ESTIMATING ENERGY CONSUMPTION FROM CROSS-COUNTRY RELATIONSHIPS

by

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SUMMARY

Cross-country statistical techniques (employing regression analysis) are used to find demand equations for four variants of a country's aggregate energy use: total commercial energy, the same measure to which has been added fuelwood consumption at 50% burning efficiency relative to commercial fuels, total petroleum and total electricity. The demand equations are fitted to either 44, 48, or 59 countries, depending upon whether or not petroleum prices, the sole available price variable, are included and whether four OPEC countries are included in the sample. Results for the three year period 1969/71 are compared with those for 1976/78, following the first of the large oil price increases. Using the 1969/71 results to "predict" Mexico's electricity consumption over the period 1960-1980 illustrates the applicability of the cross-country approach to longer-term projections for individual countries.

The demand equations, which include petroleum prices where applicable and a number of structural variables in addition to the usual measure of per capita income, are decidedly superior to income alone in "explaining" inter-country differences in energy use. The statistical fit is by no means perfect, however. While the equations can be used to establish rough international "norms" of consumption, the norms or averages are most useful, when applied to an individual country, in raising questions for further investigation.

The 1969/71 equations almost uniformly tend to overestimate the growth in energy use to 1976/78. One reason appears to be that the medium-

term response to the initial jump in petroleum prices was smaller than would be expected in the longer run. This seems to have been true for low and especially for low-to-middle income countries. A second and related reason, especially applicable to electricity use, is that demand is affected by the physical availability of the plant needed to convert primary energy into useful forms. Consumption is thus partly determined by earlier investment decisions. Both considerations suggest a further dampening of energy demand into the 1980's as higher energy prices are translated into longer-run adjustments in consumer taste and investor decisions.

A petroleum price elasticity of about -.5 is reduced to about -.2 when petroleum prices are used to represent the weighted average of all energy prices in the equations for total commercial energy. The price elasticity, as already noted, appears lower for middle and lower income countries, but this result has not been tested explicitly. Because of a slight correlation between low petroleum prices and large refining capacity (and hence of the increased petroleum use resulting from refinery fuels) petroleum price elasticities can appear to be as high as -.8 when refinery fuel consumption is not explicitly taken into account.

Per capita cross-country income elasticities (based upon per capita gross domestic product, or GDP, measured at official exchange rates) cluster close to 1.0. The inclusion of fuelwood with commercial energy lowers the aggregate elasticity slightly, and the elasticity for electricity alone is closer to 1.15. These cross-country elasticities, however, are not comparable with those found from time series studies and cannot be used directly for single country projections over time. This is because the cross-section results are based upon "nominal" GDP conversions to U.S dollars which do not impose a common set of relative prices on all countries. When the income elasticities based upon "nominal-among-country" estimates of GDP are converted to a basis of "constant prices amount countries", they increase by about thirty percent, clustering about 1.3 instead of 1.0. (The constant-price-among-countries results rely upon the recent studies of Irving Kravis and his associates.) Thus for longer-run projection purposes, modified elasticities must be used in conjunction with a country's projection of constant price or "real" GDP per capita. Alternatively, the cross-country elasticities found in this study may be used directly if a country's real GDP growth is first expressed in a form comparable to the nominal or variable price GDPs observed among countries at different stages of growth. This latter, internationally comparative concept of GDP change, as yet little discussed in the economic literature, has been termed "comparative" or "nominal-over-time" growth in the present paper.

The cross-country results reported in this paper can provide a useful starting place for examining a country's past and present energy consumption levels. In conjunction with time series analysis and more in-depth studies of particular country characteristics, they can improve our perception of likely future changes in demand. Further testing is of course needed, especially for individual countries over relatively long time periods and for an equivalent world-wide group of countries after the second oil price "shock" of 1979 and the reverse-shocks of the early 1980's. More work, too, is needed on extending energy price data beyond those for refined petroleum products (to which the current study has been limited). Finally, the effects on aggregate energy demand of the so-called non-commercial fuels is still but imperfectly understood as is the effect of the "indirect" consumption of energy. This latter aspect in particular, relating to the consumption of energy embodied in imports of machinery, semi-finished goods, and non-fuel raw and partially-processed materials, has so far been ignored in all energy demand studies.

When is a country consuming a reasonable, average, or expected amount of energy? How are today's standards of "normalcy" likely to change in ten or twenty years? During the 1970s, there was a four-to-one ratio in per capita energy use between India and Indonesia, two countries with quite similar per capita incomes. This might well have led knowledgeable Indonesians to consider their country's use of electricity to be distressingly small by the standards of comparable countries. India's consumption of total commercial energy, on the other hand, could be seen as "abnormally" high in comparison to other low-income developing countries such as Kenya or Sri Lanka. USA energy has exceeded that of Sweden, a country of near-comparable living standards and wealth, by 50 percent or more in recent years. This has led to great soul-searching (at least in the United States) and to considerable professional interest and debate. (Darmstader and others, 1977; Schipper, 1978; Dunkerly, 1980.)

In this paper these issues are explored using formal statistical techniques which permit taking into account differences in inter-country characteristics affecting aggregare energy consumption. Satisfactory estimating equations are found for four categories of country energy use: commercial energy, commercial energy-plus-fuelwood, petroleum products, and electricity. The equations are tested over a seven year period bracketing the first of the 1970's oil price shocks, and the results are then used to illuminate both intercountry differences in energy use today and the problem of forecasting country energy use in the future.

The paper is organized in five sections. The first includes a brief review of previous cross-country energy demand studies, contrasting earlier work with the current research. The present models and variables are described in the second. In part III will be found the principal statistical results, and these will be applied, in part IV, to the analysis of how country energy use changes over time. The study's implications for intercountry comparisons and for energy demand projections are discussed in the conclusions of part V.

I. Review of Earlier Studies

The monumental 1971 volume by Darmstadter on Energy in the world Economy is often cited for its cross-sectional comparison of energy use with a country's gross national product (GNP). (Darmstadter et al., 1971, p. 65-68). The 1965, 49-country analysis in this volume, however, had been preceded at least as early as 1956 by a study (for the year 1949) of per capita fuel consumption as it related to per capita income in the countries of Western Europe and North America. (Robinson and Daniel, 1956). Mason (1955) examined similar data for 42 countries in the year 1952 and anticipated most of the discussions below on the reasons for the many country deviations from a smooth energy-income relationship.

Adams and Miovic (1968), working with pooled annual cross-sectional data, 1950-1962, for a small number of countries, introduced explicit corrections for differences in the efficiencies with which different fuels are used. Adjusting aggregate energy consumption for these differences produced sharply higher estimates of demand elasticities 1/ with respect to both GNP and to total industrial output and "explained" much of the apparent drop in the energy/GNP ratios observed in more industrialized nations. (The approach, using engineering rather than statistically-derived thermal efficiency estimates, was extended to individual sectors and fuels for a larger sample of OECD countries by Adams and Griffin in 1974. Others who have employed the "net" or delivered measure of energy use include Strout [1962], Hoffman [1972], Nordhaus [1977, 1980], Griffin [1979], and Dunkerly [1980].

OPEC (Organization of Petroleum Exporting Countries) technicians analyzed overall energy elasticities with respect to GNP for the OECD countries as early as 1968. (Ismail, 1968). Brookes (1972) also examined energy elasticities using 1950-1965 data for 22 countries. He concluded that the decreasing elasticities observed as per capita GNP increased appeared to approach asymptotically a value of close to 1.0, before allowing for inter-fuel differences in thermal efficiency. For tracking an individual country's energy consumption over time, Brookes further concluded that such efficiency differences should be allowed for (following the procedures of Adams and Miovic) and that the country track could be assumed to parallel that of the "all nation prediction line". Brookes' time-series tests of "forecast" aggregate energy use, however, were limited to the United Kingdom and the USA.

de Janosi and Grayson (1972), impressed as others had been before them by the large variations found among countries in energy/GNP elasticities,

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1/ Elasticity, following the usual definition is the ratio of the rate of change of energy use to the rate of change of an independent or explanatory factor such as income or price. For the important distinction between per capita and total elasticities, see the footnote on page 6.

attempted to explain these differences using a number of structural variables. They analyzed 1953-1965 data for thirty countries representing a wide range of per capita income. In addition to the expected negative relationship between energy elasticity and per capita GDP, the share of coal in total energy was found to have a strong negative impact while the share of agriculture in total GDP, a measure of structural differences among countries with similar levels of overall per capita income, had a significantly positive effect on the aggregate energy elasticity.

The cross-country studies of Aoki (1973, 1974) differed from the above in that they focused upon one particular type of energy, electricity. They became the basis for a formal and extensively-used forecasting technique by the International Atomic Agency under the assumption that a particular country's electricity use would gradually approach a single international norm as country income increased over time. (Lane, 1975).

All of the studies discussed so far, with the exception of the 1955 NPA report by Mason, were limited to so-called commercial energy. (That is, non-commercial fuels such as wood and agricultural wastes were not included because of the almost complete lack of consumption data. Professor Mason, on the other hand, decided to base his analysis in part on some quite experimental and questionable estimates of fuelwood included in the first of the many United Nations "Series J" Statistical Papers. UN, 1952). The several studies cited from before the late 1970s were without exception dependent upon GNP or GDP estimates converted to a common currency at nominal rather than purchasing-power-adjusted exchange rates, and they did not even attempt to include energy prices. There was a tendency to be overly fascinated with "elasticities" while at the same time slighting the often important distinction between per capita elasticity and that based upon aggregate GDP and aggregate energy use. 1/ Nor was there much effort made, except by Brookes, to test derived relationships for consistency with those found for other years or for countries not included in the original sample.

In more recent cross-country demand studies Strout (1977) considered non-commercial fuels when applying cross-country equations to six small countries not included in his original sample. Dunkerly (1980) investigated aggregate income and price elasticities for nine OECD countries using pooled time series and cross section data, comparing Resources for the Future results with earlier estimates by Kouris (1976) and Nordhaus (1975). Parikh (1980) included both fuelwood and crude estimates of cereal waste in a 71-country study of 1973 energy use. Purchasing-power-adjusted GDPs were used for a later studies by Strout (1979), Pindyck (1979b), Nordhaus (1977, 1980), Dunkerly (1980) and still more recently by Chern, Ketoff and Schipper (1982). Choe (1978) used country data for 1960-1975 and aggregate energy

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1/ de Janosi and Grayson (1972), for example calculate total elasticities from time series data for individual countries and per capita elasticities from cross-section data - without mentioning problems of comparability between the two concepts. Adams and Griffin (1974) find a per capita GDP elasticity in the residential sector of 1.51, "confirming that the residential fuel sector is one of the fastest-growing sectors." The elasticities in other sectors investigated (iron and steel, other manufacturing, electric power generation, and transportation) are based either on the sector's own output or upon total GDP. Even the definitive study of energy elasticities by Bohi (1981) fails to consider the use of per capita income elasticities that is so widespread in cross-section studies. But from the common, double-logarithmic functional form used for estimating total elasticity, as long as the growth rate of total energy (r) exceeds the growth rate (g) of whatever variable, such as total GDP or total sector output, with which energy is being compared, the per capita elasticity measure (Np) will exceed the equivalent total eleasticity measure (Nt). Thus from the definition of elasticity, and letting the growth rate of population be represented by n, Nt = r/g, and Np = (r-n)/(g-n). Np/Nt will thus equal (rg-gn)/(rg-rn), and this ration will exceed 1 as long as $r > g$.

price indexes to estimate individual country price elasticities for energy as later also did Hoffman and Mors (1979). As early as 1974, Adams, Graham, and Griffin incorporated prices for a single fuel, gasoline, into a cross-country study of OECD automobile fuel consumption. (Adams, Graham, and Griffin, 1974; see also Pindyck, 1979b, Wheaton, 1982, and Chern et al, 1982). The aggregate energy prices used by Kouris (1976) and Dunkerly (1980) were weighted sectoral averages of actual fuel prices converted to a common currency. In an earlier study, Nordhaus (1975) had also computed sectoral price measures, but for his aggregare analyses he had simply used "industrial" prices rather than relying upon an average of the several sector prices.

The current paper, as already noted includes one energy measure incorporating a principal noncommercial fuel, fuelwood. Estimating equations (also referred to as "models" in the discussion below) are evaluated using both nominal and purchasing-power-adjusted GDPs, but the use of energy prices is limited by data availability to a single measure of refined petroleum product prices. All energy demand equations have been deflated by country population, and hence all calculated income elasticities are in per capita terms. Comparisons of model estimates with measured energy demand have been largely confined to the time period 1970-1978. The use of the models for longer time periods is however illustrated for the case of electricity demand in Mexico over the period 1960-1980. More testing of this nature is needed.

The trend in recent cross-country studies of energy demand has been to apply increasingly sophisticated econometric techniques to sectoral rather than aggregate energy use. (see especially Nordhaus [1977, 1980], Griffin [1979], and Pindyck [1979b]. Most of this recent analysis and modeling has been applied of necessity to more industrialized nations with better data, especially of energy prices and energy consumption by end-use sectors. The road of greater disaggregation and more advanced econometrics should lead to improved demand models for countries which can support such studies, but it by-passes questions of comparability between the more and less-developed nations of the world and arrives at few guidelines for assessing a country's overall energy-using performance.

The current study, in contrast, avoids sectoral detail in favor of focusing on the larger, aggregate picture of energy use and of including a large number of so-called developing countries in the analysis. The road followed is that of total energy use (albeit with some disaggregation of individual fuel types) and simple descriptive statistical technique plus equation-fitting by Ordinary Least Squares. Its purpose is to facilitate broad-brush comparisons both among countries and for countries and country groups over time. It aims to help raise questions which might be lost sight of in the details of a more sophisticated and usually more abstract approach.

II. Models and Variables

The theory underlying the energy demand models used for this study is that inter-country variations in energy use are related to intercountry differences in a) per capita income, b) energy prices, c) structural differences not fully reflected in per capita income differences, and d) physical or other exogenous differences such as country area or population density (neither of which were found to be significant in the current study) or winter temperatures. Early anaylsis suggested that a log-quadratic, Chenery-Syrquin-type of model, including both the log and log-squared forms of per capita GDP and total population, was distinctly superior to per capita GDP alone in capturing important structural differences among countries. (See Chenery and Syruquin, 1975. This log-quadratic model was the form applied to energy use by Strout, 1976 and 1977). Subsequent work has shown, however, that as direct measures of structural differences are added to the model, the indirect measures reflected by country population size and by the squared terms become non-significant. (See also Parikh, 1980, Table 3.1). The quantitatively most important direct measures of industrial structure, in turn, relate to the production of various energy-intensive materials. 1/

The general model, in which all variables are in log form and energy use and income are in per capita terms, follows:

LENi = f(LGDP, LPPRICE, LEIMRj, LTMPI)

where ENi = a particular type of energy

GDP = gross domestic product per capita

PPRICE = weighted average petroleum product price, deflated

EIMRj = one of several measures of energy-intensive materials production, in physical units, expressed as a ratio to total GDP

TMPI = an index of winter temperature

L = a prefix designating natural logarithms

1/ Other structural variables such as agriculture's share of national product, found significant in earlier work by de Janosi and Grayson (1972) and Parikh (1980), or the percentage of population which is urban (Parikh, 1980; Wheaton, 1982) were not examined in the current study. Parikh found these two variables only marginally superior to the full Chenery-Syrquin model whereas in the current study energy-intensive materials production turns out to offer a substantial improvement on the Chenery-Syrquin approach.

All models are log-linear, and ordinary least squares has been used for all statistical estimates.

Dependent Variables

Four aggregated energy measures have been analyzed. Per capita aggregated commercial energy (ENA) is similar to that of the United Nations' concept of commercial energy except that so-called primary electricity (hydro, nuclear, and geothermal; i.e., excluding all generation by fosil-fuel-powered thermal generating plants) has been included in terms of fossil fuel equivalents at average thermal station efficiency (generally assumed to be 30 percent). Fuelwood has been assumed to be used at one-half the average efficiency of commercial fuels before being added to the latter to give the per capita commercial energy-plus-fuelwood measure, ENB. Total per capita petroleum consumption (PC) includes crude petroleum, natural gas liquids, and refined petroleum products. Refined non-energy products such as asphalt, lubricating oils, and petroleum coke are not included. Electricity consumption per capita (ELEC) includes both private and public production plus net imports, if any.

World Bank computer tapes of UN energy data (as of early 1982) were used for all but noncommercial energy. Fuelwood consumption was derived from FAO production and trade data. Conifer and non-conifer production were separately weighted in the fuelwood energy total.

Commercial energy except for electricity was first aggregated in metric tons of coal equivalent (MTCE) using UN conversion factors and then changed to units of barrels of oil equivalent (BOE) per day per thousand population. Electricity is expressed throughout in kwh/capita. Further details on energy variables and conversion factors as well as on the several explanatory variables may be found in Annex A.

Independent Variables

Gross Domestic Product per capita (GDP) is from the World Bank data files. The numbers are similar to those published in World Tables (World Bank, 1980) and differ substantially in some cases from equivalent estimates published by the United Nations. Constant price estimates of GDP in local currencies have been converted to US dollar equivalents using the current price estimates and average actual exchange rates for the three year period 1969-1971. 1/ Purchasing-power-adjusted estimates of GDP, in 1975 US dollars, are those prepared by Kravis, using statistical extrapolations where necessary and World Bank (as opposed to UN) national accounts data. (These are from the computer tapes mentioned on the copyright page of Kravis and others, 1982, and are referred to on occasion as "Kravis-dollar" GDP estimates abbreviated as KGDP in the discussions below).

Petroleum prices are largely those collected and published on a somewhat sporadic and largely undocumented basis by the U.S. Government. (See, for example, US Department of Energy, Energy Information Administration, 1977, and earlier data published by the US Bureau of Mines). Some holes in the data have been filled from various secondary sources, but country coverage is less complete than for other variables. An aggregate measure of petroleum prices has been obtained by weighting gasoline, kerosene, and bunker C

1/ The base period, or "period 0", for the cross country analyses consisted of the three years 1969-71, The post-oil-price-increase period chosen for comparison, or "period 1", was 1976-78.

prices for each year by each country's own consumption (in the same year and in volume units) of respectively, aviation and motor gasoline, kerosene and jet fuel, and distillate and residual fuel oil.

Petroleum prices were initially collected in current US cents per US gallon, presumably converted at the current official exchange rate. The weighted average petroleum price has been deflated to give the price variable used in this study, PPRICE, by the "total resource" price index implicit in the World Bank's data files. (See, for example, World Bank, 1980). The implicit GDP price deflator was not used because for some countries it has been heavily affected by increases in petroleum export prices and thus is more applicable to country income than to country production. The resource price index makes a preferable deflator because it includes all imports and excludes exports. Even with this modification of the more conventional price deflation procedure, the OPEC countries recorded price changes for petroleum products which differ quantitatively and, it is feared, qualitatively from other countries.

Five energy-intensive materials (EIM) variables are used in the various models. In each case the variable is expressed as a ratio to GDP so as to measure only that part of the EIM effect which is <u>not</u> statistically associated with country variations in Gross Domestic Product. 1/ The most comprehensive of these is a weighted average of ten materials, including both ferrous and non-ferrous primary metals as well as several non-metals. Weights used (shown in Annex A) are direct-plus-indirect energy requirements to produce each material as derived from a 1967 US input-output table. The procedures and sources are those of Strout (1976). (Adams and Griffin, 1974, employed a somewhat similar measure, based on energy use by 2-digit manufacturing sectors rather than individual commodities, for one of their models of energy use in manufacturing).

Because of the quantitative importance of crude steel production in the aggregated variable, EIMPR, the total was divided into steel (EIMPSR) and non-steel (EIMPNSR) components for some models. This distinction, however, turned out to be important only in the case of electricity consumption.

Two other "energy-intensive" material variables are more questionable because they themselves may be dependent to some extent upon energy consumption. They are the production by petroleum refineries (REFPR) of petroleum products including non-energy products, and the consumption of solid fuels (SCR).

1/ Normalizing the variable by expressing it as a ratio to GDP affects neither the coefficient value nor its t-ratio, nor does it affect the overall measures of goodness of fit for the equation. It does, however, increase the coefficient (but not the standard error) of the GDP variable, and it is undertaken primarily to ensure greater comparability among equations in the GDP coefficient. In assigning a part of the equation's explanatory power to GDP and part to an EIM variable, as much as possible is assigned to GDP, and the "normalized" EIM variable picks up only those effects associated with differences in the ratio of the EIM-variable to GDP. Expressing each EIM variable as a ratio to GDP will reduce the variability in the EIM variable because of its generally positive correlation with GDP. In normalized form it may also be somewhat simpler to project future changes in the EIM variable.

Including the refined petroleum product variable (REFPR) as an explanatory variable is nevertheless important because of the significant quantities of energy consumed by refineries. Under 1967 US technology and industrial structure, for instance, for each 100 Btu's of refined products delivered to final consumers, 20.8 Btu's were used directly or indirectly in the production process. (Herendeen and Bullard, 1974). The consumption of solid fuels (SC) may also require additional energy if solid fuels are burned at lower average efficiencies than are other fuels. Both Adams and Miovic (1968) and Adams and Griffin (1974) estimated coal efficiencies to be lower than those for other fuels, at least in sectors other than electricity generation. As already noted, de Janosi and Grayson (1972) found higher relative consumption of coal to be a significant factor reducing a country's income eleasticity of aggregate energy use.

The winter temperature index, TMPI, is designed to reflect intercountry difference in the need for space heat. Mean temperatures for the three coldest months of the year are first found for as many cities as possible and are then weighted using the corresponding province or state populations. While it is technically possible to prepare such a measure of average "winter" temperature for each year, long term averages of monthly temperature are more readily available and have been used for the current purposes. (See Dunkerly, 1980, on the use of "fuel degree day" measures of winter heating needs). Weighted temperatures are converted to an index by dividing by 60 degree F (or 15.6 degrees C) and setting equal to 1.0 all values which are found to be greater than one. (This in essence assumes that little or no space heat will be used in countries whose coldest months average 60 degrees F. or above). The effect of climate on energy demand, especially for electricity, is of course not limited to cold weather conditions. The inclusion of a summer temperature index, perhaps derived from "cooling degree day" data, should be considered in future studies, and its use might have avoided the somewhat ambiguous winter temperature results found for the present study.

Because of correlation among the energy-intensive material variables and because some are less related than others to the consumption of particular fuels, only those variables were included in a particular model which could be justified by (a) the reduction in the equation's standard error of estimate (SEE), and (b) the statistical significance and robustness of the resulting coefficients.

The Country Sample

Several criteria, including that of data availability, were used for selecting the 59-country sample. First, a "medium-to-large-country" sample was chosen which included all non-socialist-bloc countries whose mid-1970 population was at least 10 million or whose total GDP in current prices averaged at least US$15 billions over the period 1969-1971. Of the 49 countries meeting either of these two criteria, two (South Vietnam and the Sudan) were subsequently dropped for lack of complete data. To provide some coverage of smaller and poorer countries and greater coverage of geographical regions underrepresented in the medium-to-large country sample, World Bank staff members suggested the addition of 15 additional countries of which 8 were African. Data problems led to dropping three of these World Bank nominees: Senegal, Zimbabwe, and Papua New Guinea. Another five had to be excluded from models involving price variables because of the absence of petroleum product prices.

Because of the distinctive characteristics of oil-exporting countries over the period of the 1970's, OPEC countries were excluded from many of the calculations. 1/ Finally, for models incorporating GDP estimates adjusted for purchasing power differences among countries, one further country, Yugoslavia, had to be dropped for lack of Kravis-dollar GDP estimates. Details of the various samples are presented in full in Annex Table 1, but the several sample configurations may be summarized as follows:

59-countries: 47 medium-to-large countries plus 12 smaller/poorer nominees by World Bank staff.

48-countries: Same minus 11 countries (including two OPEC countries, Algeria and Venezuela, and 6 African countries) for which adequate petroleum price data were not available.

46-countries: Same less Saudi Arabia and Yugoslavia for which Kravis dollar GDP estimates were unavailable.

44-countries: 48-country sample less four OPEC countries, Ecuador, Indonesia, Iran, and Saudi Arabia.

43-countries: Same minus Yugoslavia, for which Kravis dollar GDP estimates are not available.

40-countries: Same minus three countries for which per capita growth rate between 1969-71 and 1976-78 was negative in real terms. (This sample was not used for any cross-country regressions, but has been employed for some of the data aggregations shown in the accompanying tables).

