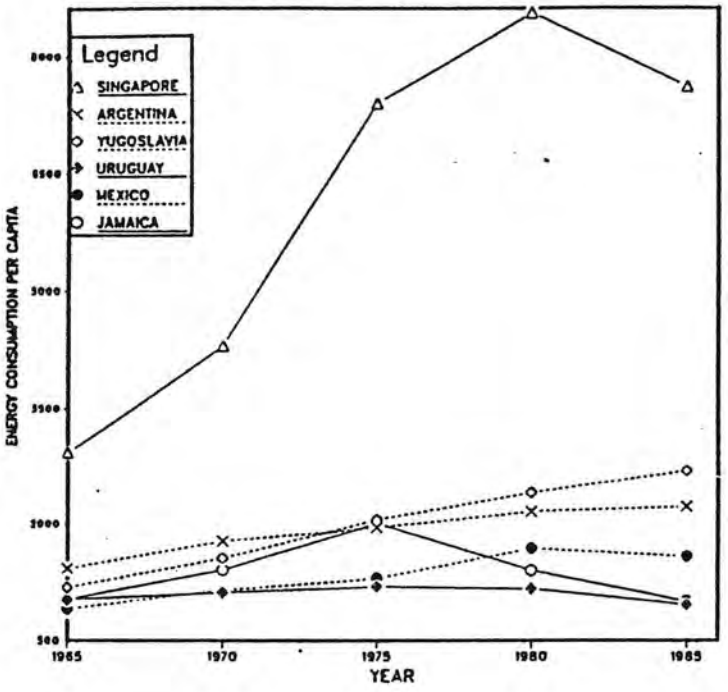

FIGURE 1–D
TREND IN GDP PER CAPITA:
HIGH INCOME COUNTRIES
(1980 U.S. $)

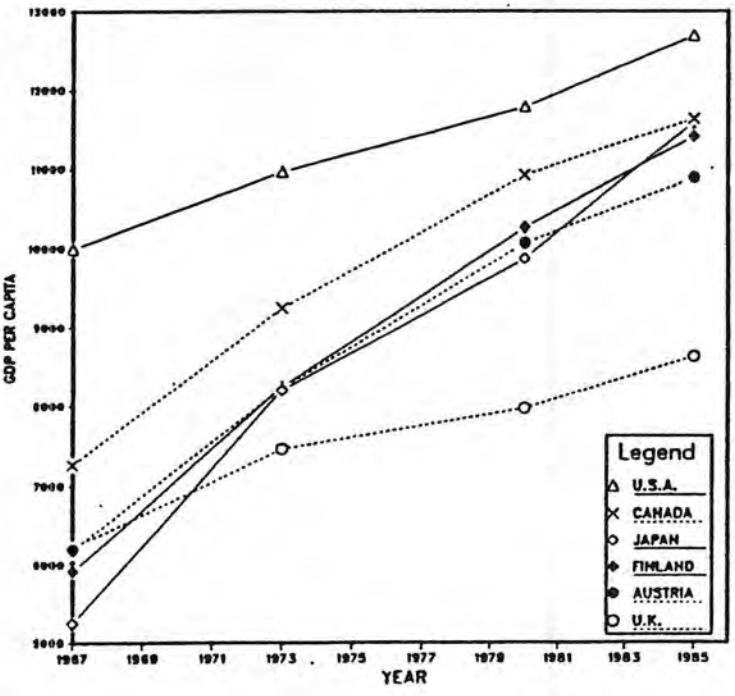

FIGURE 2–D
TREND IN ENERGY CONSUMPTION PER CAPITA:
HIGH INCOME COUNTRIES
(K–GRAMS OF COAL EQUIVALENT)