The 59-country sample is fairly representative of major regions and for all per capita incomes. The 44-country sample, which in many other respects is the most satisfactory for statistical calculations, is less

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1/ Petroleum prices in OPEC countries were considerably lower than in other countries, especially in the 1976-78 period. Petroleum price elasticities for non-OPEC countries were relatively stable between 1969-71 and 1976-78, but they decreased sharply when OPEC producers were included in the sample. See Table 3, below, for these and other regression results, shown both with OPEC (48 sample observations) and without OPEC countries included in the sample (44 observations).

representative. As can be seen from Annex Table 1, Africa is represented by only five countries, and the number of countries whose 1969/71 per capita GDP averaged less than US$150 dropped from eleven in the 59-country sample to only four in the smaller sample.

Economic Change, 1969/71 to 1976/78

What was the experience of these sample countries with regards to economic growth and energy consumption between 1969/71 and 1976/78? When the countries are ranked by per capita GDP in 1969/71 and devided into even logarithmic intervals, the following subgroups may be defined:

	Per Capita GDP			Number Countries
	1969/71 Log Interval	1969/71 Approx. US$ Interval	'69/71 to '76/78 Annual Growth Rate	59-Obs Sample
A	< 5.0	< $150	1.28%	11
B	5.0 - 5.99	$150 - 399	3.21	16
C	6.0 - 6.99	400 - 1099	2.49	13
D	7.0 - 7.99	1100 - 2999	3.24	12
E	8.0 - 8.99	3000 and over	1.93	7

[Source: Annex Tables 1 and 2. Growth rates are logarithmic and equal (ln Y1 - ln Y0) divided by 7 years times 100, where ln Y1 equals the mean of the country subsample per capita GDPs, in natural logs, for 1976-78, and ln Y0 equals the annalous mean for 1969-71].

There was a tendency for least growth to take place over this seven year period in the lowest and highest of the five income groups shown. The distribution of growth rates among the five subgroups thus has an inverted U-shape in the case of per capita GDP. The same holds for the consumption of each energy category examined. (This would have been even more apparent but for the inclusion in group C of two countries, Chile and Jamaica, whose per capita income growth over the period was negative). For energy intensive materials production as a ratio to GDP, growth rates decline as per capita GDP increases. Among the three faster-growing subgroups, the 16 countries in B exhibited the most rapid average growth in almost every category. (See Annex Table 2 for further details).

The per capita income (GDP) elasticities for commercial energy and electricity consumption was highest in the lower income and lowest in the higher income groups as would have been expected from almost all previous studies. The falling off in these elasticities (measured using the period 0 to period 1 growth rates) almost exactly paralleled the observed decline

Table 1

PER CAPITA ELASTICITIES WITH RESPECT TO GDP
BY INCOME-RANKED COUNTRY SUBGROUPS, AS DIRECTLY
MEASURED FROM RESPECTIVE SUBGROUP GROWTH RATES

	Subgroup Elasticities				
Country subgroup:	A	B	C	D	E
Commercial energy	2.11	1.55	1.56	.94	.90
Commercial energy plus fuelwood	.57	1.33	1.50	.91	.90
Petroleum fuels	.98	1.45	1.80	.73	.33
Electricity	4.28	2.29	2.41	1.51	2.18
Energy-intensive materials (excl. coal and refined petroleum)	5.54	1.92	1.86	.55	.03
Of which:					
Steel	13.58	2.79	2.31	.46	.49
Non-steel	4.54	1.64	2.05	.81	-.09

[Source: From ratios of (unrounded) annual per capita growth rates, as shown in Annex Table 2, to the annual GDP per capita growth rate of GDP (unrounded) from the same table. Since the elasticities shown represent ratios and subgroup means, standard errors have not been calculated].

in the income elasticity of energy-intensive materials production. This suggests the importance of the latter in accounting for the previously observed differences among countries in energy elasticities with respect to income. For commercial energy-plus-fuelwood and for electricity, however, highest 1969/1971 to 1976/1978 elasticities were found for the middle-income countries. As might therefore be anticipated, in the statistical regression analysis the production of energy-intensive materials other than coal and refined petroleum was of little significance for these two latter forms of energy use.

Various per capita elasticities with respect for GDP, as found for the five subgroups and the period 1969/71 to 1976/78 may be summarized as shown in Table 1.

III. Statistical Results

The directly-calculated energy/GDP elasticities shown above are roughly similar to those implicit in a conventional, cross-country regression with the logarithm and the squared logarithm or per capita GDP and no structural variables other than winter temperature. For period 0 and the 59-country sample, the relevant equation for commercial energy use, for example, would be:

$$\underset{}{LENA} = \underset{(5.76)}{-7.865} + \underset{(4.60)}{2.080}\ LGDP - \underset{(1.99)}{.073}\ LGDPSQ - \underset{(2.26)}{.573}\ TMPI \qquad (2)$$

where the variables are as defined above (and in Annex A) t-ratios are given in parentheses, R-squared adjusted for degrees of freedom = .949, and the equation's standard error of estimate (SEE) = .365

Similar equations for the other energy uses analyzed may be found in Annex Table 3.

From estimates of equation (2) and similar equations in Annex Table 3 the following per capita GDP elasticities may be found for each subgroup's average GDP between periods 0 and 1. Thus:

Table 2

PER CAPITA INCOME ELASTICITIES WITH RESPECT TO GDP BY INCOME-RANKED COUNTRY SUBGROUPS, AS IMPLIED BY LOG-QUADRATIC ESTIMATING EQUATIONS FOR 1969/71

	Subgroup Elasticities				
Country Subgroup:	A	B	C	D	E
Per capita					
Commercial energy	1.41	1.25	1.11	.95	.87
Petroleum fuels	1.44	1.28	1.14	.98	.90
Electricity	1.92	2.05	1.23	1.07	.98
(Memo: mean per capita GDP)	($97)	($289)	($774)	($2270)	($3854)

[Elasticities are calculated, from the log-quadradic equations referred to in the text, at the mean LGDP per capita of the subgroup shown. Thus elas. = coef. of LGDP + (2 x coef. of LGDPSQ x ln per capita GDP). Because elasticities were not directly estimated statistically, standard errors have not been shown. The GDP means are those of the logarithms of all subgroup countries in both period 0 and 1].

These estimates follow a similar pattern but in general show lower declines with increases in per capita GDP than do the directly-measured elasticities summarized at the end of the previous section. Only the pattern (in contrast to the absolute values) is in fact relevant to this comparison because, as will be seen below in the section on purchasing-power-adjusted GDP effects, elasticities based upon "real" GDP changes over time (Table 1) cannot be compared directly with those derived from cross-country "nominal" GDPs which do not correct for purchasing power differences among countries (as is the case for those GDPs used for Table 2). Thus any apparent similarity in the absolute elasticities between the two tables is spurius.

The addition of further structural factors to equation (2), especially those reflecting intercountry differences in the production of energy-intensive materials, renders the squared log of the GDP term not statistically significant. The same is true, as indicated earlier, for all of the other energy models. (The quadratic log GDP term in the models for commercial energy-plus-fuelwood, however, is generally not statistically significant to begin with, and for that reason commercial energy-plus-fuelwood has not been included in the above tabulation). In the presence of these additional variables and without the log-quadratic GDP term, income elasticities become constant over all ranges of per capita GDP.

After some experimentation with various combinations of these additional structural variables, the equations shown in Table 3 were chosen as representing a reasonable compromise between maximum explanatory power and robustness (among sample configurations and over time) of the individual coefficients. For energy forms other than electricity, results are presented for the 48-country sample (that is for the largest sample with petroleum price data) and for the same sample less four OPEC countries. For electricity, only the more representative, 59-country results are shown. Equations are given for both the 1969/71 and the 1976/78 period.

The selection of the equations in Table 3 has been to some extent arbitrary. Since there may be a question about the legitimacy of refined petroleum products (REFR) and solid fuels (SCR) as valid independent

Table 3

ESTIMATING EQUATIONS FOR PER CAPITA CONSUMPTION OF COMMERCIAL ENERGY (ENA), ELECTRICITY (ELEC), PETROLEUM PRODUCTS (PC) and COMMERCIAL ENERGY+FUELWOOD (at 50% Efficiency, ENB)

(See Annex A for notes on units, description of variables, etc.)

Eq. No.	Dependent Variable	Time Period	No. Observations	Equation Fit		Coefficients of Independent Variables (t-ratios in parentheses)								
				R-square (Adj. R squared)	SEE	Intercept	LGDP	LPPRICE	LREFPR	LSCR	LEIMPR	LEIMPSR	LEIMPNSR	LTMPI
1	LENA	0	44	.980	.225	-2.579	1.088	-.237	.195	.066	.111			
				(.978)		(4.15)	(28.73)	(1.69)	(2.28)	(3.05)	(1.67*)			
2	LENA	1	44	.978	.239	-2.639	1.084	-.197	.191	.045	.126			
				(.975)		(4.22)	(29.98)	(1.23*)	(1.89)	(2.19)	(1.75)			
3	LENA	0	48	.977	.236	-2.641	1.084	-.278	.273	.069	.059			
				(.975)		(4.32)	(27.65)	(2.08)	(4.30)	(3.81)	(0.96*)			
4	LENA	1	48	.978	.233	-2.471	1.083	-.282	.241	.049	.092			
				(.974)		(4.63)	(31.98)	(2.82)	(2.69)	(2.72)	(1.40*)			
5	LENB	0	44	.972	.231	-2.890	.916		.215	.043				-.486
				(.969)		(9.81)	(22.06)		(2.70)	(2.52)				(2.7
6	LENB	1	44	.972	.232	-3.134	.941		.208	.025				-.393
				(.969)		(10.06)	(21.87)		(2.34)	(1.66*)				(2.2
7	LENB	0	48	.968	.238	-2.658	.888		.203	.050				-.514
				(.966)		(9.51)	(22.19)		(3.34)	(3.46)				(2.9
8	LENB	1	48	.970	.232	-2.943	.917		.284	.023				-.442
				(.967)		(10.45)	(22.95)		(4.80)	(1.89)				(2.5
9	LPC	0	44	.991	.139	-3.246	1.111	-.552	.400					
				(.991)		(11.73)	(62.28)	(6.39)	(7.62)					
10	LPC	1	44	.980	.211	-3.163	1.083	-.455	.468					
				(.978)		(6.46)	(40.00)	(3.41)	(5.50)					
11	LPC	0	48	.988	.157	-2.876	1.104	-.677	.308					
				(.987)		(10.10)	(58.56)	(7.67)	(7.52)					
12	LPC	1	48	.977	.218	-3.839	1.086	-.265	.455					
				(.975)		(12.34)	(40.95)	(2.88)	(5.52)					
13	LELEC	0	59	.959	.382	1.150	1.176					.057	.302	
				(.957)		(1.80)	(21.35)					(2.30	(5.43)	
14	LELEC	1	59	.967	.332	1.640	1.165					.041	.365	
				(.965)		(3.14)	(28.61)					(1.89	(5.86)	

*=Not statistically significant at a 5% level of probability.

variables, and because it may be preferable not to have to forecast these two variables when making demand projections, equations without the two variables are shown in Annex Table 4. (For the same reason of possibly greater ease in projections, the division of EIMPR into steel and non-steel components is also dropped from this annex table).

The goodness-of-fit as measured by the R-squares is high for all equations. The standard errors of estimates, however, reveal the large amounts of unexplained variations which still remain. The SEE's are in logarithmic form and thus can roughly be interpreted as average percentage errors. The SEE of .225 shown for equation 1 of Table 3, for example, suggests that in two cases out of three, the estimated value of ENA from this equation will differ from the actual value by roughly 23 percent (more precisely, from a minus 20 percent to a plus 25 percent). The lowest standard errors are found for petroleum consumption in the non-OPEC sample; the highest, for electricity consumption. In an effort to assess the likely errors when applying the equations of Table 3 to the definition of expected or energy consumption in the case of any particular country, these standard errors are analyzed below in greater detail. (See section IV).

Note that the last five variables shown in the columns of Table 3 with the exception of the winter temperature index, TMPI, reflect structural differences among countries. By dividing the original variable by GDP each has been normalized to remove any affect associated with differences in per capita income. The intent of specifying the model in this manner, as discussed earlier, is to assign the maximum permissible explatory power to GDP so as to improve comparability with more conventional models in which per capita GDP is the sole structural variable. Another way to see this is to note that the model does not relate per capita energy use to per capita refinery production, for example, but to those differences among countries in refinery production which are not directly associated with differences in per capita GDP. This is done by dividing per capita refinery output by per capita GDP and specifying the model in terms of the new variable, refinery production per dollar of gross domestic product.

Specifying the demand model in this fashion turns out to make the per capita expenditure (GDP) coefficient far more stable when other "structural" variables are added to or subtracted from the estimating equation. It also, as noted, means that the resulting income elasticities are directly comparable with those found from models containing only GDP as a structural variable. (Such as those shown, for example, in Tables 1 and 2 above). It contributes nothing to improved goodness-of-fit nor to reduced standard errors of estimate. Furthermore, if it should be desired to find out what the GDP coefficient would have been if the additional structural variables had been expressed, say, as ratios to population rather than to GDP, this is a simple matter of subtracting the non-GDP coefficients shown in Table 3 from the coefficient shown for per capita GDP. Thus for the table's equation (1), structural variables REFR. SCR, and EIMPR are all ratios to GDP. If they had originally been divided instead by population, then the alternative GDP elasticity instead of being 1.008 should have been equal to 1.008 - 0.195 -

0.066 - 0.111 = 0.636. 1/ The standard error of the coefficient, however, would not have been affected.

Note, finally, the differences found if the dependent variables in Table 3 had been expressed as ratios to GDP rather than to population. In each case the coefficient of per capita GDP would be reduced by 1.0, but its standard error would not be affected. Neither the coefficient values, the standard errors, nor the t-ratios of the other independent variable would be changed. R-squared, however, would be reduced since inter-country variation in energy/GDP ratios is substantially lower than variation in energy/population. Thus in the case of equation 1 in Table 3, the LGDP coefficient would fall from 1.088 to .088. Its standard error would remain the same at .038, but the t-ratio would decrease from 28.73 to 2.31 (still statistically significant). None of the other coefficients or t-ratios for the independent variables would change, but the coefficient of multiple determination, R^2, would drop from .980 to .747.

Significance of the Independent Variables

The signs of all independent variable coefficients are correct, and in most cases the coefficients are statistically significant at a probability level of at least five percent. Comments on the individual variables will be made in the order of their appearance in Table 3.

1/ This can be seen if each variable is written out in expanded logarithmic form. Thus, since the prefix L- stands for natural logarithm, ln, in Table 3 and elsewhere in this paper, b1 LGDP + b2 LREPR + b3 LSCR + ... becomes b1 (ln GDP) + b2 (ln GDP) + b2 (ln REF - b2 (ln GDP + b3 (ln SC) - b3 (ln GDP) + ..., where REF = per capita petroleum refinery production and SC = per capita use of solid fuels. Combining terms gives: (b1 - b2 - b3 - ...) LGDP + b2 LREF + b3 LSC + ..., etc., and (b1 - b2 - b3 - ...) is thus the reformulated expenditure coefficient (elasticity).

LGDP. The coefficient of ln GDP, or the elasticity of per capita energy use with respect to per capita GDP, is encouragingly stable over time and from sample to sample. Its values are almost identical, at about 1.08 to 1.10, for commercial energy and for petroleum consumption. For commercial energy-plus-fuelwood, income elasticities appear to be considerably lower, averaging closer to 0.9. For electricity, on the other hand they are slightly higher, about 1.17.

For all but the petroleum equations, however, there is a potential statistical "misspecification" of uncertain magnitude which may bias the income elasticity results. Misspecification occurs when an important variable is left out of the specified equation and there is a possibility that the omitted variable is in turn correlated with one of the included variables, in this case per capita GDP. The omitted variable is non-petroleum prices. For the total commercial energy equations, coal, gas, and electricity prices have not been included. To these omissions may be added fuelwood prices for the commercial-energy-plus-fuelwood equations while the absence of electricity prices alone may bias the results from the final two equations in Table 3.

In each case of an omitted price variable it is reasonable to suppose that in countries where fuels prices are relatively lower, more of the particular form of energy will be consumed (and of course vice versa where prices are higher). If fuel prices tend to be lower in poorer countries, as is also likely, then the omission of a price effect in the model will reduce the amount of apparent intercountry variation in fuel consumption which must be "explained" by intercountry variations in per capita GDP. The estimated per capita GDP coefficient, in other words, will be smaller than it would have been if price effects had been fully allowed for.

It has been assumed that omitted commercial fuel prices will in fact be correlated with petroleum prices, but this may not necessarily be so. It is almost certainly true that fuelwood prices are higher for countries with higher GDP per capita, and this correlation may account for the lower income elasticities found for the ENB equations. A similar bias may be supposed to exist in the case of electricity, and the inclusion of electricity prices would then further increase the income elasticity of electricity demand -- already above those for other forms of energy shown in Table 3.

In the absence of actual data on the missing prices, however, much of the above is merely speculation. For the petroleum price variable included in the model, there was almost no correlation with per capita GDP either with or without four OPEC countries in the sample. Other energy prices, as already mentioned, are almost non-existent for sizeable samples of countries. Compiling average prices is difficult because of declining block rate pricing used for gas and electricity in many countries and, in general, the wide variety of prices charged different classes of consumers. Authors who have included prices in their demand models usually do not publish their price data (Nordhaus [1975, 1980], Pindyk [1979b], Griffin [1979]). One exception has been Dunkerly (1980), but the published price indexes for nine OECD countries show a negative rather than the expected positive correlation with per capita GDP. The aggregate price index also exhibits a negative correlation, for the nine sample countries, with the petroleum price measure used in the current study. Thus:

Table 4

SIMPLE CORRELATIONS BETWEEN ENERGY PRICES AND PER CAPITA GDP, NO ADJUSTMENTS FOR SAMPLE SIZE

	Dunkerly (1980)*		This Study			
	9 OECD Countries		44-Countries		48-Countries	
Energy use of	1970/72	1976	1969/71	1976/78	1969/71	1976/78
All final users	-.53	.00				
Residential sector	-.42	-.06				
Industrial consumers	-.35	-.26				
Petroleum (gasoline, kerosene, residual)	.31	.11	-.07	-.17	.00	.04

*Dunkerly's indexed (from Tables 4-2, 6-1, 6-7) have been converted from purchasing power equivalents to official exchange rate equivalents using the "exchange rate deviation indexes" from Darmstader, Dunkerly, and Alterman (1977), p. 215.

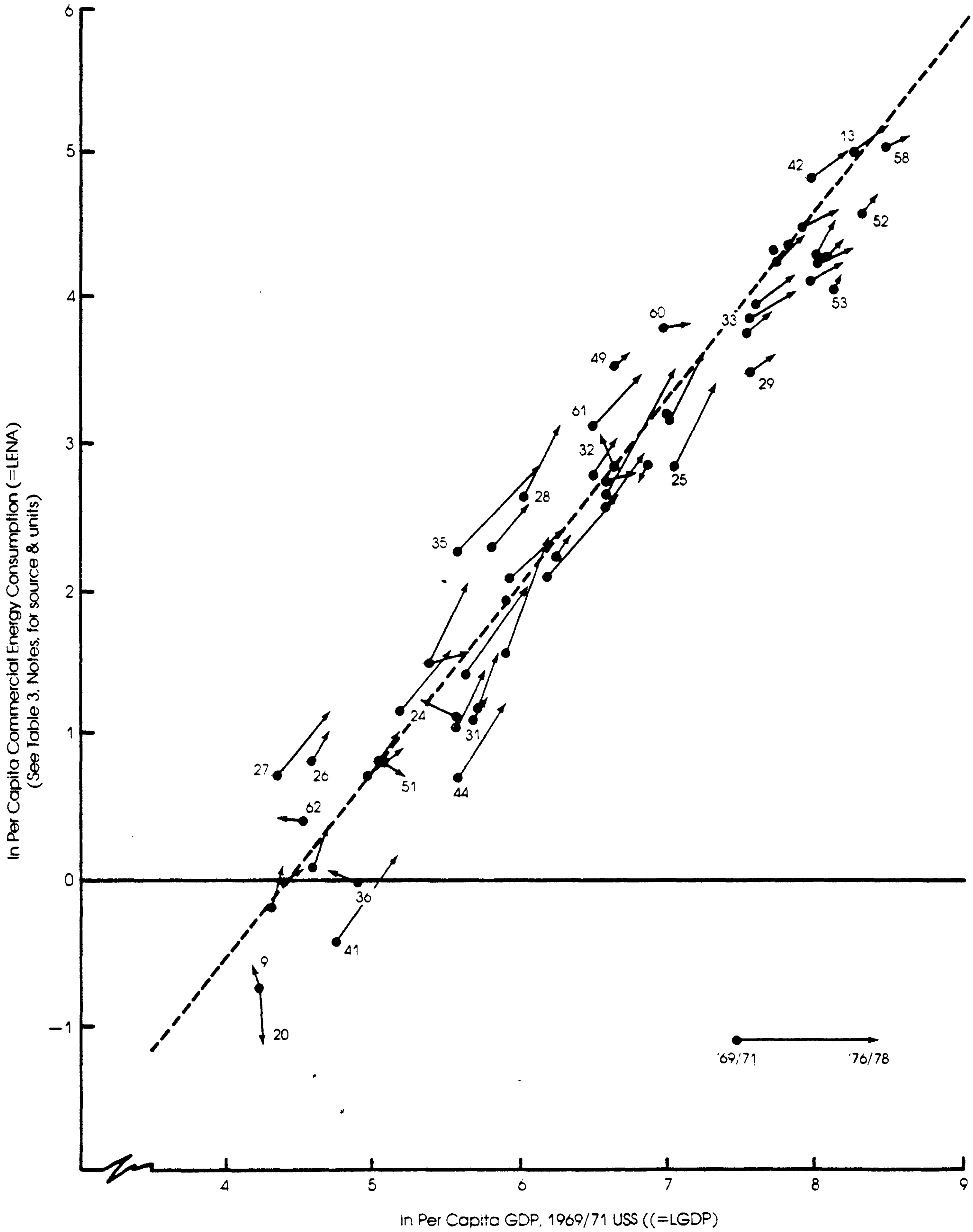
The significance of Table 4 is that if the nine country results were representative of this study's larger samples, we would expect to find an upward bias in the aggregate income elasticities of the ENA equations and probably a reduction in this bias between the two periods shown. The measured constancy of this coefficient over time tends to refute this possibility (if we believe that the underlying, long-run elasticity has in fact been stable) as does the lack of agreement betwen coefficients for the 9-country and larger samples in the case of petroleum products.

Thus the existence and even the direction of a possible bias in the GDP elasticity estimates remains at best uncertain. Considerable work on price compilations and aggregations, especially for the non-OECD countries, will be required before a better job can be done of disentangling income effects from price effects in the case of total commercial energy use and electricity use.

Returning to a consideration of Table 3, it is seen that the statistical significance of the GDP coefficients is high in all cases. The relative magnitudes of the several variables are such that the income factor plays by far the most important quantitative role in explaining intercountry differences in energy use. The strong direct relationship between, for instance, commercial energy and GDP is shown in Figure 1. The direction of the arrows in this figure suggests that between the two periods considered, the change over time was in most cases parallel to the cross-sectional relationship. (The exceptions, where GDP and energy apparently moved in quite divergent directions, are Ethiopia, no. 20; Ghana, no. 24; Jamaica, no. 32; Sri Lanka, no. 51; and Zaire, no. 61. For the key to other country numbers shown in Figure 1, see Annex Table 5).

The strong correlation between per capita GDP and per capita energy use, both among countries and for a particular country over time, should not obscure the large intercountry differences which are not "explained" by gross domestic product. The per capita GDP of Nigeria in period 0 was only five percent greater than that of Indonesia (another OPEC member) in period 1, yet Indonesia's use of commercial energy per capita was 4.8 times that of Nigeria. A similar difference occurs in the case of Paraguay and the Republic of Korea where a 370 percent difference in per capita energy use accompanied a one-half percent difference in per capita GDP. Other differences observed among countries with similar incomes include:

Figure 1
Observed Relationship Between Commercial Energy Use and Per Capita GDP, 1969/71 to 1976/78, 59-Country Sample



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Country Names (and Identifying Numbers)	Periods	Relative Differences In Per Cap GDP	Relative Differences In Per Cap ENA
Greece (25) &	0		
Venezuela (60)	0	- 5%	+154%
Ecuador (17) &	1		
Iran (28)	0	+ 0.3	+ 89
Saudi Arabia (48) &	0		
South Africa (49)	0	+ 6	+283
Isrsael (29) &	0		
Japan (33)	0	+ 2	+ 53
Sweden (52) &	1		
U.S.A. (58)	0	+ 8	+ 44

It is differences such as these that the additional independent variables are intended to help explain.

LGDPSQ. The squared value of LGDP in conjunction with LGDP, as noted earlier in this section, appears to be a useful addition to GDP itself in the case of several types of energy. In the 59-country models for period 1, the addition of LGDPSQ reduces the SEEs for commercial energy from .375 to .359 and for petroleum fuels from .394 to .354. (see Annex Table 3.) The quadratic term is not statistically significant when fuelwood is added to commercial energy and is of only marginal significance for the electricity equation when winter temperatures are also taken into account. In all cases as more direct measures of country structure are added to the models, LGDPSQ drops out, as noted above in Part II, as a statistically significant explanatory variable.

LPPRICE. Petroleum prices, as the world knows so well, increased rapidly over the years covered by this study. When average domestic prices are deflated by the implicit "resource" price deflator, however, the increase in real terms was far less than that observed in nominal terms. The average (geometric mean, or average of log values) increase found for the 48-country sample is only 29 percent between 1969/71 and 1976/78. When the four OPEC countries in this sample are omitted, the real petroleum product price increased by an average of 39 percent.

As a general rule, average prices in period 0 were slightly higher for the poorer and richer countries than for the middle-income groups. Using the same subgroup definitions as above, the five group A countries with data reported average petroleum prices of 22.3 US cents/gallon in 1969/71, and the seven members of high-income group E averaged 21.1 cents per gallon. Mean prices in middle income group C, in contrast, were about 18.6 cents/gallon. Differences among subgroups B, C, D, and E were largely eliminated by 1976/78, on the average and when OPEC countries are not counted. (Average prices in the OPEC group were considerably below those of other countries: 7.6 US cents per gallon after price deflation in 1976/78 versus a mean of 28.5 cents for the 44 non-OPEC countries). The non-OPEC countries in lowest income group A, however, did not fare so well over this period. Deflated period 1 prices for Burma, Ethiopia, Kenya, and India averaged about 36.4 cents/gallon in contrast to 27.8 cents in the other 40 non-OPEC nations.

The cross-section price elasticities were in all cases negative and of the expected magnitudes. For petroleum consumption in non-OPEC countries, the period 0 elasticity appears to have been about -.55 when refined petroleum production is included as an explanatory variable (Table 3) or -.83 when it is not (Annex Table 3). Both versions of the LPC equation show a drop of about one percentage point in the price coefficient between period 0 and period 1.

This drop apparently occurred because of the relatively low price responsiveness between 1969/1971 and 1976/1978 on the part of the middle and lower income coutries. (See further discussion, below, and for the period in question the implied price elasticities by subgroup in Table 8, below). The low price responsiveness during this particular period is believed related to the relative abundance of recycled petro-dollars which relieved balance of payments pressures resulting from increased petroleum prices. The low price response, while in most likelihood a short-run phenomenon, was nevertheless of sufficient magnitude to bias downward the "long-run" price elasticities obtained from the 1976-1978 cross-country energy consumption data.

The difference in the price elasticity found between the two forms of the LPC equation is of analytical interest. There is a tendency for petroleum refining to be slightly associated with low petroleum prices even when the OPEC countries are excluded. When refinery output is not used as an explanatory factor, the large fuel use and energy losses in refineries are at least partly attributed to low petroleum price. This probablu explains the considerably larger price coefficients found in Annex Table 3. When refinery output is included, it picks up these intercountry differences in refinery fuel use and losses, and the price elasticity estimates are reduced about one-third.

Petroleum prices are less applicable to the consumption of non-petroleum forms of energy except to the extent that they may serve as surrogates for intercountry differences in the prices of other fuels. The correlation of petroleum price differences among countries with intercountry differences in other energy prices, as discussed above, is by no means certain. The variable nevertheless is at least marginally significant from a purely statistical viewpoint in the Table 3 model for commercial energy as a whole. Its coefficient values, however, were considerably smaller than for petroleum alone, probably reflecting the fact that petroleum generally represents only 60 percent or so of the commercial energy total. The same significance of petroleum prices is found when refined petroleum production is dropped as an explanatory variable, as in Annex Table 3. The petroleum price coefficients shown in the ENA equations of Table 3, in other words, should not be referred to as elasticities of aggregate energy demand with respect to aggregate energy prices but only with respect to one component of these prices, namely those for petroleum products.

The price of refined petroleum products turned out to have no statistical relationship with the consumption of electricity. Nor was the price variable of any help in explaining intercountry variations in the consumption of commercial energy-plus-fuelwood.

LREFR. A country's production of refined petroleum is statistically related not only to the consumption of petroleum but to commercial fuels as a whole and to commercial fuel-plus-fuelwood. The coefficients in the latter two models, reflecting the share of the petroleum component, are smaller than for petroleum consumption alone. The coefficients are in all cases statistically significant and, for the non-OPEC countries, show little change between period 0 and 1.

LSCR. As had been anticipated by the work of earlier analysts, the consumption of solid fuels (SC) is positively correlated with the consumption of total commercial energy. It presumably reflects the lower average efficiency with which coal has traditionally been burned. The small but significant elasticity coefficient falls considerably in value between the two periods, suggesting possible increases in average coal-burning efficiencies. The positive correlation continues to hold although the coefficient size is reduced when fuelwood is added to commercial fuels. The solid fuels consumption factor, however, has little or no statistical significance when the dependent variable is the per capita consumption of petroleum fuels or of electricity.

LEIMPR. As may be seen from Annex Table 4, the production of energy intensive materials other than fuel (EIMP) is statistically significant and positive in the case of all models except that of petroleum fuels. The fuel-related measures, however, are superior to and replace LEIMPR when they are added to the models for petroleum consumption and commercial energy-plus-fuelwood. In fact, even the LEIMPR coefficient in the commercial energy model is reduced in significance by the inclusion of LREFR and LSC, especially for the 48-country sample.

LEIMPSR and LEIMPNSR. For the electricity model, standard errors of estimate are reduced by small amounts when the LEIMPR variable is divided into its steel and non-steel components. Worthy of note is the much larger coefficient found for the non-steel as opposed to steel production. This reflects the importance of primary aluminum and refined copper production, both heavy consumers of electricity, in the non-steel variable.

LTMPI. The winter temperature index is important for the ENB model and for simpler versions of the commercial energy model. Its value in the ENA model, however, is sharply reduced as other structural factors are added. This is because of the considerable negative correlation between winter temperatures and all of the independent variables other than petroleum price. It has not yet been investigated whether the use of actual winter temperatures rather than long term averages would change the statistical importance of this variable. Nor, as already noted, has any study yet been made of the importance, especially as incomes rise, of average summer temperatures or "cooling-degree days". Summer temperatures are probably strongly correlated with winter temperature.

See Figure 2 for a graphical summary, by income-ranked subgroups, of period 0 to period 1 changes for petroleum prices (PPRICE), refined petroleum production as a ratio to GDP (REFR), and the production of energy intensive materials as a ratio to GDP (EIMPR). Note that Figure 2 is based upon the data from Annex Table 2 and thus represents the average of 48 countries in the case of petroleum prices and 59 countries in the case of the other two variables.

Overall Importance of the Non-GDP Structural Variables

How important are the several non-GDP structural factors, just discussed, in improving overall goodness of fit? One way to answer this question is to observe the standard errors of estimate with and without the variables in question. When this is done it is seen that the reductions in the standard errors attributable to the additional variables are about one-third in the case of petroleum consumption, one-fourth in the case of commercial energy and electricity, and little more than one-tenth or so in the case of commercial energy-plus fuelwood. Thus, for the 1969/71 base period:

Figure 2
Changes in Principal Energy Demand Factors, Means for Income-Ranked Subgroups, 59-Country Sample, 1969/71 to 1976/78

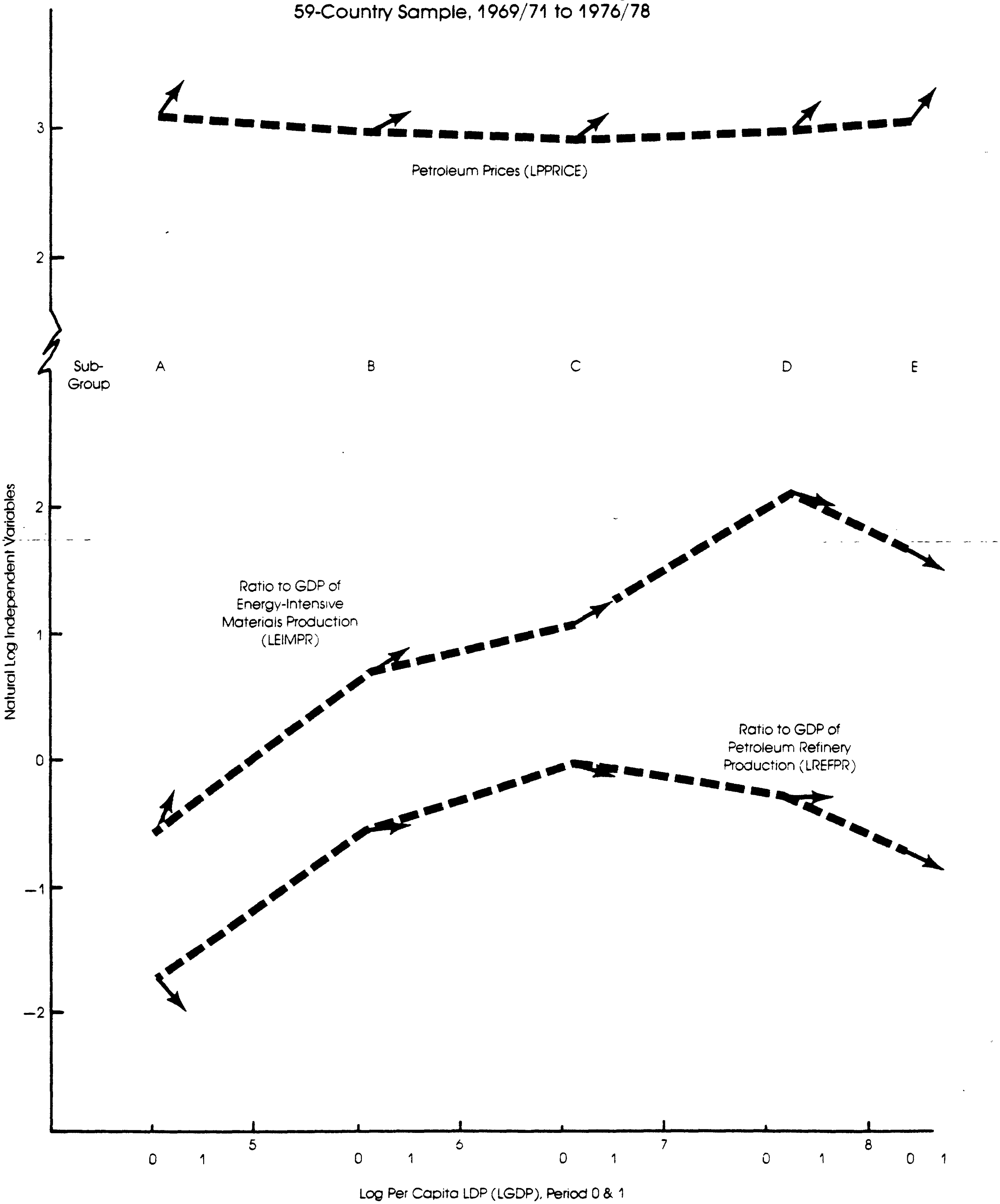

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Fig. 2 (Cont.)

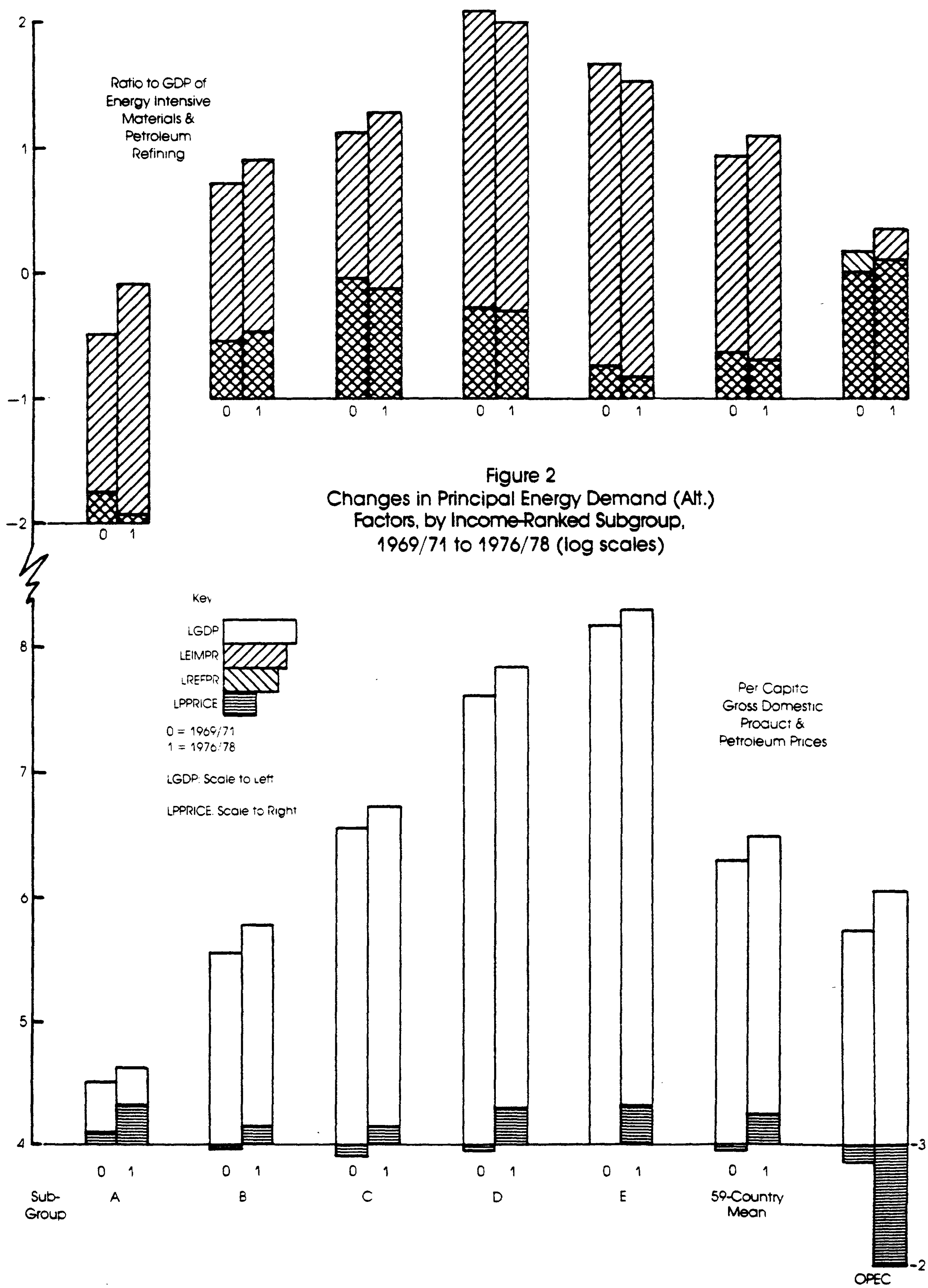

Figure 2
Changes in Principal Energy Demand (Alt.) Factors, by Income-Ranked Subgroup, 1969/71 to 1976/78 (log scales)

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Table 5

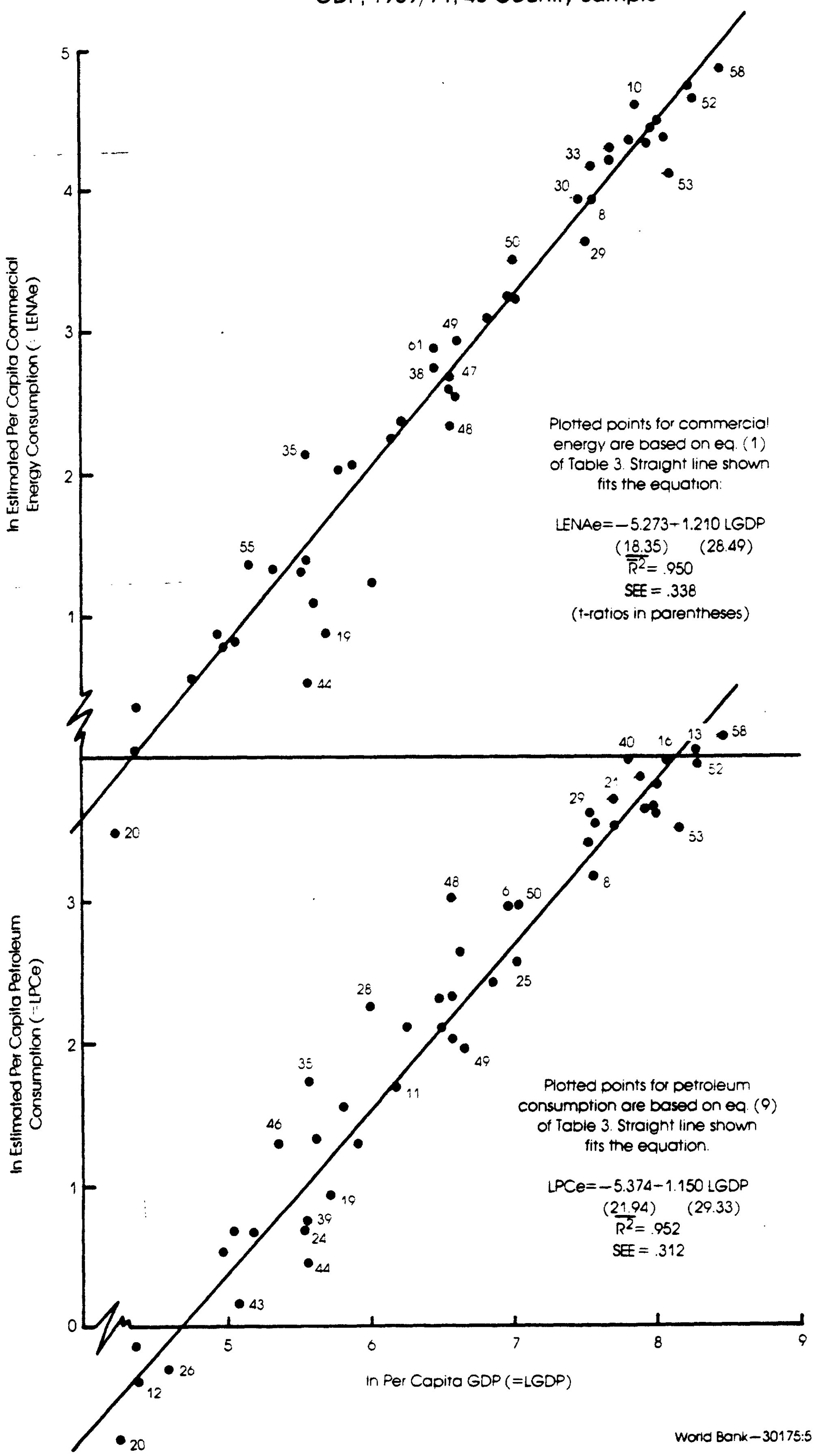
SUMMARY OF GOODNESS-OF-FIT MEASURES (SEEs), ALTERNATIVE ESTIMATING EQUATIONS AND SAMPLE SIZES, PERIOD 0

Dependent Variable	Sample Size	Standard Errors of Estimate: With LGDP, LPPRICE, LTMPI	Standard Errors of Estimate: As Shown In Table 3
LENA	44	.300	.225
	48	.309	.236
LENB	44	.267	.231
	48	.254	.238
LPC	44	.215 (excl.	.139
	48	.235 LTMPI)	.157
LELEC	59	.492	.382

(The first column of coefficients gives the SEEs when the independent variables are limited to those shown in the column heading. See Annex Table 3 for further details).

Figure 3 presents a second approach to answering the question of overall signifcance. In this figure "expected" consumption values for period 0, as obtained from the LENA and LPC equations in Table 3, are plotted against per capita GDP. If GDP were the only explanatory variable employed, the expected energy consumption values would lie along the straight lines shown. Instead, non-GDP variables are included in the estimating models leading to the very considerable dispersion about the energy/GDP line of expected energy use.

Figure 3
Estimated Consumption of Commercial Energy and Petroleum vs. Per Capita GDP, 1969/71, 48-Country Sample



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The expected energy levels obtained from the expanded model are considerably closer to actual levels than if GDP alone had been employed. Estimating errors and the unaccounted-for influence of other factors will of course still remain. Earlier it was noted, for example, that Korea's consumption of per capita commercial energy 1969/71 exceeded that of Paraguay, a country of comparable per capita income, by 380 percent. Equation 1 of Table 3 would predict a difference in "expected" energy consumption of 466 percent. This is an overestimate of the difference but comes much closer to the true situation than would a simple application of energy/GDP ratios. The same equation overestimates the difference noted earlier between Iran in period 0 versus Ecuador in period 1 (136 percent versus 89 percent) and underestimates the difference observed between South Africa and Saudi Arabia (explaining 116 percent whereas the actual difference was 283 percent). In the often-cited comparison between Sweden and the United States, US consumption of ENA in 1969/71 exceeded by 44 percent that of Sweden in 1976/78 whereas the Table 1 equation would have predicted a difference of 33 percent.

Thus the models of Table 3 (or those from Annex Table 3 or 4) can account for much but by no means all of the intercountry differences observed in the real world. They should put into clearer perspective, however, the extent to which a country's consumption is high or low by cross-country standards.

In terms of the questions posed at the beginning of this paper, the consumption of commercial energy in 1976/1978 by both India and Indonesia was about 40 percent greater than expected from international averages - as also was India's consumption of electricity. Indonesia's consumption of electricity, in contrast, was indeed low by cross-country standards in period

1, but the 22 percent "deficit" was only one-third as large as might be suggested from a superficial comparison with India. Sweden's use of commercial energy, after correcting for the several factors shown in Table 1, was about as expected from international norms in 1969/1971 and perhaps 13 percent higher in 1976/1978 than the period 0 norm. The USA on the other hand showed a modest improvement between these two periods with respect to the 1969/1971 commercial energy norm although remaining about 20 percent higher than the average in 1976/1978.

IV. Changes in Energy Use Over Time

The relative stability over time of the various estimating equation coefficients has already been noted. There is a further element of stability which may be equally important for purposes of forecasting. The unexplained differences between actual and expected energy use for many countries tended to remain relatively unchanged over the time period of the study. These unexplained differences, in other words, often appear to be related to country characteristics omitted from the general model but which remain relatively unchanged in the medium run. The differences may thus be assumed to be roughly constant over time for purposes of medium-term projection. (This is the same conclusion reached by Brookes in the study cited in Part 1, above).

This observation suggests that the various cross-country estimating equations may be more successful in predicting a country's change in energy use over time than in predicting the consumption level at a particular point in time. But before this proposition can be tested, an important conceptual difficulty must be confronted.

The cross-country equations are based upon nominal GDP estimates obtained by dividing each country's GDP in national currency by a conversion factor which in almost every case is the country's official foreign exchange rate. This means that the resulting estimates of GDP in US dollars (or in any other common currency) do not take account of the structural price changes which normally accompany the process of economic development. It is these price changes which make India's per capita GDP in 1975 appear to be only one-fiftieth (1/50) that of the United States. In contrast, when both country's GDPs are expressed in a common set of "international" prices, India's per capita GDP appears to have been closer to one-fifteenth (1/15) of the USA in 1975. (Kravis and others, 1982).

When changes over time in a country's energy use are analyzed it is common to relate these changes to a "constant price" measure of GDP (or other monetary output measure) which has been implicitly adjusted for these structural price changes. This is to say that the process of holding prices constant over time not only removes inflationary trends but also any relative price changes resulting from structural shifts. (The structural factors are mostly related to the composition of domestic product, especially the relative production of "traded" or tradable as opposed to "non-traded" goods and services). This means that for use in time series tests, especially for longer time periods, either (1) the cross-country equations must be based upon constant price estimates of GDP or (2) some way must be found to express a country's own GDP growth not in "real" or constant-price terms but in inflation-corrected nominal terms.