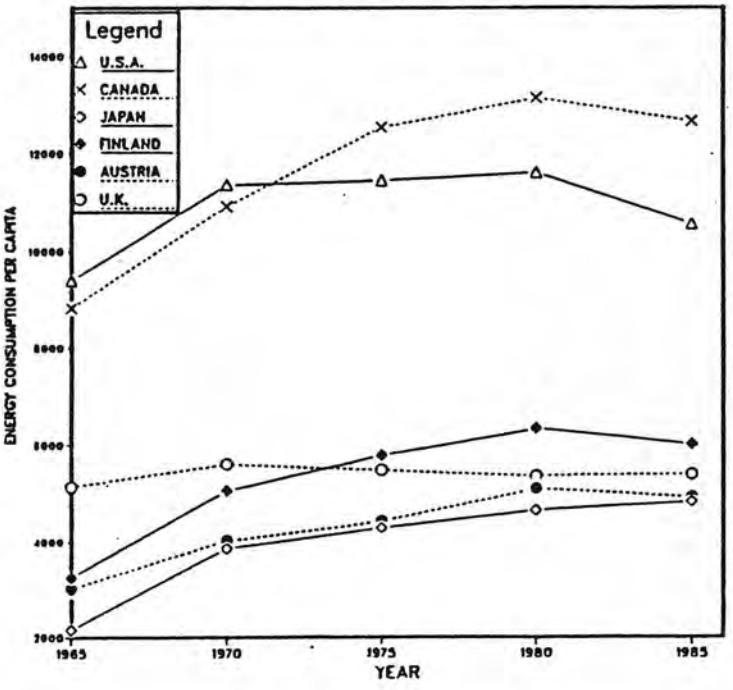

FIGURE 3–A
TREND IN GDP PER CAPITA
(1980 U.S. $)

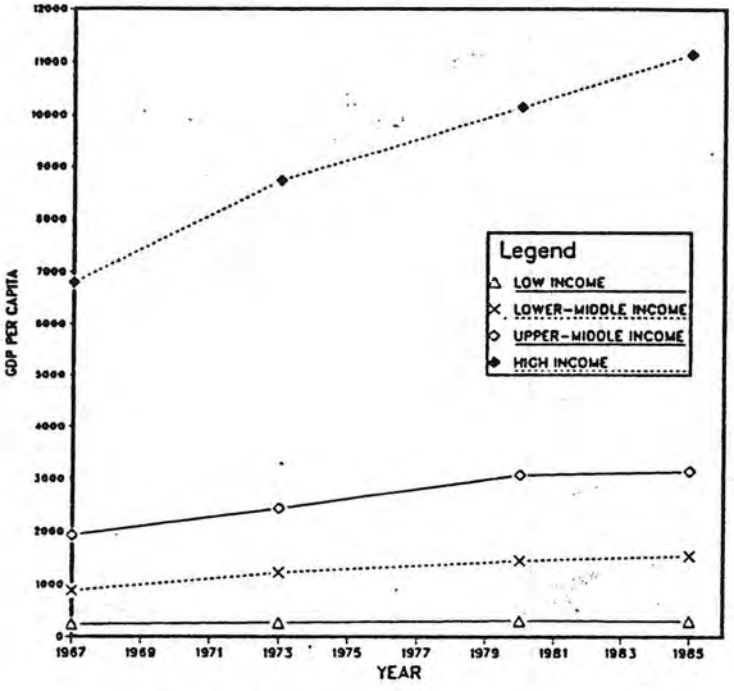

FIGURE 3–B
TREND IN ENERGY CONSUMPTION PER CAPITA
(K–GRAMS OF COAL EQUIVALENT)

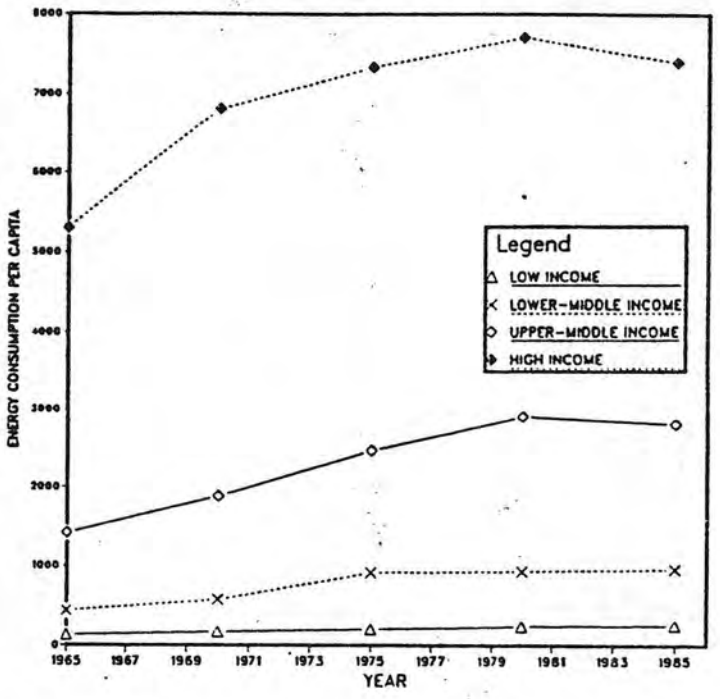

FIGURE 4–A
GROWTH RATES OF GDP
(PERCENT)