Purchasing-Power Adjusted GDP Effects

A United Nations and World Bank supported project on "international comparisons of real gross product", led by Professor Irving Kravis, has made great strides in adjusting country GDPs to a comparable price basis. This has been accomplished, in effect, by reweighting each country's GDP components, on a fairly disaggregated level, by a common set of prices. While the process has so far been carried out for only 34 countries for the year 1975 (and about 16 countries for 1970 and 1973), so-called short-cut methods have been used to extend the results in a less detailed fashion to another, larger group of countries. To do this, a base period statistical relationship has been derived between "real" (that is, purchasing-power-adjusted or constant international price) GDP on the one hand and "nominal" GDP (as derived using nominal foreign exchange rates) plus minor additional explanatory factors on the other. This relationship is used to approximate a non-sample country's "real" (constant international price) GDP in a base year. The base year estimate of purchasing-power-adjusted GDP is then extrapolated backward and forward using (most importantly) the country's own time series of GDP measured in constant domestic prices. (See Kravis and others, 1978b, 1981, and 1982; and Ahmad, 1980).

A number of the energy demand equations shown in Table 3 and the various Annex tables have been reestimated using Professor Kravis' estimates of "real" per capita GDP. Unfortunately, these Kravis-dollar estimates of GDP are uniformly less helpful than are the more conventional, nominal GDP measures in statistically explaining intercountry energy use differences. Furthermore, when Kravis-dollar GDPs are used, the statistical significance of other explanatory factors is reduced. For the period 1 petroleum models shown in Table 3, for example, the overall standard errors of estimate are increased slightly. The price coefficients are sharply reduced, often by almost one-half, and become statistically less significant.

The reduced statistical significance of the results undoubtedly reflects the information loss which occurs when country GDP is reconstructed using short-cut methods.

Income elasticities estimated using Kravis-dollar GDPs, on the other hand, are uniformly higher than those derived from nominal GDPs. Instead of clustering around 1.0 as shown in Table 3, the model value is closer to 1.3. This occurs because of the sharp reduction in the observed range of per capita GDPs (noted above in the India-USA comparison). Any income effect on energy use, in other words, is attributed to a smaller GDP range, and the resulting energy/GDP coefficient must therefore be larger to account for the same energy effect. When country GDP growth is measured in constant domestic prices, as is usually attempted in the construction of conventional "real" national accounts, the growth rates in the medium run approximate those obtained from using purchasing-power adjusted GDP. (See Table 6, below). The larger, Kravis-dollar based income elasticities, therefore, are more appropriate to use with conventional time series data than are those derived from cross-country studies. Income elasticities from time series analysis of individual countries, in other words, should exceed those from cross-country comparison, providing that all other factors can be held about equal.

Given the uniformly poorer statistical results it seems preferable not to reestimate the energy demand equations with Kravis-dollar GDPs but instead to adopt the second of the two options noted above and to reestimate each country's GDP growth over time in measures which are comparable to the nominal GDPs used for cross-country analysis. Conceptually this means that the time-series GDP estimates will be adjusted for inflation but not for the structural changes in price which can be anticipated as per capita GDP increases.

This reestimation process is accomplished by starting out with Professor Kravis' estimates of purchasing-power-adjusted GDP for each country in period 0 (1969/1971) and period 1 (1976/1978) and then reversing the "short-cut" process to find nominal GDP for these same two periods. Since the Kravis-dollar GDP estimates are already corrected for price inflation, the derived estimates of nominal GDP will reflect, in theory at least, real income growth plus stylized or world-wide average changes in the structure of prices. These GDP estimates for a single country will thus be closer conceptually to those nominal GDPs from the cross-section country sample used for the original demand equations.

This procedure creates a new kind of GDP measure, as yet undefined and unnamed in national accounting literature. In this paper it will be referred to as a "comparative" or an inflation adjusted, "nominal-over-time" measure of gross domestic product. The intent is to maintain an analogy with the conventional comparative-among-country or nominal GDPs derived by converting gross domestic product at a particular point in time to a common currency through the use of nominal exchange rates.

The short-cut procedure used in this paper could in theory be based upon either of two log-quadratic regressions relating nominal-among-countries and real, purchasing-power-corrected GDPs. For 1969/1971 and using the 57 countries for which Kravis-dollar GDP estimates are available, the equations are:

$$LGDP = 3.635 - .654\ LKGDP + .136\ LKGDPSQ \qquad (3)$$
$$(2.35)\quad (1.52)\qquad (4.60)$$
$$R^2 = .982,\ SEE = .178$$

$$LKGDP = .847 + 1.350\ LGDP - .0485\ LGDPSQ \qquad (4)$$
$$(1.67)\quad (8.19)\qquad (3.73)$$
$$R^2 = .980,\ SEE = .139$$

where: LGDP = Per capita GDP, in 1969/1971 US dollars, converted at nominal exchange rates, natural logs

LKGDP = Purchasing-power-adjusted estimates of per capita GDP (Kravis-dollar) in 1975 US dollar equivalents, natural logs

LKGDPSQ = LKGDP-squared

LGDPSQ = LGDP-squared

Equations such as those shown in Kravis and others (1982, Tables 8.6 or 8.8, pp. 337 and 340) will give comparable results but have not been used because the published equations are probably derived from United Nations rather than World Bank estimates of GDP. 1/ In using equation (4) above, to obtain estimates of nominal GDPs from Kravis-dollar GDPs, the equation must of course first be solved for LGDP. Thus:

$$LGDPek = (-1.3503 + SQRT(1.3503^2 - 4(-.0485)\ (.8470 - LKGDP)))/(2(-.0485)) \qquad (4a)$$

where: LGDPek is estimated LGDP, based on equation (4) and Kravis GDP estimates (KDGP)

SQRT = square root

and coefficients are shown with four significant figures to right of the decimal

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1/ The equations shown here differ in two further respects from those in Kravis and others (1982). First, LGDP in equations (3) and (4) is measured in 1969-1971 prices while LKGDP, taken from a different source, is in 1975 prices. Second, both LGDP and LKGDP are expressed in US dollars per capita, while "n" and "r", the logarithms of which are the dependent and independent variables in the Kravis equations, are ratios of a country's (nominal) GDP or "real" GDP (KGDP) to that of the United States.

It is estimated nominal-over-time GDP values, GDPek, which have been used in the final column of Table 6 and the "LGDPek" column of Table 7, below, and the "...ek" columns of Annex Tables 5 through 8.

The effect of this conversion from constant-price into nominal GDPS may be summarized as follows for the country subsamples previously described. (The growth rates shown equal the mean differences in logs divided by the number of years between period 0 and 1, seven, expressed in percentage terms).

Table 6

MEAN ANNUAL PER CAPITA GROWTH RATES OF GDP, 1969/71 TO 1976/78, BY INCOME-RANKED COUNTRY SUBGROUPS, AS MEASURED BY ALTERNATIVE PROCEDURES

Subgroup	No.	Constant Domestic Prices, World Bank Data 1969/71 US$	Kravis-$ Estimates, World Bank Data 1975 US$	After Conversion to Nominal-Over-Time GDP, Using: Equation (3), in '69/71 US$	Equation (4), in '69/71 US$
A	4	1.56%	1.54%	1.52%	1.71%
B*	10	3.58	3.53	4.44	4.48
C*	7	2.42	2.43	3.43	3.40
D	12	3.24	3.20	5.23	5.39
E	7	1.93	1.95	3.36	3.61
F*	3	-1.58	-1.58	-2.00	-2.02
Total	43	2.48	2.46	3.60	3.70

* Three countries with negative per capita GDP growth between period 0 and 1 (Chile, Ghana, and Jamaica) have been removed from subgroups B and C and combined to give the negative growth rage subgroup, F.

The small differences between the first two columns probably reflect GDP revisions made by the World Bank between the time of furnishing data to the Kravis group and to the current study. The much larger differences between the first two and the last two columns reflect the presumed structural price differences associated with countries at different levels of per capita income. These cross-section differences have been assumed to be duplicated in each country's medium term growth over time. The resulting nominal-over-time or "comparative" growth rates of GDP are, except for subgroup A in the next-to-last column, considerably higher than are the constant price growth rates. While for many purposes the constant price rates are preferred, the comparative rates will give a truer picture of a country's success in catching up to higher-income countries. They are also conceptually superior for the testing over time of cross-section equations derived from nominal estimates of per capita GDP.

Of the comparative or nominal-over-time GDPs, those obtained from equation (4a) and shown in the table's final column are preferred because it was from an equation analagous to that of equation (4) that was used originally by Kravis and his collaborators for obtaining base year KGDPs for non-sample countries. Equation (3), in addition, tends to understate substantially the nominal GDP growth among the lowest income countries.

Note that constant-price-and-quantity-weight growth rates of GDP, comparable to those of Table 6's first column, were used in deriving the implicit sub-group demand elasticities shown earlier in Table 1. If, instead, nominal-over-time GDP estimates similar to those shown in the last column of Table 6 had been employed, the Table 1 elasticities would have been considerably smaller on the average.

A Test of the 1969/1971 Equations over Time

The stability of the estimating equations may now be tested further by using the period 0 equations for predicting the change in energy use between period 0 and period 1 and then comparing these results with the actual change.

Annex Tables 5 through 8 show the country-by-country results of such a test for six estimating equations and all four types of energy use. Each annex table gives actual energy use change by country, in barrels of oil equivalent per day per thousand population, and the ratios of actual to "expected" change according to each of several alternative estimating equations. The results by income-ranked subgroups, are summarized at the end of each table for the six income-ranked subgroups described earlier. The subgroup means in natural logarithms are also shown in Table 7. Column (4) of Table 7 gives the mean change between period 0 and 1 in per capita energy use. Since the numbers in Table 7 represent changes in logarithms, they may be interpreted as rough percentage increases or decreases between the two periods. Thus between the two periods subgroup E experienced an increase in per capita commercial energy use of .1221 (natural logs), equivalent to a percentage gain of 13 percent. Alternatively, the change in logarithms may be divided by seven years to give annual rates of geometric growth.

Columns (5) through (10) of Table 7 present the estimated results from equations having, in general, additional explanatory variables in the higher-numbered columns. Columns (5) and (6) are similar except that the first is based upon GDP change in constant domestic prices while the results of the second are derived from equation (4a), used for finding the "comparative" or nominal-over-time GDP estimates, GDPek, described in the

Table 7

ACTUAL AND ESTIMATED GROWTH IN PER CAPITA ENERGY USE, 1969/71 to 1976/78,
43-COUNTRY SAMPLE BY INCOME-RANKED SUBSAMPLES, ALTERNATIVE ESTIMATING EQUATIONS

("Growth" coefficients equal the mean change, in natural logs, of actual or estimated per capita energy use; for annual growth rates, divide by 7 years.)

			Growth, 1969/71 to 1976/78						
				Estimated Using Independent Variables Shown					
Type of Energy (1)	Sub-group (2)	No. of Coun-tries (3)	Actual (from 3-year means) (4)	LGDP (5)	LGDPek (6)	LTMPI LGDPSQ LGDP (7)	LTMPI LGDPekSQ LGDPek (8)	LPPRICE LTMPI LGDPekSQ LGDPek (9)	As Shown in Table 3 + LGDPek (10)
Commercial (ENA)	A	4	.0332	.1356	.1483	.1519	.1684	-.0054	-.0620
	B*	10	.3139	.3111	.3889	.3136	.3872	.2275	.2631
	C*	7	.2435	.2101	.2948	.1901	.2672	.1022	.1432
	D	12	.2134	.2816	.4674	.2166	.3551	.2965	.2347
	E	7	.1221	.1678	.3137	.1181	.2177	.1827	.1171
	F*	3	.0772	-.1367	-.1754	-.1339	-.1737	-.2789	-.2761
	Total	43	.2003	.2155	.3215	.1883	.2716	.1621	.1440
Commercial + fuelwood at 50% efficiency (ENB)	A	4	-.0155	.1124	.1230	.1037	.1134		.0273
	B*	10	.2563	.2579	.3224	.2379	.2973		.2743
	C*	7	.2273	.1742	.2444	.1607	.2254		.2038
	D	12	.2072	.2334	.3875	.2153	.3574		.2889
	E	7	.1218	.1391	.2601	.1283	.2398		.1710
	F*	3	.0711	-.1133	-.1455	-.1045	-.1341		-.1623
	Total	43	.1778	.1787	.2665	.1648	.2458		.1967
Petroleum (PC)	A	4	-.0394	.1292	.1413	.1548	.1717	-.0328	-.1550
	B*	10	.2985	.2963	.3704	.3204	.3957	.2078	.1504
	C*	7	.2631	.2001	.2808	.1947	.2736	.0081	.0180
	D	12	.1661	.2682	.4452	.2228	.3653	.1178	.1587
	E	7	.0450	.1598	.2988	.1217	.2245	.0224	.0411
	F*	3	.0533	-.1302	-.1671	-.1369	-.1775	-.3665	-.3263
	Total	43	.1660	.2053	.3062	.1930	.2786	.0575	.0517
Electricity (ELEC)	A	4	.3181	.1515	.1657	.1653	.1831		.1634
	B*	10	.5300	.3475	.4343	.3439	.4250		.4089
	C*	7	.3550	.2347	.3293	.2102	.2955		.3262
	D	12	.3426	.3145	.5221	.2431	.3990		.3694
	E	7	.2949	.1875	.3504	.1337	.2469		.2068
	F*	3	.2077	-.1527	-.1960	-.1471	-.1908		-.0747
	Total	43	.3688	.2408	.3591	.2089	.3022		.2949

*Three negative GDP growth countries (Chile, Ghana, and Jamaica) have been removed from subgroups B and C and combined as subgroup F.

previous section. A similar difference is all that distinguishes column (7) from column (8). Column (9) is similar to (8) except that petroleum prices have been added to the list of explanatory factors. (Where petroleum price is not significant, as in the case of electricity and commercial energy-plus-fuelwood, the results have not been shown). The results in column (10) are based upon comparative GDPs and the period 0 equations shown in Table 3.

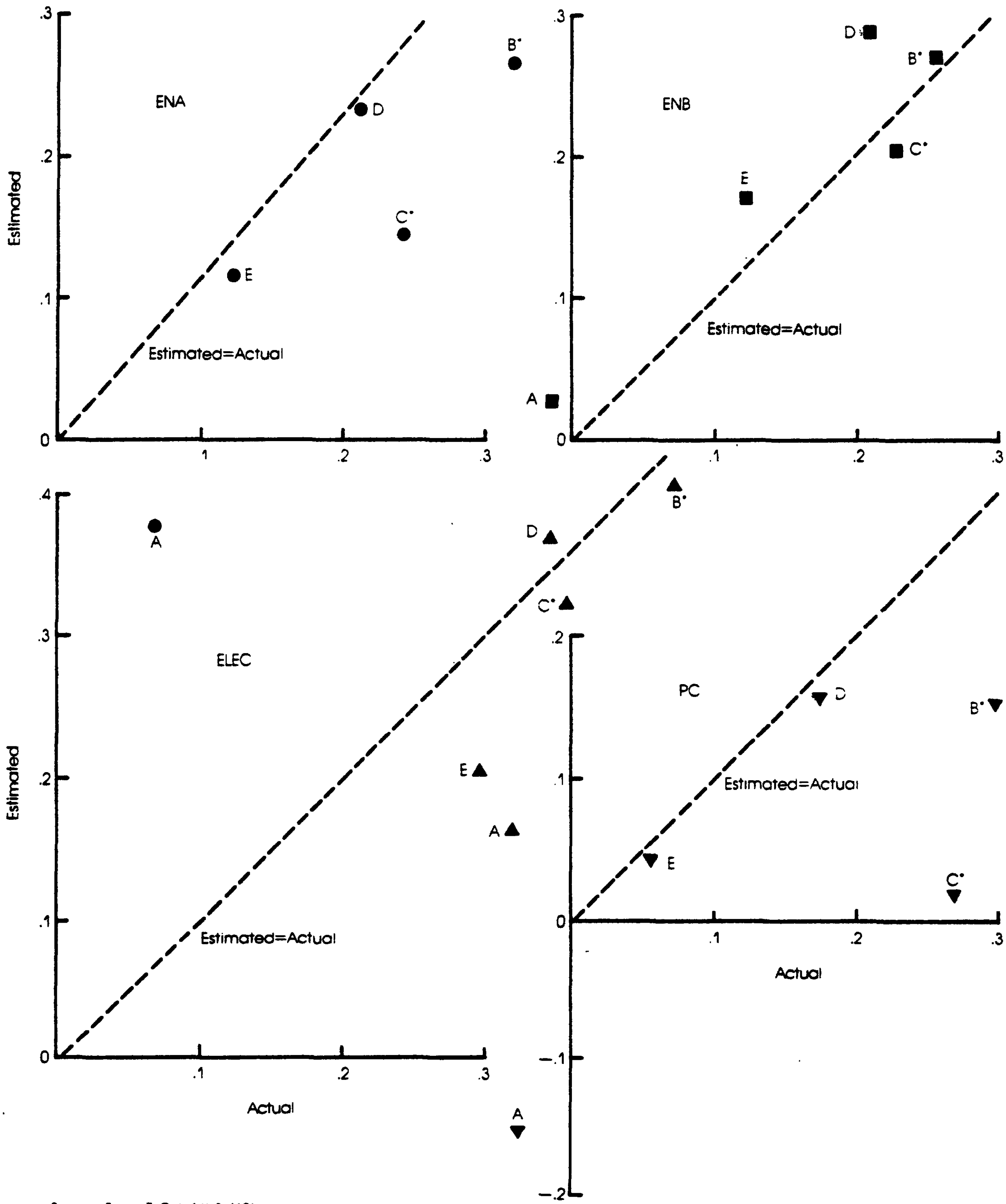
The results from the final column of Table 7 but in non-logarithmic (that is relative) to terms are also shown in Figure 4 for the same income-ranked subgroups. Note that in this figure a value of 1.0 indicates that actual and estimates changes were identical while a value of, say, 1.05 says that actual change exceeded that estimated by five percent.

A close inspection of Table 7 and of Annex Tables 5-8 reveals the following:

1. No single estimating model is consistently superior to all others in "projecting" changes in energy use for the individual subgroups. For the 43-country means and for all energy use but electricity, however, the constant-domestic-price assumption for GDP growth <u>without</u> additional explanatory variables gives distinctly the best results. This is contrary to our theoretical expectations which are that the use of constant-price GDPs should underestimate the actual energy consumption increases. Country subgroups on the average, in other words, this period by smaller amounts than would otherwise have been expected even before taking in account the large price increases which occurred.

2. For commercial energy use and for petroleum consumption, superior results are sometimes obtained by ignoring the petroleum price variable. (Compare columns 8 and 9). As a general rule when using the conceptually

Figure 4
Actual Ratios vs. Preferred Estimates of Energy Growth, Means of Period 1 ÷ Period 0 Values for Income-Ranked Sub-Groups



Source: Table 7, Cols (4) & (10)

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correct "GDPek" estimates, the exclusion of petroleum prices leads often to an overestimate of expected energy growth while including these price results in an underestimation. This suggests that, especially for lower-income subgroups, the cross-section-derived estimates of price elasticity may be too high. This would be consistent with the usual belief that short-to-medium range price elasticities are lower than longer-run elasticities.

3. The difference between medium and longer-term effects also probably explains why every model underestimates energy consumption increases for the three "negative-growth-rate" countries as a group. The negative GDP rates of the three countries concerned plus the corresponding drops in other structural factors lead to estimates of decreased energy use in all cases. For Chile, if the effect of higher energy prices is ignored, the results are often close to those projected. For Ghana and Jamaica (and for Chile in the case of electricity), however, energy use per capita actually increased rather than decreased over the period. Estimating errors are thus in all cases very large for Ghana and Jamaica.

4. Judging by the results from the "preferred" models shown in column (10), there is some tendency for lower income and especially lower-middle income countries (subgroups A, B*, and C*) to consume more energy than expected and for the opposite to be true for higher-income countries. This is equally true for model variants which include petroleum prices (commercial energy and petroleum) and for those which do not include an explicit price variable. Put another way, the lower-income countries appear not to have been able to adjust downward their energy consumption as well as have the higher-income groups in response to price and other changes occuring during this particular time period. The less flexible economies of the lower income

countries, in other words, may have made it more difficult to pass through the petroleum price effects, or, alternatively, sufficient international loans were forthcoming to postpone the full impact of the price changes. The case of petroleum consumption is a particularly good example of this general phenomenon.

5. For both petroleum and for commercial energy, the assumption of a petroleum price elasticity equal to about one-half to one-quarter of that obtained from cross-country equations would largely remove the estimating errors for subgroups A and B* in the case of petroleum and commercial energy. While this adjustment would also substantially improve the fit for subgroup C*, a significant underestimation would still exist because of large unexplained consumption increases in Mexico, Portugal, and the South African Customs Union. Thus, when equations (1) and (9) of Table 3 are solved for the implicit price elasticities which would account for actual changes in consumption between 1969/1971 and 1976/1978, the results shown in Table 8 are found.

6. Other reasons for significant discrepancies between actual changes in energy consumption and those shown, for example, in column (10) of Table 7, probably include the following:

a) The commercial energy model assigns a positive coefficient to solid fuel use and thus implies that energy consumption will decrease as coal use declines - as uniformly occurred over the period under review. In fact, the lower coal-use efficiencies implicit in the positive SCR coefficient may be more of an historical than a current reality, and declining coal use may not have contributed greatly to aggregate energy decreases. (See below,

Table 8

PETROLEUM PRICE ELASTICITIES FROM 44-COUNTRY REGRESSIONS AND AS IMPLIED BY ACTUAL CHANGE IN ENERGY USE FOR EACH INCOME-RANKED SUBGROUP BETWEEN 1969/71 AND 1976/78

	Commercial Energy (ENA) (Equation 1)	Petroleum Consumption (PC) (Equation 9)
Original 1969/71 cross-country-derived price elasticity (Table 3)	-.237	-.552
Implicit price elasticities [a] from actual 1969/71 to 1976/78 changes in energy use:		
Subgroup A	-.127	-.247
Subgroup B*	-.067	-.121
Subgroup C*	-.030	-.006
Subgroup D	-.321	-.531
Subgroup E	-.240	-.538
Subgroup F*	.667	.639
43-Country Mean	-.111	-.229

a/ Implicit elasticity = (actual change in energy consumption minus changes attributable to non-price factors) / (change in prices); all values in logs.

Table 11, for evidence on the low statistical significance of the SCR coefficient in the medium-run).

b) The omission of a price variable in the electricity equations, as already noted, may have resulted in underestimates of electricity consumption. Electricity is a politically sensitive good with a price largely controlled by public authorities, and it is likely that electricity prices in many countries did not increase as fast as did other fuels over this period. It is also likely that electricity consumption depends in part upon supply availability and that supply in many countries may be influenced as much by previously-scheduled construction programs as by current economic factors.

The larger differences between estimated and actual changes in per capita energy consumption are summarized in Table 9. Reductions in coal consumption were particularly important in the case of six of the eleven countries shown in the "large underestimate" ENA column of Table 9, namely Kenya, Pakistan, Sri Lanka, Peru, Israel, and Switzerland.

For about two out of three non-OPEC sample countries for which data are available, the growth in generating capacity between 1969/1971 and 1976/1978 exceeded the projected growth in electricity consumption (as estimated from the equation underlying column (10) of Table 7). It would be expected in such cases that the actual growth of electricity use would either lie between the other two growth rates or, if anything, exceed the higher rate. (The latter might occur if both capacity and consumption were responding to growth factors not included in the electricity estimating

Table 9

COUNTRIES WHOSE INCREASE IN PER CAPITA ENERGY USE
DIFFERED FROM PROJECTED INCREASES /a BY MORE THAN 10 PERCENT,
1969/71 to 1976/78, BY INCOME-RANKED SUBGROUPS

Subgroup (and no. countries)	1969/71 Range, Per Capita GDP ('69/71 US$)	Commercial Energy (ENA)	Comm. Energy + Fuelwood (ENB)	Petroleum (PC)	Electricity (ELEC)
I. ACTUAL INCREASE EXCEEDS PROJECTED BY 10% OR MORE /b					
A (4)	< $150	India Kenya		Burma INDIA Kenya	Burma ETHIOPIA India
B* (10)	$150- 399	El Salvador PAKISTAN Paraguay Sri Lanka	Pakistan	EL SALVADOR KOREA, REP. Pakistan PARAGUAY PHILIPPINES SRI LANKA	Colombia El Salvador Morocco PAKISTAN SRI LANKA THAILAND Turkey
C* (7)	400-1099	Argentina PERU	Peru	ARGENTINA Brazil Mexico PERU Portugal SO. AFRICA Uruguay	Argentina So. Africa Mexico
D (12)	1100-2999	Israel Spain	Spain	ISRAEL SPAIN	Finland
E (7)	3000 +	SWITZERLAND	Australia Switzerland	Switzerland	Australia Denmark Sweden SWITZERLAND
II. PROJECTED INCREASE EXCEEDS ACTUAL BY 10% OR MORE /b					
A (4)	< $150		BURMA		
B* (10)	$150- 399	Philippines	Korea, Rep. Philippines Sri Lanka	Colombia	
C* (7)	400-1099				Brazil
D (12)	1100-2999	Belgium-Luxemburg Norway Austria France Japan	Austria Belg.-Lux Finland France Japan NORWAY U.K.	Finland Greece U.K.	Austria Japan Norway U.K.
E (7)	3000 +	Canada U.S.A.	Canada Denmark U.S.A.	CANADA	Germany, F.R. U.S.A.

a/ Projected using Kravis-based GDPs (LGDPek) and Eqs. 1,5, 9, and 13 from Table 3.
b/ Country names in capital letters indicate that estimating error exceeds 20%.

equation or if, as has historically been the case at earlier stages of development, capacity utilization rates were increasing along with higher electricity consumption). These relationships were indeed observed in 23 of the 28 relevant cases.

When, on the other hand, the growth of generating capacity falls short of the projected growth of consumption, then actual consumption might again lie between the two other rates or, responding to extra-model factors tending to depress both capacity growth and consumption, the actual consumption growth rate might lag even the low rate of capacity growth. This situation occurred in 9 of the 15 relevant cases. The subgroup averages of the three growth rates under discussion are shown in Table 10.

Table 10

GROWTH OF ELECTRICITY GENERATING CAPACITY, ACTUAL AND ESTIMATED CONSUMPTION PER CAPITA, PERIOD 0 TO PERIOD 1

	Growth Between 1969/71 and 1976/78, Mean of Logs		
	Per Capita Generating Capacity	Per Capita Electricity Consumption	
Subgroup		Actual	Projected
A	.3989	.3181	.1634
B	.5086	.5300	.4089
C*	.3498	.3550	.3262
D	.3788	.3426	.3694
E	.3497	.2949	.2068
F*	.2714	.2077	-.0747
43-Country Mean	.3939	.3688	.2949

Source: World Bank computer tapes of United Nations Statistical Office, Series J data; and Table 7, columns 4 and 10.

In all six subgroups the growth of generating capacity between 1969/1971 and 1976/1978 exceeded the expected growth of energy consumption. Capacity growth presumably was responding to longer-run, historical expectations of electricity demand growth. "Expected" electricity consumption growth, in contrast, reflects the actual changes in per capita GDP and the production of energy-intensive materials. In the two lower-middle income subgroups, actual electricity growth, on the average, exceeded the growth of generating capacity by small amounts. In subgroup D where projected consumption was very close to the actual increase in generating capacity, the increase in actual consumption fell short of that projected by a little under three percent. In the remaining three subgroups, average consumption increased at rates somewhere between those expected and those made possible by increases in generating capacity.

Direct Estimates of 1969/1971 to 1976/1978 Energy Growth

Rather than estimating period 0 to period 1 energy growth on the assumption of unchanging base period relationships, it would of course be possible to treat actual growth as the dependent variable and estimate new, medium-term models of energy growth using the change in other factors as the independent variables. One set of such equations is shown in Table 11. The income growth variable in these equations is per capita GDP measured in constant domestic prices. The equations are thus suitable for projection use with GDP growth as conventionally measured.

In general, most of the structural coefficients, especially those representing income elasticity, are smaller in Table 11 than in Table 3. The effect on energy use of the various growth factors, in other words, appears to be smaller in the medium-run than over the longer-run. In addition, a number of factors which are statistically significant in the long-run version of the models are not significantly related to energy growth during the period under review. The most important of these is solid fuel consumption (for both ENA and ENB) and, interestingly, the growth of non-steel energy-intensive-materials production in the case of electricity.

Of particular interest are the low income elasticities of Table 11 (shown in the LRGDP column) compared to those of Table 3. The GDP values used for the Table 3 equations, it will be recalled, represent nominal rather than real purchasing power differences among countries. The estimated GDP elasticities, as a consequence, are smaller than would have been the case if "real" (constant price and constant weight) GDP differences had been used. The equations of Table 11, on the other hand, are based upon just such estimates of "real" GDP growth for each country. The Table 11 GDP elasticities should therefore be compared not with those of Table 3 (which cluster about 1.0) but with estimates approximately thirty percent larger. The cross section versus time series differences are therefore much larger than would at first seem to be the case.

Perhaps the most interesting point of contrast between Tables 3 and 11, however, is the relatively small decrease in the petroleum price coefficients in the case of commercial energy (ENA). For the 44-country equations the "long-run" and "medium-term" price elasticities are almost identical at about -.22. For aggregate petroleum consumption, on the other hand, the drop in the price elasticity is substantial, from a range of -.46 to -.55 for the non-OPEC countries of Table 3 to -.23 for the same group in Table 11.

Table 11

ESTIMATING EQUATIONS FOR 1969/71 TO 1976/78 CHANGE IN PER CAPITA CONSUMPTION OF COMMERCIAL ENERGY (ENA), ELECTRICITY (ELEC), PETROLEUM (PC) AND COMMERCIAL ENERGY+FUELWOOD (at 50% Efficiency, ENB)

(See Annex A for notes on units and descriptions of variables)

Eq. No.	Dependent Variable	Time Period	No. Observations	Equation Fit: R-square (Adj. R squared)	Equation Fit: SEE	Coefficients of Independent Variables (t-ratios in parentheses): Intercepy	LRGDP	LRPPRICE	LRREFR	LRSCR	LREIMPR	LREIMPSR	LREIMNSR
1	LRENA	1/0	44	.793	.090	.149	.726	-.222	.162	.010	.255		
				(.766)		(4.81)	(6.39)	(4.31)	(2.29)	(0.46*)	(4.21)		
2	LRENA	1/0	48	.779	.107	.150	.756	-.217	.113	.032	.119		
				(.753)		(.421)	(6.12)	(5.67)	(1.64*)	(1.36*)	(2.35)		
3	LRENB	1/0	44	.597	.107	.076	.638		.341	.015			
				(.567)		(2.33)	(4.73)		(4.36)	(0.67*)			
4	LRENB	1/0	48	.478	.147	.028	.952		.099	.003			
				(.442)		(0.67*)	(5.91)		(1.07*)	(0.09*)			
5	LRELEC	1/0	59	.567	.136	.218	.960					.036	.054
				(5.43)		(7.62)	(8.03)					(2.58)	(1.21*)
6	LRPC	1/0	44	.647	.148	.082	.975	-.213	.478				
				(.621)		(1.73)	(5.52)	(2.57)	(4.35)				
7	LRPC	1/0	48	.683	.161	.100	1.025	-.294	.301				
				(.661)		(2.07)	(5.74)	(5.17)	(3.00)				

*=Not statistically significant at a 5% level of probability.

The standard estimating errors of the medium-term-growth equations (Table 11) are considerably smaller, except for petroleum, than those from the single-period equations. When the Table 11 equations are used to "project" period 0 to period 1 change for the individual income-ranked subgroups, average errors are also very small.

Despite the strong statistical results reported in Table 11, the equations are not recommended for use in making future projections. This is because of their relatively large and generally significant intercept terms. The intercept in these cases can be interpreted as a time trend resulting from factors excluded from the model. For the non-OPEC countries, the exogenous trend ranges from 1.2 percent per year in the case of commercial energy-plus-fuelwood to 2.1 percent in the case of commercial energy alone. For electricity estimated from the entire 59-country sample, the exogenous time trend amounts to 3.4 percent per year.

If, as might be anticipated, these trends represent inertial effects (such as the growth of electricity generating capacity) which had not had time during the review period to adjust to the generally changed economic conditions, then projecting these positive growth trends into the future could lead to serious overestimates of future demand. For the period of the 1980s, equations such as those found in Table 3 are probably to be preferred despite their tendency to underestimate energy growth during a period of sharp price increases and generally declining economic activity.

<u>Electricity Consumption in Mexico, 1960-1980</u>

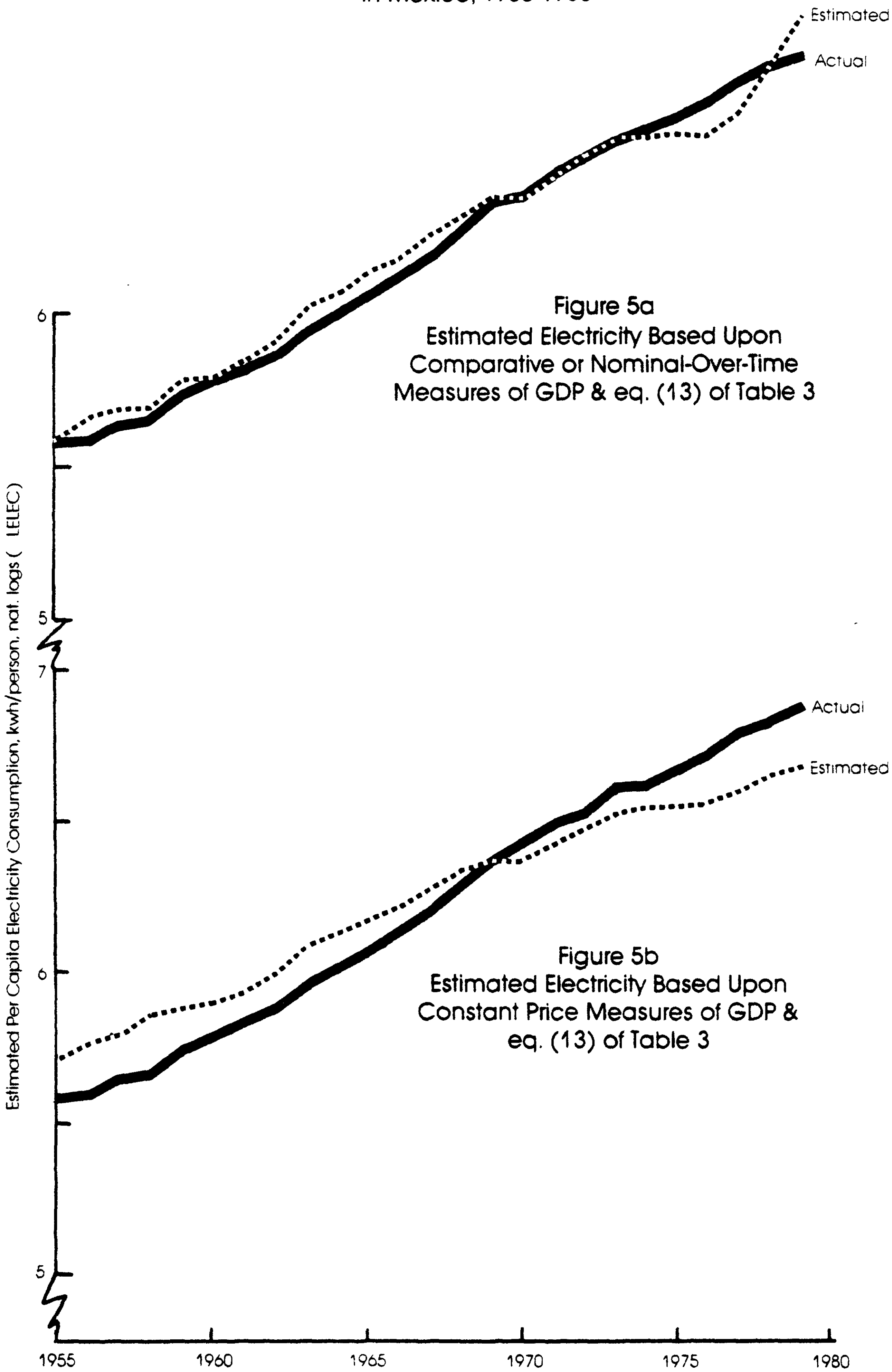
The period 1969/1971 to 1976/1978 offers a particularly rigorous but relatively short testing ground for the cross-country estimating equations.

It has not yet been possible to undertake extensive testing over longer periods of time, but the case of electricity consumption in Mexico offers insights into the results that might be obtained from such tests.

Equation (13) of Table 3, applied using the "comparative" GDPs described earlier, suggests that expected electricity consumption in Mexico between 1969/1971 and 1976/1978 would have grown at about 3.84 percent annually per capita. The actual rate of increase was significantly greater, 5.22 percent. When a longer time period is examined, however, it is seen that the 1969/1971 cross-country model replicates Mexico's electricity use in the years 1960-1975 quite well, and that the 1976/1978 period may have been a temporary aberration from a longer term relationship.

Figure 5a shows time series of annual electricity consumption data for 1956 through 1980. The heavy line represents actual per capita use; the crosses, electricity use estimated from equation (13) of Table 3. Figure 5b shows identical time series except that estimated use has been based upon constant-domestic-price rather than comparative GDPs (as used for Figure 5a). The correlation of the actual with the estimated trends in Figure 5a is striking. When per capita GDP in constant domestic prices is used as an independent variable as in Figure 5b, the standard error of estimate is .076, equivalent (since electricity use is in logarithms) to about 7.6 percent. The use of constant-domestic-price GDP produces a persistently downward-biased growth rate of electricity, however. This bias is largely removed by the use of comparative or nominal-over-time GDP as shown in Figure 5b. The standard

Actual vs. Estimated Electricity Consumption
in Mexico, 1960-1980



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error of estimate in this case is reduced to about 2.4 percent for the 1960-1980 time period.[1/]

The Mexican electricity example can be used to illustrate a further point. This is that the several non-GDP independent variables in the energy models may reflect structural differences among countries as much or more than shorter-run influneces on energy demand. The corrolary is that for energy projection purposes, lagged moving averages of the variables may serve as well as do current values. In the cases of electricity estimates for Mexico, for example, the statistical fit is actually improved when 3-year moving averages of the two energy intensive materials variables, lagged either two, three or

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1/ It should be noted that the time series estimates for Mexico's constant-international-price GDP (KGDP), prepared by Kravis and Associates for the World Bank on the basis, presumably, of World Bank GDP estimates available in 1981, or 1982, produced per capita electricity consumption estimates with highly auto-correlated errors and standard error of estimate, about 6.9 percent, not appreciably smaller than that obtained when using constant-domestic-price GDP. For Figure 5b, therefore, KGDP has been assumed to bear the same relationship to constant-domestic-price GDP (GDP) as was observed between the original Kravis-estimates of KGDP and the February 1983 World Bank GDP estimates used for the bulk of the current report, namely:

$$KGDP = 59.437 + 2.969\ GDP, \quad r^2 = .9997 \qquad (5)$$

where GDP = per capita GDP in 1970 US$ and the GDP coefficient has been adjusted slightly to ensure exact correspondence between the equation (5) KGDP for 1975 and that estimated by Kravis and Associates ($2487.2; compare Kravis and others, 1982, Table 1.2).

The nominal-over-time estimates of GDP (GDPek) used for Figure 5b were then estimated from KGDP using equation (4a) from page 46. (Further details on the data estimates for Mexico may be found in Annex B.) For both Figures 5a and 5b, the initial estimates of electricity use were adjusted by a constant multiplicative factor that the 1969-1970 estimates matched actual reported consumption for that period. (It may also be noted that estimated per capital electricity consumption for 1969/71 to 1976/78, using these revised estimates of GDPek, was 4.9 percent per year rather than the 3.8 percent found before the revisions.)

even five years behind the current year, are substituted for the current year values.[1/] This observation, if substantiated by further testing in other countries, may ease the task of using the cross-country models for estimating future consumption.

V. Conclusions

Abnormally High and Low Energy-Users

Returning now to the central concern of this paper, what if anything can be said about expected or "normal" (in a statistical sense) energy consumption levels as a result of the cross-country investigations? The first response is that there is enough normal variation around even the best of the statistical results so that an analyst should be cautious about assigning such statements as "high" or "low" in normative terms to any country's consumption of fuel or electricity. Qualifications are essential. The most that should initially be said, for example is that by international cross-country standards, country X's consumption of energy type Y appears to have been high (or low) during such-and-such a time period.

A subsequent step would be to ask *why* a country's energy consumption might appear to be high or low. Among the first things to look for are data irregularities and energy-influencing factors not included in the simple cross-country equations. Thus Mexico's GDP measurements during 1977-1980

1/ When three-year means of the two non-GDP independent variables from Table 3's equation 13 (namely LEIMPS and LEIMPNS) are lagged 2 and 5 years, the resulting standard errors of electricity consumption estimates for 1960-1980 are reduced, respectively, to 1.7 and 1.9 percent.

deserve careful scrutiny, and Norway's apparently "high" electricity consumption in both 1969/1971 and 1976/1978 (about two and a quarter times the cross-country "norm") may simply reflect that country's abundant and presumably low cost supplies of hydro-generated power.

If, in fact, a country's relative position remains substantially above or below the cross-country averages over time, this may be taken as strong evidence of missing explanatory factors (or persistent measurement biases). Until more can be learned or surmised about the nature and effect of these omitted variables or measurement biases, their impact may be assumed constant for the purposes of medium-term projections.

These several qualifications should be kept in mind when viewing compilations of high or low consumers of energy such as those which follow. In some cases a country specialist will immediately be able to guess why consumption is above or below the cross-country averages. In other cases the tabulations can provide only an incentive for further investigations.

If we consider only the third or so of each sample whose estimating errors exceed the standard error for each estimating equation (as found in Table 3), we find a substantial group of countries whose actual consumption exceeded expected consumption in both periods. For the opposite case of country energy use lying below that estimated in both periods by one standard deviation or more, a much smaller group is found. Countries in both groups are listed in Table 12.

Table 12

COUNTRIES WHOSE ACTUAL ENERGY CONSUMPTION DIFFERED FROM THE CROSS-COUNTRY NORM BY MORE THAN ONE STANDARD ERROR OF ESTIMATE IN BOTH 1969/71 AND 1976/78, BY TYPE OF ENERGY

	Commercial Energy (ENA)	Commercial Energy-plus-Fuelwood (ENB)	Petroleum (PC)	Electricity (ELEC)
I. Actual exceeds estimated	Canada	Afghanistan**	Burma	
	Colombia	Colombia		
	Ecuador	Ethiopia**	Denmark	
	El Salvador*			
	India			
	Indonesia*	Indonesia**		India
	Iran			
	Jamaica*		Jamiaca*	Jamiaca*
	Norway**			Norway**
	Saudi Arabia*			Philippines
	So. Africa**	So. Africa**	Sweden	So. Africa*
	Yugoslavia	Tanzania**	Thailand**	Tanzania
		Venezuela	Uruguay*	United Kingdom
		Zaire**		Zaire**
II. Estimated exceeds actual		Bangladesh**	Ghana	Chile
	Greece	Morocco	Netherlands	Saudi Arabia
			Zaire*	

* Difference exceeds two standard errors in 1976/78 only.
** Difference exceeds two standard deviations in both periods.

Especially for the double-asterix countries in section I of Table 12 it would seem legitimate to conclude that energy consumption has been persistently high by cross-country standards through most of the 1970s. For all countries shown in the table, further investigations are warranted to uncover the reasons for the consistently high or low apparent consumption levels as measured by international statistical norms.

A second group of countries, listed in Table 13 appeared to be moving away from the cross-country-based averages after 1969/1971. Increases above the norm were especially noticable in the case of petroleum consumption, probably because of a smaller-than-predicted response to rising petroleum prices. A similar situation occurred for electricity consumption and may have been related to the increases in generating capacity already discussed.

For the countries shown in Table 13 there is the presumption that dynamic factors were at work leading, in general, to increases in "unexplained" consumption. For Chile, Ghana, and Jamaica, as already noted, the changes involved decreases in per capita income which were not followed by comparable drops in some forms of energy use. In the case of two other countries, Israel and Peru, there was a shift from a significant <u>shortfall</u> in consumption in period 0 to a substantial <u>excess</u> of actual over-estimated consumption in period 1. The reason for these striking changes are not immediately obvious.

Finally, for a third group of countries listed in Table 14 there appeared to be movements during the 1970s from consumption which differed considerably from that estimated to levels which were much closer to those based upon the cross-country equations. In almost all of such cases, the changes tended to reduce previous shortfalls in estimated energy use.

Central Tendencies

The principal conclusion of this investigation is that strong central tendencies do seem to exist for per capita energy consumption among a wide

Table 13

COUNTRIES WHOSE ACTUAL ENERGY CONSUMPTION DIFFERED FROM CROSS-COUNTRY NORM BY MORE THAN ONE STANDARD ERROR OF IN 1976/78 BUT NOT IN 1969/71, BY TYPE OF ENERGY

	Commercial Energy (ENA)	Commercial Energy-plus-Fuelwood (ENB)	Petroleum (PC)	Electricity (ELEC)
I. Actual exceeds estimated		Australia	Argentina	Afghanistan
			Chile	Colombia
				El Salvador
		Ghan	Israel**	Ghana
	Pakistan	Iran	Korea, R.	Pakistan
		Jamaica		
	Paraguay	Paraguay	Paraguay	
			Peru**	
			Philippines*	
			Portugal	
			So. Africa	
			Sri Lanka	
			Turkey	Yugoslavia
II. Estimated exceeds actual	Greece	Sri Lanka	Ecuador*	Indonesia

* Difference in 1976/78 exceeds two standard errors.
** In 1969/71, reported consumption fell short of that estimated by more than one standard error.

Table 14

COUNTRIES WHOSE ACTUAL ENERGY CONSUMPTION DIFFERED FROM THE CROSS-COUNTRY NORM BY MORE THAN ONE STANDARD ERROR OF ESTIMATE IN 1969/71 BUT NOT IN 1976/78, BY TYPE OF ENERGY

	Commercial Energy (ENA)	Commercial Energy-plus-Fuelwood (ENB)	Petroleum (PC)	Electricity (ELEC)
I. Actual exceeds estimated	Uruguay	USA	Indonesia*	
II. Estimated exceeds actual	Chile	Algeria	Germany, FR	Algeria
	Ethiopia	Greece	Iran	Bangladesh
		Madagascar	Israel**	Ivory Coast
			Pakistan	
			Peru**	Nigeria
		Turkey	Spain*	Turkey

* Difference in 1969/71 exceeds two standard errors.
** In 1976/78, actual consumption exceeds estimated by more than one standard error.

range of countries. These central tendencies are related primarily to per capita income and secondarily to a number of other measures of structural differences among countries. Statistical descriptions of these central tendencies can be used for reaching preliminary assessments of a country's use of energy vis-a-vis other countries with similar income levels and structural characteristics.

Considerable country variation exists about these central tendencies, at least when employing the simple models investigated in this paper. Final judgements about a country's relative energy use, therefore, must be withheld until a more complete understanding is obtained of why a country differs from the cross-country norm and of whether there seems to be any movement away from or toward the same norms.

The statistical equations describing cross-country energy use do a fair job of replicating a country's change in energy use over time, although for lower to lower-middle income countries price responses during the 1969/1971 to 1976/1978 period were apparently less than might have been expected from the longer-run price elasticities. It is likely, too, that other structural variables relate more to longer-term differences among countries than to shorter-run changes in the demand for particular type of fuel or power.

Elasticity Values

Income elasticities from the cross-country regressions tend to cluster in the neighborhood of 1.0, but these are not conceptually comparable with similar elasticities obtained from time-series regressions. (Nor, it should be recalled, are per capita elasticities comparable with those derived from total energy use equations). Comparability can be achieved only by measuring country GDPs in constant prices across countries or by first adjusting a country's constant domestic price GDP to simulate the changes in price structure which occur as per capita incomes grow. When constant prices over time and among countries provide the basis for comparison, income elasticities would tend towards a value of 1.3 or so.