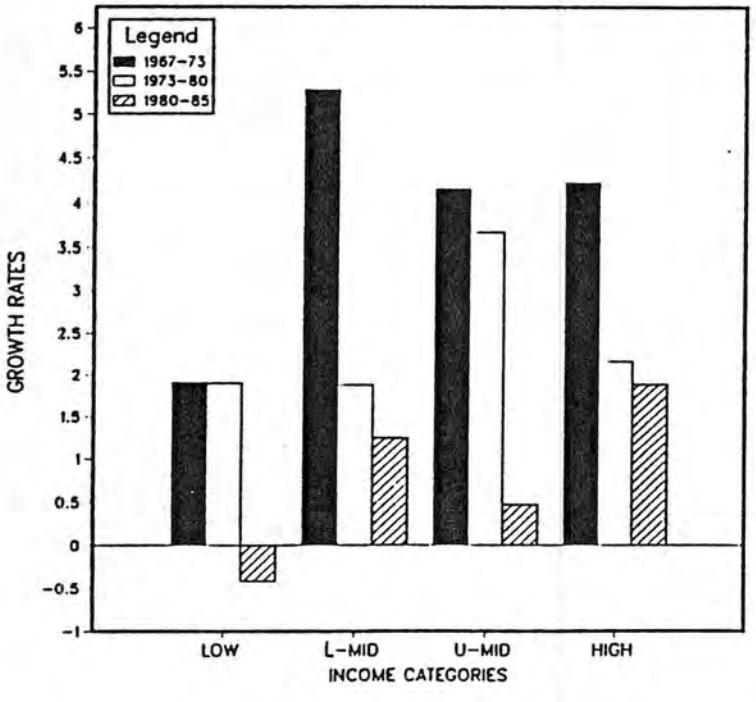
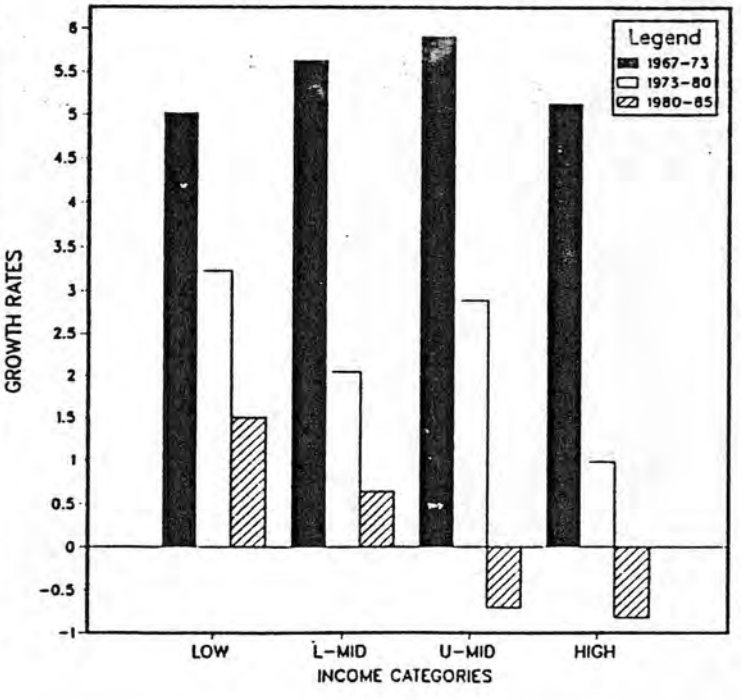
FIGURE 4–B
GROWTH RATES OF ENERGY CONSUMPTION PER CAPITA
(PERCENT)