Longer-run petroleum price elasticities in the more fully specified models run no higher than about -.55 for petroleum itself and -.25 or so for aggregate commercial energy. No price data have as yet been obtained which yield significant price elasticities for electricity or for commercial energy-plus-fuelwood.

Demand Projections

For purposes of describing the central tendencies identified in this paper, the equations of Table 3 used in conjunction with comparative or nominal GDP are preferred. Despite the tendency of the Table 3 equations to understate actual consumption in 1976/1978, these equations are the most fully specified from the perspective of longer-run adjustments and yield the most satisfactory statistical results. For projection purposes, however, it will be best to drop the solid fuel consumption variable and to combine steel and non-steel energy intensive materials. Replacing refined petroleum production by energy intensive materials production (as in Annex Table 4, equations 3 and 4) may be advisable when projecting total commercial energy. Omitting refinery production from the petroleum consumption models, however, may bias upward the petroleum price elasticity (as in Annex Table 4, equations 11 and 12). For further projection details and an example of demand projections for Mexico, see Annex B.

In general and when used in connection with other data and with a country's own time-series-based models of energy demand, cross-country-based models should provide a powerful check both on perceptions of relative parsimony or extravagance with regards to energy use and on forecasts of changing energy use in the future.

LIST OF REFERENCES

Adams, F. Gerard, Hugh Graham, and James M. Griffin. 1974. "Demand Elasticities for Gasoline: Another View," Discussion Paper No. 279, Department of Economics, University of Pennsylvania.

Adams, F. Gerard, and James M. Griffin. 1974. "Energy and Fuel Substitution Elasticities: Results from an International Cross Section Study," a study prepared for the United Nations Conference on Trade and Development, Economics Research Unit, University of Pennsylvania.

Adams, F. Gerard, and Peter Miovic. 1968. "On Relative Fuel Efficiency and the Output Elasticity of Energy Consumption in Western Europe", The Journal of Industrial Economics, (November).

Ahmad, Sultan. 1980. "Approaches to Purchasing Power Parity and Real Product Comparisons Using Shortcuts and Reduced Information", World Bank Staff Working Paper No. 418 (Washington, The World Bank).

Aoki, H. 1973. "Long Range Forecasting of the Demand for Electrical Energy," Appendix F in International Atomic Energy Agency (1973).

______________. 1974. New Method of Long Range or Very Long Range Demand Forecast of Energy, Including Electricity, Viewed from a Worldwide Standpoint (Tokyo, Electric Power Development Co., Ltd).

Bohi, Douglas R. 1981. Analyzing Demand Behavior: A Study of Energy Elasticities (Baltimore, The Johns Hopkins Press for Resources for the Future).

Brookes, L.G. 1972. "More on the Output Elasticity of Energy Consumption", Journal of Industrial Economy, Vol. 21, No. 1 (November).

Chenery, Hollis, and Moises Syrquin. 1975. Patterns of Development, 1950-1970 (London, Oxford University Press for the World Bank).

Chern, Wen S., Andrea Ketoff, and Lee Schipper. 1982. "Residential Demand for Energy: A Time-Series and Cross-Section Analysis for Eight OECD Countries," draft report LPL 14251, Lawrence Berkeley Laboratory.

Choe, B.J. 1978. "Energy Demand Prospects in Non-OPEC Developing Countries," in International Energy Agency Workshop on Energy Supply and Demand (Paris, Organization for Economic Co-operation and Development).

Darmstadter, Joel, with Perry D. Teitelbaum and Jaroslav G. Polach. 1971, Energy in the World Economy: A Statistical Review of Trends in Output, Trade and Consumption since 1925 (Baltimore, The Johns Hopkins University Press for Resources for the Future).

Darmstader, Joel, Joy Dunkerly and Jack Alterman. 1977. How Industrial Societies Use Energy: A Comparative Analysis (Baltimore, The Johns Hopkins University Press for Resources for the Future).

de Janosi, Peter E., and Leslie E. Grayson. 1972. "Patterns of Energy Consumption and Economic Growth and Structure," The Journal of Development Studies, Vol. 8, No. 2 (January).

Dunkerly, Joy, ed. 1978. International Comparisons of Energy Consumption, Research Paper R-10 (Washington, Resources for the Future).

____________. 1982. Trends in Energy Use in Industrial Societies: An Overview, Research Paper R-19 (Washington, Resources for the Future).

Griffin, James M. 1979. Energy Conservation in the OECD: 1980 to 2000 (Cambridge, Mass., Ballinger Publishing Co.).

Herendeen, Robert A., and Clark W. Bullard III. 1974. "Energy Cost of Goods and Services, 1963 and 1967," CAC Document No. 140, Center for Advanced Computation, University of Illinois at Urbana-Champaign.

Hoffmann, Kenneth. 1972. "The U.S. Energy System - A Unified Planning Framework," unpublished Ph.D dissertation, Brooklyn Polytechnical Institute, Brooklyn, N.Y.; cited in Nordhaus, 1980.

Hoffman, Lutz, and Matthais Mors. 1979. "Energy Demand in the Developing World: Estimation and Projection up to 1990 by Region and Country," report prepared for the World Bank.

Hollander, Jack M., ed. 1977. Annual Review of Energy, Vol. 2 (Palo Alto, California, Annual Reviews, Inc.).

International Atomic Energy Agency. 1973. Market Survey for Nuclear Power in Developing Countries: General Report (Vienna, IAEA).

Ismail, Salem K. 1968. The Correlation between Energy Consumption and Gross National Product: A Statistical Analysis (Vienna, Organization of the Petroleum Exporting Countries).

Kouris, G. 1976. "The Determinants of Energy Demand in the EEC Area," Energy Policy, Vol. 4, No. 4 (December).

Kravis, Irving B., Alan Heston, and Robert Summers. 1978a. International Comparisons of Real Product and Purchasing Power (Baltimore, The Johns Hopkins University Press for the World Bank).

____________. 1978b. "Real GDP Per Capita for More than One Hundred Countries," The Economic Journal, Vol. 88, (June).

____________. 1981. "New Insights into the Structure of the World Economy," The Review of Income and Wealth, Series 27, No. 4 (December).

______________. 1982. World Product and Income: International Comparisons of Real Gross Product (Baltimore, The Johns Hopkins University Press for the World Bank).

Lane, J.A. 1975. "Long-Range Forecasting of the Demand for Electrical Energy," in International Atomic Energy Agency, Nuclear Power Planning Study for Bangladesh (Vienna, IAEA).

Mason, Edward S. 1955. Energy Requirements and Economic Growth, a report on Productive Uses of Nuclear Energy (Washington, National Planning Association).

Nordhaus, William D. 1975. "The Demand for Energy: An International Perspective," in Proceedings of the Workshop on Energy Demand (Laxenberg, Austria, International Institute for Applied Systems Analysis).

______________. 1977. International Studies of the Demand for Energy (Amsterdam, The Netherlands, North-Holland Publishing Co.).

______________. 1980. The Efficient Use of Energy Resources (New Haven and London, Yale University Press).

Parikh, Jyoti K. 1980. Energy Systems and Development: Constraints, Demand and Supply of Energy in Developing Regions (Delhi, Oxford University Press).

Pindyck, Robert S., ed. 1979a. Advances in the Economics of Energy and Resources, Vol. I: The Structure of Energy Markets (Greenwich, Conn., JAI Press).

______________. 1979b. The Structure of World Energy Demand (Cambridge, Mass., The MIT Press).

Ridker, Ronald G., ed. 1976. Changing Resource Problems of the Fourth World, RFF Working Paper PD-1 (Washington, Resources for the Future, distributed by the Johns Hopkins University Press).

Robinson, E.A.G., and G.H. Daniel. 1956. "Need for a New Source of Energy," in the World's Requirements for Energy (New York, United Nations; cited in deJanosi and Grayson, 1972).

Schipper, Lee. 1978. "The Swedish-U.S. Energy Use Comparison and Beyond: A Summary," in Dunkerly (1978).

Strout, Alan M. 1962. "Market Trends in Mineral Fuels, 1951-1960," ASME Paper No. 62-FUS-4, Fuels Symposium, American Society of Mechanical Engineers, June 5-7.

______________. 1976. "Energy and the Less Developed Countries: Needs for Additional Research," in Ridker (1976).

______________. 1977. "Energy and Economic Growth in Central America," in Hollander (1977).

______________. 1979. "Prospects for Nuclear Power in the Developing Countries," in Pindyck (1979a).

United Nations. 1952. World Energy Supplies in Seclected Years, 1929-1950, Statistical Papers, Series J, No. 1 (New York, United Nations).

United Nations Department of Energy, Energy Information Administration, 1977. International Petroleum Annual, 1977. (Washington, U.S. Government Printing Office).

Wheaton, William C. 1982. "The Long Run Structure of Transportation and Gasoline Demand," The Bell Journal of Economics, Vol. 13, No. 2 (autumn).

World Bank. 1980. World Tables, second edition (Baltimore, The Johns Hopkins University Press for the World Bank).

ANNEX A

Definitions and Conversion Factors: Notes to Tables 3, 7 and 11

1. All energy demand equations are double log. (The prefix L-for the variable designations indicates that the natural log of the variable has been used.)

2. Time period 0 = 1969-1971 (mean value of 3-years data); period 1 = 1976-1978 (mean value of three years).

3. Under "Number of Observations" is shown the country sample size. The basic 59-country sample (for which equations are shown only for electricity consumption) includes (a) all countries other than socialist bloc countries which had either (i) a mid-1970 population of 10 million or more persons, or (ii) a mean 1969-1971 total GDP of $15 billions or greater in current prices and exchange rates; and (b) countries nomiated by the World Bank staff on the grounds of special interest to the Bank or in an effort to improve either country type or regional coverage. Of the 49 countries meeting the medium-to-large country criteria, two were subsequently excluded because of data problems (South Vietnam and the Sudan). Of the 15 additional countries nomiated by the World Bank staff, three (Papua New Guinea, Senegal, and Zimbabwe) were dropped for similar reasons, leaving a total of 59 in the basic sample.

The 48-country sample excludes countries for which it was not possible to obtain petroleum product prices, and the 44-country sample excludes four OPEC countries included in the 48-country listing.

See Annex Table 1 for a complete list of countries in the various samples.

4. R-square = coefficient of multiple determination. Adj. R-squared has been adjusted for degrees of freedom. SEE = standard error of estimate.

5. The dependent variables in Tables 3 and 7 are defined as follows:

ENA	=	Commercial energy consumption per capita, from UN sources but primary electricity has been expressed in thermal station consumption rather than in heat value of output equivalents; 3-year averages in BOE/D/1000 persons (barrels of oil equivalent per day per 1000 population)
ENB	=	Equals ENA + per capita consumption of fuelwood (from FAO sources), assuming a conversion efficiency relative to "commercial" energy of 50 percent; 3-year averages in BOE/D/1000 persons
PC	=	Petroleum (liquid fuels) consumption per capita, from UN sources; 3-year averages in BOE/D/1000 persons
ELEC	=	Electricity consumption per capita, UN sources; 3-year averages in kwh/person.

6. For some purposes (as in part IV and Table 11), dependent variables are defined as the ratio of the period 1 to the period 0 value. A prefix R- (for ratio) identifies these variables. The same prefix also identifies the period 1-to-period 0 ratio form of the independent variables.

7. The independent variables are defined as follows:

GDP = Gross domestic product per capita, World Bank sources, in 1969-1971 US dollars converted from domestic currencies at nominal exchange rates; three-year means in US dollars per person.

GDPek = Nominal-over-time gross domestic product estimated from Kravis-dollar measures of GDP (KGDP), using equation (4a) in the text.

KGDP = GDP in Kravis dollars (1975) price from computer tapes provided to the World Bank by Irving Kravis. (See p. iv of Kravis and others, 1982).

PRICE = petroleum prices (average of gasoline, kerosene, and bunker

C prices, largely from U.S. Government sources, weighted by each country's reported consumption of motor-plus-aviation gasoline, kerosene-plus-jet fuel, and distillate-plus-residual fuel oils); in 1970 US cents/US gallon. For period 1 current prices deflated using implicit price deflator of "total resources" use (equals to GDP minus exports of goods and services plus imports of goods and services from World Bank national accounts data. 1970 data used for period 0; 1976-78 means for period 1.

REFR = Ratio to GDP of refined petroleum product production (from refineries only), including non-fuels such as naptha, lube oils, bitumen (asphalt), etc., 3-year means from UN sources; in kg/US dollar.

SCR = Ratio to GDP of solid fuel consumption (primary plus secondary fuels such as coke and briquets), U.N. sources, in 3-year means of BOE/D per $1000 US.

EIMPR = Ratio to GDP of energy-intensive materials production; 3-year means in BOE/D per US$1000. Energy intensive materials production consists of reported production of 10 materials, weighted by USA 1967 direct-plus-indirect energy coefficients. The commodities and weights (in MT coal equivalent/MT of material produced) are: wood pulp (.99), paper and paperboard (.40), chemical fertilizers in NPK equivalents (.77), hydraulic cement (.32), steel products in crude steel equivalents (1.87), primary copper (4.47), primary lead (1.1), smelter zinc (3.0), primary aluminum (8.97), primary tin (1.42).

Principal data sources were FAO's Yearbook of Forest Products for woodpulp, paper and paperboard; FAO, Annual Fertilizer Review; UN Statistical Yearbook (cement); the World Bank's Commodity Division for the production of steel and steel products; and Metallgesellschaft

Aktiengesellschaft, Metal Statistics, for the production for all non-ferrous metals.

EIMPSR = Ratio to GDP of the steel production component of EIMPR; 3-year averages in BOE/D/US$1000.

EIMPNSR = Ratio of GDP on the non-steel component of EIMPR; 3-year averages in BOE/D/ per US$1000. (Note that EIMPR = EIMPSR + EIMPNSR.)

TMPI = Winter temperature index, computed from mean long run temperatures of the three coldest months of the year for as many stations as possible to obtain, weighted by state or province population, and converted to an index by dividing by 60 degrees F. All ratios above 1.0 were reduced to 1.0 on the basis that little space heating fuel would be needed above 60 degrees Fahrenheit.

8. L- as a prefix signifies that the value is in natural logarithms.
-R as a suffix signifies that the variable has been divided by GDP.
LR- as a prefix signifies the logarithm of the ratio of the period 1 to the period 0 value. In practice this is calculated as the difference between the values in logs of period 1 and 0.

9. Where necessary to convert from metric tons of coal equivalent (MTCE) per person to barrels of oil equivalent per day per thousand persons (BOE/D/1000 persons), the former was multiplied by 13.75246 (=.687623 MTOE/MTOE x 7.3 (BOE/MTOE divided by 365 days per year x 1000 persons)

10. Where necessary to convert primary electricity production to thermal station energy consumption equivalent, a 30% electricity generating efficiency was assumed for all countries but a few "primarily hydro" countries where a generating efficiency of 36% was assumed. The primarily hydro countries in the sample were identified by World Bank staff and consisted of: Austria, Portugal, Spain, Sweden, Switzerland, and Turkey. For unexplained reasons, Norway was not included. If Norway had been specified as "hydro" Norway's ENA would have been reduced by 13.9% in period 0 and 11.8% in period 1.

Annex Table A-1

SAMPLE COUNTRIES INCLUDED IN CROSS-COUNTRY ENERGY USE REGRESSIONS

Per Capita Income Range, Approximate (1969/71 GDP in '69/71 US$)	Basic, 44-Country Sample (excl. OPEC and countries with insufficient petroleum price data)	OPEC Countries with price data	Countries with insufficient petroleum price data	Full Sample (Total number countries)
A. Less than $150	Burma, Ethiopia, India, Kenya a/	Indonesia	Afghanistan, Bangladesh, Madagascar a/, Nigeria, Tanzania a/, Zaire	11
B. $150-$399	Colombia, El Salvador, Ghana a/, Rep. Korea, Morocco, Pakistan, Paraguay, Philippines, Sri Lanka a/, Thailand, Turkey	Ecuador	Algeria a,c/, Egypt, Ivory Coast a/, Malaysia a/	16
C. $400-$1099	Argentina, Brazil, Chile a/, Jamaica, Mexico, Peru a/, Portugal a/, South Africa Customs Union b/, Uruguay, Yugoslavia	Iran, Saudi Arabia	Venezuela c/	13
D. $1100-$2999	Austria, Belgium-Luxemburg, Finland, France, Greece, Israel, Italy, Japan, Netherlands, Norway, Spain, United Kingdom	(none)	(none)	12
E. $3000 and over	Australia, Canada, Denmark, Fed. Republic of Germany, Sweden, Switzerland, U.S.A.	(none)	(none)	7
Total Numbers	44	4	11	59

a/ Countries nominated for inclusion by World Bank staff and not meeting medium-to-large country criteria of a mid-1970 population of at least 10 millions or a mean 1969-1971 GDP total of at least US$15 billions at current prices and exchange rates.

b/ Includes Botswana, Lesotho, Namibia and Swaziland. This grouping is made necessary because disaggregated data for each are not available.

c/ OPEC country without sufficient petroleum price data.

Annex Table A-2

MEAN VALUES OF DEPENDENT AND INDEPENDENT VARIABLES, 1969/71, 1976/78, AND ANNUAL GROWTH RATES, 59 COUNTRY SAMPLE, BY INCOME-RANKED SUBGRAOUPS

(Means are geometric, from country values in natural logarithms. Annual growth rates are expressed in percentages, as shown in parentheses. For variable definitions and units, see Annex A.)

Variable	Time Period	Income-Ranked Subgroup (and number of countries*) A (11)	B (16)	C (13)	D (12)	E (7)	59-country Sample Means	Negative Growth Rate Countries
GDP	0	92.3	258.6	706.3	2026.5	3601.5	553.3	229.8
	1	101.1	323.8	841.0	2543.1	4123.5	661.4	204.0
	1/0 (in %)	1.29	3.21	2.49	3.24	1.93	2.55	-1.69
PPRICE*	0	22.3	19.7	18.6	19.3	21.1	19.7	20.4
	1	28.3	23.6	23.6	27.4	27.9	25.6	28.1
	1/0 (%)	3.41	2.60	3.38	5.02	3.99	3.69	4.55
REFPR	0	.168	.567	.955	.762	.476	.527	.455
	1	.142	.617	.874	.749	.432	.505	.368
	1/0 (%)	-2.39	1.21	-1.25	-.22	-1.37	-.60	-3.00
EIMPR (x1000)	0	.593	1.988	3.033	8.163	5.264	2.605	2.182
	1	.894	2.447	3.505	7.365	4.613	2.961	2.325
	1/0 (%)	5.86	2.97	2.07	-1.46	-1.87	1.83	.91
EIMPSR (x1000)	0	.029	.065	.43	3.679	2.486	.297	.022
	1	.091	.098	.537	3.255	2.32	.417	.089
	1/0 (%)	16.21	5.76	3.19	-1.74	-.98	4.81	20.10
EIMPNSR (x1000)	0	.512	1.662	1.75	3.174	2.434	1.611	1.960
	1	.699	1.917	2.087	3.04	2.100	1.797	1.982
	1/0 (%)	4.45	2.03	2.52	-.61	-2.10	1.56	.16
SCR (x1000)	0	.481	.105	.478	2.765	3.182	.568	.347
	1	.275	.085	.340	1.98	2.548	.408	.195
	1/0 (%)	-7.98	-3.03	-4.86	-4.76	-3.16	-4.73	-8.20
TMPI	**	.97	.92	.88	.64	.55	.81	.97
ENA	0	1.1	4.1	17.1	52.0	91.1	10.5	2.9
	1	1.3	5.8	22.5	64.3	103.0	13.5	3.2
	1/0 (%)	2.72	4.99	3.89	3.03	1.74	3.54	1.27
ENB	0	2.6	5.1	17.8	52.5	91.4	13.4	4.5
	1	2.7	6.9	23.1	64.6	103.3	16.4	4.7
	1/0 (%)	.74	4.27	3.73	2.96	1.74	2.93	.57
PC	0	.69	2.9	10.2	30.4	51.1	6.7	1.8
	1	.75	4.1	14	35.9	53.4	8.2	1.9
	1/0 (%)	1.27	4.67	4.48	2.37	.64	3.05	.59
ELEC	0	36.4	179.0	680.3	3162.8	5484.1	480.5	157.6
	1	53.5	299.8	1035.6	4455.4	7365.0	723.3	201.8
	1/0 (%)	5.51	7.37	6.00	4.89	4.21	5.84	3.53

*For PPRICE, 11 countries without petroleum price data have been omitted from the means
**Based on log run average monthly temperatures; usually about 30 years.

Annex Table A-3

Estimating Equations, Based on GDP, PPRICE, and TMPI only, for Per Capita Consumption of Commercial Energy (ENA), Electricity (ELEC), Petroleum Products (PC) and Commercial Energy+Fuelwood (at 50% Efficiency, ENB)

(See Annex A for units and description of variables)

Eq. No.	Dependent Variable	Time Period	No. Observations	Equation Fit: R-square (Adj. R squared)	Equation Fit: SEE	Intercept	LGDP	LGDPSQ	LPPRICE	LTMPI
1	LENA	0	59	.949 (.947)	.375	-5.208 (17.12)	1.185 (22.46)			-.366 (1.52*
2	LENA	1	59	.948 (.946)	.375	-5.117 (16.53)	1.181 (22.60)			-.192 (0.79*
3	LENA	0	59	.952 (.949)	.365	-7.865 (5.76)	2.080 (4.60)	-.073 (1.99)		-.583 (2.26)
4	LENA	1	59	.953 (.951)	.359	-8.874 (6.16)	2.309 (5.02)	-.088 (2.42)		-.631 (2.48)
5	LENA	0	44	.960 (.957)	.313	-3.759 (6.06)	1.133 (20.49)		-.372 (2.09)	-.410 (1.80)
6	LENA	1	44	.960 (.957)	.314	-3.042 (4.20)	1.156 (20.37)		-.569 (3.05)	-.135 (0.57*
7	LENB	0	59	.938 (.936)	.343	-3.511 (12.60)	.948 (19.61)			-.537 (2.44)
8	LENB	1	59	.952 (.950)	.306	-3.555 (14.08)	.965 (22.63)			-.394 (1.99)
9	LPC	0	59	.945 (.944)	.367	-5.562 (22.84)	1.181 (31.23)			
10	LPC	1	59	.937 (.936)	.394	-5.415 (20.52)	1.158 (29.07)			
11	LPC	0	59	.949 (.948)	.354	-8.375 (6.62)	2.107 (5.13)	-.073 (2.26)		
12	LPC	1	59	.954 (.953)	.338	-11.108 (9.04)	2.856 (7.11)	-.126 (4.12)		
13	LPC	0	44	.978 (.977)	.218	-3.076 (6.57)	1.221 (3.57)	-.006 (0.25*)	-.825 (8.53)	
14	LPC	1	44	.975 (.973)	.234	-7.915 (2.39)	2.582 (7.24)	-.111 (4.14)	-.579 (4.08)	

Coefficients of Independent Variables (t-ratios in parentheses)

(Continued, next page)

*=Not statistically significant at a 5% level of probability.

Annex Table A-3 (Cont.)

Estimating Equations, Based on GDP, PPRICE, and TMPI only, for Per Capita Consumption of Commercial Energy (ENA), Electricity (ELEC), Petroleum Products (PC) and Commercial Energy+Fuelwood (at 50% Efficiency, ENB)

(See notes to Table 1 for units and description of variables)

Eq. No.	Dependent Variable	Time Period	No. Observations	Equation Fit: R-square (Adj. R squared)	Equation Fit: SEE	Coefficients of Independent Variables (t-ratios in parentheses): Intercept	LGDP	LGDPSQ	LPPRICE	LTMPI
15	LELEC	0	59	.927 (.926)	.499	-2.576 (7.80)	1.385 (26.95)			
16	LELEC	1	59	.931 (.930)	.470	-1.998 (6.35)	1.321 (27.83)			
17	LELEC	0	59	.933 (.930)	.487	-4.887 (2.69)	2.212 (3.67)	-.074 (1.51*)		-.723 (2.10)
18	LELEC	1	59	.931 (.928)	.479	-4.037 (2.10)	1.944 (3.17)	-.054 (1.12*)		-.893 (2.63)

*=Not statistically significant at a 5% level of probability.

Annex Table A-4

ALTERNATIVE ESTIMATING EQUATIONS FOR PER CAPITA CONSUMPTION OF COMMERCIAL ENERGY (ENA), ELECTRICITY (ELEC), PETROLEUM (PC) AND COMMERCIAL ENERGY+FUELWOOD (at 50% Efficiency, ENB)

(See Annex A for units and description of variables)

Eq. No.	Dependent Variable	Time Period	No. Observations	Equation Fit: R-square (Adj. R squared)	Equation Fit: SEE	Coefficients, Independent Variables (t-ratios in parentheses): Intercept	LGDP	LPPRICE	LEIMR	LTMPI
1	LENA	0	44	.960 (.957)	.313	-3.759 (6.06)	1.133 (20.49)	-.372 (2.08)		-.372 (1.80)
2	LENA	1	44	.960 (.957)	.314	-3.042 (4.20)	1.156 (20.37)	-.569 (3.05)		-.135 (0.57*)
3	LENA	0	44	.973 (.970)	.259	-1.804 (2.67)	1.071 (25.15)	-.357 (2.44)	.265 (4.84)	
4	LENA	1	44	.973 (.971)	.255	-2.061 (3.30)	1.082 (28.10)	-.281 (1.72)	.255 (4.59)	
5	LENB	0	44	.960 (.958)	.267	-3.524 (12.50)	.947 (20.14)			-.582 (3.04)
6	LENB	1	44	.964 (.962)	.254	-3.654 (12.96)	.973 (21.19)			-.430 (2.28)
7	LENB	0	44	.965 (.962)	.254	-2.493 (4.76)	.903 (18.60)		.128 (2.29)	-.460 (2.42)
8	LENB	1	44	.970 (.968)	.236	-2.645 (5.84)	.936 (20.85)		.131 (2.73)	-.329 (1.84)
9	LPC	0	44	.953 (.952)	.312	-5.374 (20.26)	1.150 (29.23)			
10	LPC	1	44	.947 (.945)	.333	-5.295 (18.37)	1.134 (27.33)			
11	LPC	0	44	.978 (.977)	.215	-2.788 (6.96)	1.136 (41.91)	-.833 (6.88)		
12	LPC	1	44	.964 (.962)	.276	-2.683 (4.26)	1.108 (31.73)	-.726 (4.48)		
13	LELEC	0	59	.956 (.955)	.390	.650 (1.10*)	1.174 (22.13)		.318 (6.09)	
14	LELEC	1	59	.965 (.964)	.339	1.452 (2.77)	1.131 (26.24)		.380 (7.30)	

*=Not statistically significant at a 5% level of probability.
**LEIMI = unexplained residual from regression of LEIMP on LGDP & LGDPSQ.

Annex Table A-5 ACTUAL AND ESTIMATED CHANGES IN RENA,

		Group**	Actual	RENAe1	RENAek1	RENAe2
	Values for Period 1 Divided by Values for Period 0					
4	AFGAN	(A)	1.382	1.104	1.117	1.122
5	ALGERIA	(B,OPEC)	1.941	1.259	1.358	1.251
6	ARGEN	C*	1.141	1.096	1.145	1.081
7	AUSTL	E	1.253	1.162	1.299	1.115
8	AUSTRIA	D	1.24	1.399	1.78	1.294
9	BANGLA	(A)	1.214	.95	.943	.941
10	BELGLUX	D	1.121	1.327	1.631	1.231
11	BRAZIL	C*	1.751	1.785	2.17	1.707
12	BURMA	A	1.107	1.156	1.168	1.183
13	CANADA	E	1.219	1.333	1.734	1.22
14	CHILE	F* (C)	.909	.949	.925	.955
15	COLOMBIA	B*	1.247	1.351	1.487	1.343
16	DENMARK	E	1.054	1.229	1.449	1.159
17	ECUADOR	(B,OPEC)	1.771	1.673	1.934	1.666
18	EGYPT	(B)	1.763	1.391	1.489	1.404
19	ELSAL	B*	1.464	1.193	1.256	1.192
20	ETHIOPIA	A	.69	1.039	1.043	1.047
21	FINLAND	D	1.251	1.294	1.522	1.215
22	FRANCE	D	1.143	1.327	1.658	1.228
23	GERM FR	E	1.136	1.241	1.492	1.169
24	GHANA	F* (B)	1.131	.782	.742	.775
25	GREECE	D	1.733	1.467	1.805	1.375
26	INDIA	A	1.233	1.14	1.154	1.16
27	INDONESIA	(A,OPEC)	1.564	1.591	1.671	1.701
28	IRAN	(C,OPEC)	1.615	1.356	1.558	1.337
29	ISRAEL	D	1.162	1.24	1.406	1.182
30	ITALY	D	1.132	1.217	1.37	1.166
31	IVORYCST	(B)	1.18	1.067	1.095	1.068
32	JAMAICA	F* (C)	1.226	.894	.861	.904
33	JAPAN	D	1.196	1.437	1.85	1.322
34	KENYA	A	1.213	1.256	1.288	1.279
35	KOREA R	B*	1.767	1.967	2.417	1.952
36	MADAG	(A)	1.105	.775	.749	.753
37	MALAYSIA	(B)	1.434	1.58	1.819	1.549
38	MEXICO	C*	1.291	1.188	1.277	1.168
39	MOROCO	B*	1.374	1.3	1.334	1.303
40	NETHERL	D	1.197	1.249	1.471	1.181
41	NIGERIA	(A,OPEC)	1.815	1.593	1.729	1.664
42	NORWAY	D	1.24	1.412	1.844	1.283
43	PAKISTAN	B*	1.244	1.111	1.126	1.12
44	PARAG	B*	1.681	1.473	1.622	1.475
45	PERU	C*	1.171	1.069	1.092	1.065
46	PHILIPP	B*	1.083	1.333	1.418	1.345
47	PORTUGAL	C*	1.429	1.328	1.52	1.287
48	SAUDI A	(C,OPEC)	2.439	1.769	N/A	1.647
49	S AFRICA	C*	1.11	1.109	1.149	1.097
50	SPAIN	D	1.566	1.367	1.581	1.3
51	SRI LANK	B*	.898	1.187	1.22	1.202
52	SWEDEN	E	1.113	1.124	1.238	1.085
53	SWITZERL	E	1.096	1.029	1.044	1.021
54	TANZANIA	(A)	1.341	1.143	1.156	1.163
55	THAILAND	B*	1.588	1.465	1.585	1.492
56	TURKEY	B*	1.61	1.437	1.62	1.418
57	UK	D	1.016	1.199	1.351	1.148
58	USA	E	1.055	1.184	1.427	1.12
59	URUGUAY	C*	1.148	1.19	1.301	1.168
60	VENEZ	(C,OPEC)	1.025	1.222	1.375	1.185
61	YUGOSLAV	(C)	1.389	1.538	N/A	1.468
62	ZAIRE	(A)	1.009	.845	.839	.823

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Annex Table A-5 (Cont.)

	Subgroup**	Actual	RENAe1	RENAek1	RENAe2
Subgroup Means of Period 1/Period 0 Values Shown Above					
59 MEAN		1.312	1.269		1.242
48 MEAN		1.296	1.296		1.296
44 MEAN		1.301	1.309		1.307
43 MEAN		1.243	1.257	1.416	1.222
44A MEAN	4 (11)	1.061	1.148	1.163	1.167
43B* MEAN	10 (16)	1.396	1.382	1.509	1.384
44C* MEAN	7 (13)	1.292	1.252	1.379	1.225
44D MEAN	12 (12)	1.25	1.328	1.606	1.244
44E MEAN	7 (7)	1.132	1.186	1.383	1.127
44F* MEAN	3 (0)	1.089	.875	.843	.878

=Countries with negative per capita GDP growth rates f (Chile, Ghana, Jamaica) constitute group F and have b their original groups, B and C. Group 43C also excl

**43-country subgroup followed by 59-country subgroup,

a/ Notes: Model "e1" is based upon LGDP; "e2" upon LGDP, LGDPSQ, significant); "e3" upon LGDP, LGDPSQ, LTMPI, & LPPRICE "e4" on "best" equations from Table 3.

The "ek" models are the same except that "normative-ove derived from Kravis-dollar estimates have replaced the

"N/A" means that either the petroleum price data or Kra unavailable and hence that energy consumption cannot be

Annex Table A-6 ACTUAL AND DIRECTLY ESTIMATED VALUES OF RENB, Ratio

Data for Change, Period 1 divided by 0 (ratios of absolute values)

		Group**	RENB	RENBe1	RENBek1	RENBe2
4	AFGAN	(A)	1.189	1.086	1.096	1.079
5	ALGERIA	(B,OPEC)	1.906	1.21	1.289	1.193
6	ARGEN	C*	1.129	1.079	1.119	1.072
7	AUSTL	E	1.254	1.132	1.243	1.121
8	AUSTRIA	D	1.237	1.321	1.613	1.293
9	BANGLA	(A)	1.118	.958	.953	.961
10	BELGLUX	D	1.12	1.265	1.5	1.242
11	BRAZIL	C*	1.603	1.617	1.901	1.557
12	BURMA	A	.761	1.128	1.137	1.117
13	CANADA	E	1.219	1.269	1.578	1.246
14	CHILE	F* (C)	.905	.957	.938	.961
15	COLOMBIA	B*	1.168	1.283	1.39	1.259
16	DENMARK	E	1.054	1.186	1.36	1.171
17	ECUADOR	(B,OPEC)	1.709	1.532	1.728	1.482
18	EGYPT	(B)	1.762	1.315	1.391	1.287
19	ELSAL	B*	1.339	1.157	1.208	1.144
20	ETHIOPIA	A	.924	1.033	1.035	1.03
21	FINLAND	D	1.22	1.239	1.417	1.218
22	FRANCE	D	1.141	1.264	1.521	1.241
23	GERM FR	E	1.135	1.196	1.393	1.18
24	GHANA	F* (B)	1.115	.816	.78	.829
25	GREECE	D	1.707	1.374	1.632	1.341
26	INDIA	A	1.203	1.115	1.126	1.105
27	INDONESIA	(A,OPEC)	1.309	1.469	1.531	1.426
28	IRAN	(C,OPEC)	1.613	1.287	1.444	1.262
29	ISRAEL	D	1.161	1.195	1.326	1.179
30	ITALY	D	1.131	1.177	1.298	1.162
31	IVORYCST	(B)	1.039	1.056	1.078	1.051
32	JAMAICA	F* (C)	1.226	.912	.883	.918
33	JAPAN	D	1.195	1.351	1.665	1.32
34	KENYA	A	1.112	1.208	1.233	1.19
35	KOREA R	B*	1.711	1.752	2.078	1.678
36	MADAG	(A)	1.112	.81	.787	.823
37	MALAYSIA	(B)	1.385	1.461	1.642	1.418
38	MEXICO	C*	1.279	1.153	1.225	1.141
39	MOROCO	B*	1.337	1.243	1.269	1.222
40	NETHERL	D	1.197	1.202	1.377	1.185
41	NIGERIA	(A,OPEC)	1.2	1.471	1.574	1.427
42	NORWAY	D	1.238	1.331	1.661	1.302
43	PAKISTAN	B*	1.219	1.091	1.104	1.084
44	PARAG	B*	1.361	1.379	1.494	1.345
45	PERU	C*	1.166	1.057	1.076	1.052
46	PHILIPP	B*	1.078	1.269	1.336	1.246
47	PORTUGAL	C*	1.418	1.265	1.415	1.242
48	SAUDI A	(C,OPEC)	2.439	1.604	N/A	1.546
49	S AFRICA	C*	1.105	1.09	1.122	1.083
50	SPAIN	D	1.545	1.296	1.462	1.27
51	SRI LANK	B*	.911	1.153	1.179	1.14
52	SWEDEN	E	1.111	1.102	1.194	1.094
53	SWITZERL	E	1.095	1.024	1.036	1.022
54	TANZANIA	(A)	.979	1.117	1.128	1.108
55	THAILAND	B*	1.452	1.372	1.465	1.339
56	TURKEY	B*	1.535	1.35	1.492	1.319
57	UK	D	1.016	1.162	1.283	1.149
58	USA	E	1.054	1.151	1.343	1.138
	URUGUAY	C*	1.16	1.155	1.244	1.142
	VENEZ	(C,OPEC)	1.023	1.181	1.302	1.166
	YUGOSLAV	(C)	1.363	1.429	N/A	1.389
	ZAIRE	(A)	.826	.87	.864	.879

* *

Annex Table A-6 (Cont.)

Subgroup**		RENB	RENBe1	RENBek1	RENBe2
Subgroup Means, Period 1/Period 0 Values Shown Above					
59 MEAN		1.255	1.216	N/A	1.196
48 MEAN		1.26	1.233	N/A	1.212
44 MEAN		1.269	1.248	N/A	1.227
43 MEAN		1.21	1.206	1.329	1.188
44A MEAN	4 (11)	1	1.121	1.133	1.111
43B* MEAN	10 (16)	1.311	1.305	1.402	1.278
44C* MEAN	7 (13)	1.266	1.202	1.3	1.184
44D MEAN	12 (12)	1.242	1.265	1.48	1.242
44E MEAN	7 (7)	1.132	1.151	1.307	1.139
*44F MEAN	3 (0)	1.082	.895	.867	.903

**Countries with negative per capita GDP growth rates f (Chile, Ghana, Jamaica) constitute group F and have b their original groups, B and C. Group 43C* also excl

**43-country subgroup followed by 59-country subgroup,

a/ Notes: Model "e1" is based upon LGDP; "e2" upon LGDP, LGDPSQ, significant); "e3" upon LGDP, LGDPSQ, LTMPI, & LPPRICE "e4" on "best" equations from Table 3.

The "ek" models are the same except that "normative-ove derived from Kravis-dollar estimates have replaced the

"N/A" means that either the petroleum price data or Kra unavailable and hence that energy consumption cannot be

Annex Table A-7 ACTUAL AND DIRECTLY ESTIMATED VALUES OF RPC, Ratio

		Group**	RPC	RPCe1	RPCek1	RPCe2
	Data for Change, Period 1 divided by 0 (ratios of absolute value					
4	AFGAN	(A)	1.193	1.099	1.111	1.125
5	ALGERIA	(B,OPEC)	1.66	1.245	1.338	1.257
6	ARGEN	C*	1.002	1.091	1.138	1.083
7	AUSTL	E	1.141	1.154	1.283	1.119
8	AUSTRIA	D	1.244	1.377	1.732	1.303
9	BANGLA	(A)	.954	.952	.946	.94
10	BELGLUX	D	1.029	1.31	1.593	1.239
11	BRAZIL	C*	1.632	1.737	2.092	1.729
12	BURMA	A	.95	1.148	1.159	1.186
13	CANADA	E	1.119	1.315	1.689	1.227
14	CHILE	F* (C)	.862	.951	.929	.954
15	COLOMBIA	B*	1.115	1.332	1.459	1.352
16	DENMARK	E	.903	1.217	1.424	1.164
17	ECUADOR	(B,OPEC)	1.803	1.632	1.874	1.685
18	EGYPT	(B)	1.682	1.37	1.461	1.415
19	ELSAL	B*	1.45	1.183	1.242	1.197
20	ETHIOPIA	A	.62	1.038	1.04	1.048
21	FINLAND	D	1.14	1.279	1.492	1.222
22	FRANCE	D	1.137	1.309	1.619	1.236
23	GERM FR	E	1.07	1.228	1.464	1.175
24	GHANA	F* (B)	1.102	.791	.752	.771
25	GREECE	D	1.674	1.441	1.755	1.387
26	INDIA	A	1.209	1.133	1.147	1.163
27	INDONESIA	(A,OPEC)	1.558	1.556	1.631	1.718
28	IRAN	(C,OPEC)	2.021	1.336	1.525	1.346
29	ISRAEL	D	1.188	1.227	1.383	1.188
30	ITALY	D	1.043	1.205	1.349	1.171
31	IVORYCST	(B)	1.218	1.064	1.091	1.069
32	JAMAICA	F* (C)	1.235	.899	.867	.902
33	JAPAN	D	1.254	1.413	1.797	1.332
34	KENYA	A	1.199	1.242	1.272	1.286
35	KOREA R	B*	1.954	1.905	2.318	1.981
36	MADAG	(A)	1.104	.784	.759	.749
37	MALAYSIA	(B)	1.398	1.546	1.768	1.565
38	MEXICO	C*	1.357	1.178	1.262	1.173
39	MOROCO	B*	1.555	1.283	1.315	1.311
40	NETHERL	D	.887	1.236	1.444	1.186
41	NIGERIA	(A,OPEC)	1.699	1.558	1.684	1.68
42	NORWAY	D	1.159	1.389	1.791	1.293
43	PAKISTAN	B*	1.099	1.106	1.12	1.122
44	PARAG	B*	1.547	1.446	1.585	1.487
45	PERU	C*	1.137	1.065	1.087	1.066
46	PHILIPP	B*	1.058	1.315	1.394	1.353
47	PORTUGAL	C*	1.652	1.31	1.49	1.295
48	SAUDI A	(C,OPEC)	2.719	1.721	N/A	1.667
49	S AFRICA	C*	1.309	1.104	1.141	1.099
50	SPAIN	D	1.756	1.347	1.547	1.309
51	SRI LANK	B*	.796	1.178	1.209	1.207
52	SWEDEN	E	.954	1.118	1.226	1.087
53	SWITZERL	E	1.009	1.028	1.042	1.021
54	TANZANIA	(A)	.901	1.136	1.148	1.167
55	THAILAND	B*	1.587	1.438	1.551	1.504
56	TURKEY	B*	1.771	1.412	1.583	1.43
57	UK	D	.942	1.189	1.332	1.152
58	USA	E	1.155	1.175	1.403	1.124
59	URUGUAY	C*	1.156	1.18	1.285	1.172
60	VENEZ	(C,OPEC)	.895	1.21	1.354	1.19
61	YUGOSLAV	(C)	1.79	1.506	N/A	1.482
62	ZAIRE	(A)	1.035	.852	.846	.82

* *

Annex Table A-7 (Cont.)

Subgroup**		RPC	RPCe1	RPCek1	RPCe2
Subgroup Means, Period 1/Period 0 Values Shown Above					
59 MEAN		1.285	1.254	N/A	1.249
48 MEAN		1.293	1.274	N/A	1.265
44 MEAN		1.288	1.287	N/A	1.272
43 MEAN		1.213	1.242	1.391	1.228
44A MEAN	4 (11)	.995	1.14	1.155	1.171
43B* MEAN	10 (16)	1.393	1.36	1.478	1.394
44C* MEAN	7 (13)	1.321	1.238	1.356	1.231
44D MEAN	12 (12)	1.204	1.31	1.57	1.252
44E MEAN	7 (7)	1.05	1.176	1.362	1.131
*44F MEAN	3 (0)	1.066	.88	.849	.876

=Countries with negative per capita GDP growth rates (Chile, Ghana, Jamaica) constitute group F and have their original groups, B and C. Group 43C also ex

**43-country subgroup followed by 59-country subgroup

a/ Notes: Model "e1" is based upon LGDP; "e2" upon LGDP, LGDPS significant); "e3" upon LGDP, LGDPSQ, LTMPI,& LPPRICE "e4" on "best" equations from Table 3.

The "ėk" models are the same except that "normative-o derived from Kravis-dollar estimates have replaced th

"N/A" means that either the petroleum price data or K unavailable and hence that energy consumption cannot

Annex Table A-8 ACTUAL AND ESTIMATED CHANGES IN RELEC, Ratio Period 1 to 0 of ELEC a/

		Group**	LRELEC	RELECe1	RELECek1	RELECe2	RELECek2	RELECe4	RELECek4
	Values for Period 1 Divided by Values for Period 0								
4	AFGAN	(A)	1.612	1.117	1.131	1.133	1.15	1.334	1.344
5	ALGERIA	(B,OPEC	1.928	1.294	1.408	1.279	1.375	1.355	1.424
6	ARGEN	C*	1.327	1.108	1.163	1.09	1.137	1.158	1.192
7	AUSTL	E	1.368	1.182	1.34	1.131	1.236	1.123	1.209
8	AUSTRIA	D	1.375	1.455	1.904	1.335	1.627	1.31	1.536
9	BANGLA	(A)	1.75	.944	.937	.936	.93	1.211	1.205
10	BELGLUX	D	1.416	1.372	1.727	1.264	1.494	1.261	1.444
11	BRAZIL	C*	1.849	1.91	2.376	1.805	2.24	1.875	2.133
12	BURMA	A	1.63	1.176	1.189	1.2	1.216	1.317	1.326
13	CANADA	E	1.372	1.379	1.849	1.253	1.537	1.235	1.468
14	CHILE	F* (C)	1.121	.943	.917	.951	.925	1.006	.989
15	COLOMBIA	B*	1.601	1.399	1.558	1.383	1.517	1.291	1.375
16	DENMARK	E	1.467	1.259	1.513	1.181	1.346	1.14	1.27
17	ECUADOR	(B,OPEC	1.869	1.776	2.089	1.752	2.061	1.52	1.673
18	EGYPT	(B)	1.563	1.446	1.56	1.45	1.572	1.398	1.462
19	ELSAL	B*	1.623	1.217	1.29	1.213	1.288	1.344	1.391
20	ETHIOPIA	A	1.121	1.044	1.048	1.051	1.055	.798	.799
21	FINLAND	D	1.498	1.334	1.599	1.245	1.428	1.218	1.355
22	FRANCE	D	1.441	1.372	1.759	1.261	1.506	1.197	1.387
23	GERM FR	E	1.364	1.273	1.563	1.193	1.377	1.178	1.329
24	GHANA	F* (B)	1.173	.76	.716	.757	.712	1.035	1
25	GREECE	D	1.871	1.534	1.934	1.426	1.732	1.591	1.824
26	INDIA	A	1.421	1.157	1.174	1.175	1.191	1.2	1.21
27	INDONESIA	(A,OPEC	1.95	1.68	1.775	1.781	1.88	2.588	2.673
28	IRAN	(C,OPEC	2.122	1.405	1.64	1.377	1.536	2.186	2.395
29	ISRAEL	D	1.338	1.271	1.463	1.206	1.351	1.186	1.288
30	ITALY	D	1.347	1.245	1.421	1.187	1.322	1.205	1.302
31	IVORYCST	(B)	1.652	1.076	1.107	1.074	1.106	1.143	1.163
32	JAMAICA	F* (C)	1.418	.883	.846	.894	.856	.829	.808
33	JAPAN	D	1.385	1.5	1.988	1.368	1.685	1.335	1.576
34	KENYA	A	1.374	1.289	1.326	1.308	1.362	1.474	1.499
35	KOREA R	B*	2.611	2.129	2.68	2.085	2.555	2.175	2.49
36	MADAG	(A)	1.253	.752	.724	.734	.705	.782	.765
37	MALAYSIA	(B)	1.754	1.666	1.951	1.619	1.878	1.615	1.772
38	MEXICO	C*	1.441	1.212	1.314	1.188	1.27	1.247	1.308
39	MOROCO	B*	1.503	1.34	1.379	1.337	1.375	1.333	1.355
40	NETHERL	D	1.388	1.282	1.539	1.205	1.375	1.292	1.44
41	NIGERIA	(A,OPEC	2.337	1.682	1.843	1.742	1.897	1.67	1.763
42	NORWAY	D	1.257	1.47	1.981	1.325	1.645	1.251	1.491
43	PAKISTAN	B*	1.216	1.125	1.142	1.132	1.152	.961	.969
44	PARAG	B*	1.717	1.542	1.717	1.532	1.701	1.685	1.796
45	PERU	C*	1.249	1.077	1.103	1.071	1.095	1.265	1.283
46	PHILIPP	B*	1.49	1.378	1.477	1.383	1.482	1.46	1.521
47	PORTUGAL	C*	1.564	1.373	1.597	1.322	1.515	1.387	1.516
48	SAUDI A	(C,OPEC	2.366	1.891	N/A	1.739	N/A	1.475	N/A
49	S AFRICA	C*	1.411	1.123	1.168	1.108	1.149	1.167	1.194
50	SPAIN	D	1.585	1.418	1.668	1.339	1.505	1.427	1.569
51	SRI LANK	B*	1.436	1.211	1.249	1.223	1.262	1.17	1.191
52	SWEDEN	E	1.347	1.14	1.27	1.097	1.183	1.071	1.142
53	SWITZERL	E	1.219	1.032	1.049	1.023	1.035	.971	.98
54	TANZANIA	(A)	1.124	1.161	1.176	1.179	1.198	2.042	2.057
55	THAILAND	B*	2.237	1.532	1.673	1.549	1.681	1.634	1.721
56	TURKEY	B*	1.967	1.499	1.714	1.469	1.658	1.574	1.703
57	UK	D	1.125	1.225	1.4	1.168	1.294	1.15	1.244
58	USA	E	1.277	1.208	1.488	1.138	1.307	1.121	1.268
59	URUGUAY	C*	1.232	1.214	1.342	1.187	1.282	1.198	1.271
60	VENEZ	(C,OPEC	1.466	1.251	1.427	1.207	1.33	1.232	1.332
61	YUGOSLAV	(C)	1.678	1.617	N/A	1.53	N/A	1.58	N/A
62	ZAIRE	(A)	1.077	.829	.822	.81	.796	.885	.881

* *

Annex Table A-8 (Cont.)

Subgroup**		LRELEC	RELECe1	RELECek1	RELECe2	RELECek2	RELECe4	RELECek4
Subgroup Means, Period 1/Period 0 Values Shown Above								
59 MEAN		1.537	1.308	N/A	1.273	1.339	1.337	N/A
48 MEAN		1.524	1.333	N/A	1.29	1.361	1.337	N/A
44 MEAN		1.528	1.344	N/A	1.296	1.365	1.316	N/A
43 MEAN		1.469	1.293	1.48	1.25	1.387	1.275	1.376
44A MEAN	4 (11)	1.387	1.167	1.184	1.184	1.206	1.197	1.209
43B* MEAN	10 (16)	1.74	1.437	1.588	1.431	1.567	1.463	1.551
44C* MEAN	7 (13)	1.439	1.288	1.438	1.253	1.384	1.328	1.414
44D MEAN	12 (12)	1.419	1.373	1.699	1.277	1.497	1.285	1.455
44E MEAN	7 (7)	1.345	1.21	1.439	1.145	1.289	1.12	1.238
*44F MEAN	3 (0)	1.237	.862	.826	.867	.831	.957	.932

=Countries with negative per capita GDP growth rates from per. 0 to per. 1 (Chile, Ghana, Jamaica) constitute group F and have been excluded from their original groups, B and C. Group 43C also excludes Yugoslavia.

**43-country subgroup followed by 59-country subgroup, if different, in parentheses.

a/ Notes: Model "e1" is based upon LGDP; "e2" upon LGDP, LGDPSQ, and LTMPI (where latter two a significant); "e3" upon LGDP, LGDPSQ, LTMPI, & LPPRICE (where sigificant); and "e4" on "best" equations from Table 3.

The "ek" models are the same except that "normative-over-time" values of LGDP, derived from Kravis-dollar estimates have replaced the original LGDPs.

"N/A" means that either the petroleum price data or Kravis-dollar GDP estimates are unavailable and hence that energy consumption cannot be estimated.

ANNEX B

Estimating Per Capita Energy Use: A Numerical Illustration for Mexico

This annex deals with the practical problem of applying cross-country energy equations to a particular country in a particular year. The country chosen for illustrative purposes, partly because of the time series analysis performed in Section IV of the paper, is Mexico. A series of equations developed for the cross-country sample of countries will be applied to Mexico for the base period 1969-1971 and for a single projected year, 1980. Mexico, of course, with the 1970's boom in oil prices and in domestic production of oil and gas represents an especially challenging case for analysis. This annex should also provide a useful reminder, therefore, of the limitations of cross-country equations for "projecting" actual energy use in a given country-specific situation.

For this illustrative example, estimates will be made for all estimating equations previously reported in either Table 3 or Annex Table 3 and for which all coefficients were statistically significant. Shown in Annex Table B-1, these equations can be broadly divided into those which rely upon per capita GDP as the sole non-price measure of economic structure (equations 1-10) and those which employ a number of other non-price structural measures associated with the production of energy-intensive materials (equations 11-18). Energy prices, it will be recalled, can be fully taken into account only in the case of petroleum consumption although the same measure of petroleum product prices may also provide limited explanatory power in the case of total commercial energy use.

On *a priori* grounds there is little reason to favor one set of equations over another. The more fully specified equations presumably do a better job of taking into account industrial structure differences among countries. These "structural" factors, however, probably reflect basic, longer-run differences among countries, and year-to-year variations in actual energy use may have little to do with short term variations in these same structural factors. Similarly, given the choice, an economist will usually be most comfortable with a demand equation involving commodity price. But the long-run price elasticities from cross-country equations may bear little relationship to the shorter-run price responsivness of individual countries, and in the case of electricity consumption, for example, factors such as generating plant capacity may completely outweigh whatever short-run price responsivness may exist.

Annex Table B-2 presents the complete detail used for estimating all dependent and independent variables (with the exception of "TMPI", for which see below) for the year 1980. Note that the sources used in the annex (and listed in the separate list of references at the end of the annex) generally date from 1983 or even early 1984 and thus in most cases do not give results identical with those used for the original statistical work. The question of how to handle constantly revised and updated source materials is common to most work of this kind. The author's preference is to use the most recent and reliable information available, to employ it to replicate base-year results obtained from earlier data series, and then to make whatever adjustments are necessary - generally to the intercept terms of the original estimating equations - for bringing the new set of estimates in line with the current numerical version of reality.

In Annex Tables B-3a and B-3b (to be discussed in greater detail below), for example, where actual estimates are shown for energy consumption in Mexico, the new data have been used to make consumption estimates for the base period 1969-1971 (bottom section of tables). Base period adjustment factors for each equation are then calculated as the ratio of actual energy use (according to the new data series for the dependent variables) to that estimated from the equation in question. When employing the same equation for the year 1980, the 1969-1971 adjustment factor can be applied to the preliminary 1980 estimate to give an adjusted estimate for the latter year. (This accounts for the difference between the "adjusted" and "unadjusted" figures shown in the middle portions of Tables B-3a and B-3b.)

The 1969-1971 adjustment factor is assumed to pick up structural differences between the country in question and the worldwide cross-country norm. The application of this base year adjustment factor to a later year implies the assumption of no subsequent change in these base period differences.

Returning to Annex Table B-2 and the problem of estimating values of the several variables, the following deserve a special note:

Primary electricity consumption, lines 2,3. The United Nations has traditionally included primary energy consumption at its caloric equivalent while this study includes this electricity at its rough primary fuel equivalent under average thermal plant production efficiencies. This latter adjustment, assuming a 30% conversion efficiency, is achieved by multiplying the UN figure by (1/.3 - 1).

Fuelwood and other bio-mass fuels, lines 7-11. The United Nations is now beginning to publish estimates of fuelwood, charcoal, and bagasse (United

Nations, 1983a, 288), and these may be used in place of the fuelwood estimates shown in Annex Table B-2. The latter were derived by applying the author's estimates of .26 and .31 MT Coal Equivalent (MTCE), respectively, to FAO estimates of conifer and non-conifer consumption (equals production + imports - exports). This procedure gives a 1980 Mexico estimate of 1,481,000 MTCE compared with 1,951,000 for 1980 shown in the UN source. Inclusion of bagasse, according to United Nations (1983a) data, would bring the total to 4,337,000 MTCE. This would increase the ENB total shown in Table B-2 by about 0.47 BOE/D/1000 person (barrels of oil equivalent per day per 1000 persons) - in this case a relatively unimportant addition to the total.

Kravis-dollar estimates of per capita GDP, lines 25-27. These estimates are supposed to be extrapolations from base year data prepared by Kravis and Associates. 1960-1980 estimates of "RGDP" furnished to the World Bank by Kravis in 1982 (see Kravis and others, 1982, p. 329, and note on copyright page concerning computer tapes) may in fact represent "GDY" or gross domestic income. After 1977 or thereabouts, the Kravis time series data for Mexico and many other countries diverge sharply from the most recent constant price national accounts data prepared by the World Bank (1983). For the present exercise, the official Kravis data have therefore not been used. Instead, an estimate of a Kravis-type base period figure was found by applying equation 4a (text, p. 47) to 1969-71 per capita GDP in 1969-71 US dollars. The resulting figure of US$1984.3 per capita in 1975 Kravis prices, shown in Tables B-2 and B-4, line 25, compares with K$2174.87 obtained from the original Kravis source. This 1969-71 base figure is then extrapolated forward to 1980 using the most recent estimate of constant price GDP (World Bank, 1983). The result of K$2845.56 shown in Table B-2, line 25, compares with

K$3255.8 given in the 1982 Kravis source. Until more is learned about the specific method used by Kravis and his associates for projecting the constant purchasing power estimates and about the affect of recent data revisions on these estimates, the method described here is probably to be preferred.

Nominal-over-time estimate of per capita GDP, line 28. When cross country equations are applied to time series projections, a GDP per capita measure must be used which is conceptually similar to the nominal-over-countries measure used for the original regressions. As explained in the text, such an analogous "nominal-over-time" measure can be derived by solving for the nominal GDP estimate that is implied by the Kravis-dollar per capita GDP estimate for the year in question. This is what has been done in line 28 of Table B-2. The result, $1148.49 per capita, is supposed to represent Mexican per capita GDP after allowing for structural price adjustments expected to occur (for the average country as estimated using cross-country statistical analysis) as a country moves from a Kravis-dollar GDP level of K$1984.3 (Mexico in 1969-71) to 2845.56 per capita (Mexico in 1980, as shown in line 25).

Petroleum product prices, lines 30-36. These prices, largely from the United States Department of Energy (DOE in the table), are now beginning to appear in the UN's Yearbook of World Energy Statistics. (See, for example, United Nations, 1983a, p. 776, for the 1980 Mexican data.) It should be recalled, however, that the data generally represent only the capital city at one point in time (July of the year shown). The prices in the UN source are in US$ per US gallon except for Bunker "C" fuel oil where the price is given in US$ per petroleum barrel, and therefore for comparability the latter must be divided by 42 gallon/barrel. Note that in the case of Mexico, deflation by the "resource" (equals GDP - exports + imports) price deflator rather than by the implicit GDP price deflator gives a 1980 weighted petroleum price higher by about four percent. Note, too, the generally low petroleum prices reported for Mexico City: a little under 14 US cents/gallon in 1970 compared with a 48-country average of 19.7 (Annex Table 2), and 8.9 cents/gallon in 1980 compared with a sample average of 25.5.

Winter temperature index, TMPI. The long-term winter temperature index for Mexico is estimated as close to 1.0 which means that winter temperatures are presumed to have no effect on domestic commercial energy consumption. This situation will hold for most of the so-called developing countries, although as incomes rise it can be expected that summer temperatures, the obverse of winter temperatures in most cases, will become increasingly important as a determinant of electricity consumption for cooling. If it should be desired to calculate a winter temperature index for a country, the Mexican procedure can be followed as shown below:

		Province	Temperatures, 3 Coldest Months					
		Population	Maximums, F			Minimums, F		
City	Province	('000)	1	2	3	1	2	3
Guaymas	Sonora	1092	74	73	79	56	55	57
Las Pas	Baja Cal. Sur	124	74	72	74	59	57	56
Manzanillo	Colima	240	86	85	86	68	67	66
Mazatlan	Sinaloa	1273	71	71	73	61	62	63
Merida	Yucatan	774	82	83	85	64	62	63
Mexico City	Fed. Dist.	10804	66	66	69	43	42	43
Monterrey	Nuevo Leon	1654	65	68	72	50	48	52
Salina Cruz	Oaxaca	2012	85	85	85	72	72	72
Veracruz	Veracruz	3813	78	77	78	67	66	67

Source: Conway and Liston (1974); Websters' New Geographical Dictionary (1972).

Averaging the six monthly temperatures shown for each city gives the "average winter temperature" for that city in degrees Fahrenheit. Weighting these by the province populations shown gives, for Mexico, 62.5 degrees F. Since this exceeds 60F, TMPI is set automatically to 1.0. If the weighted average, say, turned out to be 54.8 degrees F (equal to that for Mexico City, then TMPI would equal 54.8/60 = 0.91.

The estimated variable values from Table B-2 (along with a similar set for 1970 and 1969-1971 from Table B-4) are summarized in Table B-3a. The independent variables are used in conjunction with the equations of Table B-1 to provide the unadjusted energy consumption estimates for 1980 and 1970 shown in the lower section of Table B-3a. The "adjusted" figures for 1980, as already explained above, equal the unadjusted estimates times the adjustment factor needed in 1970 to bring the estimates from the same equations in line with actual 1970 consumption.

It is difficult to generalize about the accuracy of the equations when applied to 1970. For commercial fuels plus fuelwood (ENB) and for petroleum (PC) when price is not included, the equations give per capita energy use estimates rather close to those observed. (This would have been equally true if the comparison had been made with the mean fuel quantities for 1969-71 rather than for 1970 alone as shown in the table.) For commercial energy without fuelwood (ENA), the results are not as good, especially when equations 2 and 12 from period 1 (1976-78) are employed. The inclusion of petroleum product prices in one ENA equation improves the base year fit slightly (equation 3), but the opposite is the case when the dependent variable is petroleum alone (equation 8). In this latter case the inclusion of Mexico's rather low petroleum product price (representing Mexico City only, in mid-1970) would suggest consumption considerably greater than that actually observed. (See equations 8, 15, and 16.) Mexico in 1970, judging from international norms, consumed petroleum products in amounts more consistent with a mean price of perhaps 20 rather than 13.8 US cents/gallon.

The electricity equations, where price has not been included, uniformly predict a higher per capita level of electricity consumption, by from 14 to 33 percent, than was actually observed in 1970.

Mexico in 1970, in other words, did not seem as responsive to its (apparent) low petroleum price as would have been suggested from comparisons with other countries. Electricity use was also significantly below cross-country norms, perhaps reflecting inadequate levels of generating capacity for a country of Mexico's level of per capita GDP and related structural characteristics.

For 1980, as shown in the middle section of Table B-3a, the cross-country equations almost uniformly suggest higher per capital consumption levels than were in fact recorded. The ENB equations once again perform moderately well. Initial errors for ENA are reduced by application of the 1970 adjustment factors - except in the case (eq. 3) where petroleum prices are employed. This same petroleum price measurement also leads to substantial overestimates of the 1980 demand for petroleum products (equations 8, 15, and 16) even with the 1970 adjustment factor. Electricity consumption in 1980 continues to be overstated by the cross-country equations.

Mexico during the 1970-1980 period experienced rapid rates of income growth, especially for that income which derived from petroleum production and petroleum price increases. Private and public consumption did not increase as rapidly as did GDP, and much of the increased demand for investment goods (and presumably also for consumer goods) was met through high rates of imports rather than through domestic production. Indirect imports of energy associated with non-energy goods and services in 1967 may have amounted to 1.78 BOE/D/1000 persons. (Strout, 1984.) By extrapolation, the 1970 average may have been in the order of 2.0, and these "imputed" energy imports may have reached 4.2 BOE/D/1000 by 1980. Adding these net increases in indirect energy imports to the direct total shown in Table B-3a would have produced a closer correspondence with the cross-country estimates.

Interestingly in the case of Mexico (and possibly for other countries) the fit of the estimating equations for 1980 is substantially improved by assuming no response to the apparent petroleum product price changes between 1970 and 1980. Table B-3b is identical to B-3a, except that the petroleum price for all 1980 equations has been assumed to remain at 13.817 US cents/gallon. In Table B-3a, the equations which included petroleum product price as an independent variable (numbers 3, 8, 11, 12, 15, and 16) gave uniformly poorer results for 1980 than did equations without this price variable. Table B-3b shows that when petroleum product prices are assumed to have remained constant, the same price-dependent equations produce almost uniformly better estimates. Petroleum prices, in other words, seem to reflect longer run structural differences among countries, and these differences do not appear to change much in the short or even medium term. In other experiments, in fact, a three-year price average lagged by as many as five or ten years tend to give about as good results as do petroleum product prices for the current year.

In conclusion, while the rapid growth in petroleum exports during the 1970's led to GDP figures which overstate the growth in energy-using domestic production and consumption, 1980 energy consumption nevertheless seemed somewhat low by international standards, especially with respect to electricity consumption and especially given the apparent domestic decline in real petroleum product prices. When it is assumed that the 1970-1980 changes in these prices had no effect on Mexican consumption and that other, residual base year peculiarities of Mexico did not change between 1970 and 1980, the cross country equations suggest that Mexico's use of total energy (including fuelwood), petroleum products, and electricity were within a few percentage points of the international norm. Commercial energy use when fuelwood is excluded, on the other hand, remained below the international norm by about nine percent. In all cases, estimated consumption would have more closely matched actual use if it had been possible to include the increased, indirect per capita consumption of energy embodied in rapidly expanding imports of non-energy commodities.

Annex B References

Conway, H. Mckinley, and Linda L. Liston, eds. 1974. The Weather Handbook, revised ed. (Atlanta, Conway Research, Inc.).

Food and Agricultural Organization of the United Nations (FAO). 1983. Yearbook of Forest Products (Rome, FAO).

Kravis, Irving B., Alan Heston, and Robert Summers. 1982. World Product and Income: International Comparisons of Real Gross Product (Baltimore, Johns Hopkins University Press for the World Bank).

Metallgesellschaft AG. 1981. Metal Statistics, 1970-1980 (Frankfurt AM Main, Metallgesellschaft Aktiengesellschaft).

Strout, Alan M. 1976. "Energy and the Less Developed Countries: Needs for Additional Research," in Ronald G. Ridker, ed., Changing Resource Problems of the Fourth World, RFF Working Paper PD-1 (Washington, Resources for the Future, distributed by the Johns Hopkins University Press).

____________. 1984. "The Hidden World Trade in Energy," research report to the World Bank, unpublished draft dated Feb. 11.

United Nations. 1983a. 1981 Yearbook of World Energy Statistics (New York, UN).

____________. 1983b. Statistical Yearbook, 1981 (New York, UN).

United States Department of Energy (DOE), Energy Information Administration. 1981. 1980 International Energy Annual (Washington, U.S. Department of Energy).

Webster's New Geographical Dictionary. 1972. (Springfield, Massachusetts, G. and C. Merriam Co.).

World Bank, 1983. World Tables, third edition, volume I (Baltimore, Johns Hopkins University Press for the World Bank).

Annex Table B-1

Summary of Equations for Estimating Cross-Country Average Energy Consumption

Eq. No.	Dependent Variable	Time Per.	SEE	Inter- cept	LGDPek	LGDPekSQ	LPPRICE	LREFPR	LSCR	LEIMPR	LTMPI	Ref. Table/Eq.
	I. NO STRUCTURAL VARIABLES EXCEPT FOR GDP AND TMPI											
1	LENA	0	.365	-7.865	2.08	-.073					-.583	AT3/3
2	LENA	1	.359	-8.874	2.309	-.088					-.631	AT3/4
3	LENA	0	.313	-3.759	1.133		-.372				-.41	AT3/5
4	LENB	0	.343	-3.511	.948						-.537	AT3/7
5	LENB	1	.306	-3.555	.965						-.394	AT3/8
6	LPC	0	.354	-8.375	2.107	-.073						AT3/11
7	LPC	1	.338	-11.108	2.856	-.126						AT3/12
8	LPC	1	.234	-7.915	2.582	-.111	-.579					AT3/14
9	LELEC	0	.499	-2.576	1.385							AT3/15
10	LELEC	1	.470	-1.998	1.321							AT3/16
	II. STRUCTURAL VARIABLES REPRESENTING SOLID FUEL USE AND ENERGY-INTENSIVE MATERIALS PRODUCTION											
11	LENA	0	.225	-2.579	1.088		-.237	.195	.066	.111		T3/1
12	LENA	1	.239	-2.639	1.084		-.197	.191	.045	.126		T3/2
13	LENB	0	.231	-2.89	.916			.215	.043		-.486	T3/5
14	LENB	1	.232	-3.134	.941			.208	.025		-.393	T3/6
15	LPC	0	.139	-3.246	1.111		-.552	.4				T3/9
16	LPC	1	.211	-3.163	1.083		-.435	.468				T3/10
									LEIMPSR	LEIMPNSR		
17	LELEC	0	.382	1.15	1.176				.057	.302		T3/13
18	LELEC	1	.332	1.64	1.165				.041	.365		T3/14

Notes: For definitions of variables, see Annex A.

SEE = standard error of estimate. A lower number means a smaller base year error.

Annex Table B-2

Calculation of Variables for Use With Cross-Country Estimating Equations, Energy Use in Mexico, 1980

Line	Variable	Estimated Value	Units	Equals:	Line-by-line Description	Source/page no.
I.	DEPENDENT VARIABLES					
1	ENA	24.255	BOE/D/	(117123000 MTCE	Primary energy consumption, UN def.	UN(1983a),19
2			1000	+(2257000 MTCE	Primary electricity consumption, UN def.	UN(1983a),19
3			persons	*((1/.30)-1)))	Thermal fuel equivalent of primary electricity cons. at 30% efficiency	Working assumption
4				*13.75246	Conversion factor, MTCE/yr to BOE/day	Annex A, note 9
5				/69393000	Mid-year population	World Bank (1983),123
6	ENB	24.549	Same	24.255	Adjusted primary energy use/person (ENA)	(line 1, above)
7				+((2728	Conifer fuelwood prod'n, '000 Cubic M	FAO(1983),84
8				*.26)	Est'd MTCE per cubic meter, conifers	Author's estimate
9				+ ((0 - 1	Fuelwood imports - fuelwood exports	FAO(1983),87,89
10				+ 2491)	Nonconifer fuelwood prod'n, '000 CuM	FAO(1983),85
11				*.31))*13.75246	Est'd MTCE/CuM of nonconifers x conversion	Author's estimate
12				/69393	factor, divided by '80 pop. in thous.	World Bank (1983),123
13	PC	16.307	Same	82282000 MTCE	Primary liquid fuel consumption	UN(1983a),19
14				*13.75246	Conversion factor, MTCE/yr to BOE/day	Annex A, note 9
15				/69393000	Mid-year population	
16	ELEC	972.43	Kwatt-hrs	67480	Elec. consumption, mil. kilowatt-hr.	UN(1983),717
17			/person	/69.393	Mid-yr population, millions	World Bank (1983),123
II.	INDEPENDENT VARIABLES					
18	GDP	978.3	US$/per-	841854.5	1980 total GDP, const. mkt prices	World Bank (1983),123
19			son, in	/((391745+444271.4	1969+1970 GDP, const. mkt prices	World Bank
20			1969/71	462803.8	1971 total GDP, const. mkt prices	World Bank (1983),122
21			prices	*((374900/12.5)	'69 GDP in cur. prices/'69 exch rate	World Bank
22				+(444271.4/12.5)	'70 GDP in cur. prices/'70 exch rate	World Bank (1983),122
23				+(490011.0/12.5))	'71 GDP in cur. prices/'71 exch rate (where GDPs in mil. units dom. currency)	World Bank (1983),122
24				/3/69.393	no. yrs/1980 population in millions	World Bank (1983),123
25	KGDPest	2845.56	same, in	1984.30	Est'd Kravis-$ per cap. GDP, mean '69/71 in 1975 US dollars	Annex Table B-4, line 25
26			1975 US$	*841854.5/432940	Ratio,'80-to-mean-'69/71 GDP, const. prices	(lines 18-20, above)
27				/(69.393/51.176)	Ratio,'80-to-'70 population, in millions	World Bank (1983), 122,123
28	GDPek	1148.49	same, in 1969/71 US$	EXP((-1.3503 +SQRT((1.3503^2) -4*(-.0485)*(.847 -LN(KGDPest))))/ /(2*(-.0485)))	Equation for estimating nominal-over-time per capita GDP, in '69/'71 US$, from Kravis-dollar per capita GDP (=KGDPest), in '75 US$	Eq. 4a, text, p.47; KGDPest=2845.56 (from line 25, above)
29	LGDPekSQ	49.64898	---	ln(1319.66) *ln(1319.66)	ln GDPek, squared	(line 28, above)

Annex Table B-2

Calculation of Variables for Use With Cross-Country Estimating Equations, Energy Use in Mexico, 1980, Continued

Line	Variable	Est.Value	Units	Equals:	Line-by-line Description	Source/page no.
II.	INDEPENDENT VARIABLES					
30	PPRICE	8.919	US cents	((13.734*1.351	Cons. gasolines, mil. MT, x CuM/MT (gaso.)	UN(1983a),391,412,xxiv
31			/gallon,	*(66+46)/2)	mean 1980 price regular+premium gasoline	DOE(1981),48
32			in 1970	+(3.600	cons. kerosene + jet fuel, mil. MT,	UN(1983a),437,459
33			prices	*1.235	Cubic Meters/MT (kerosene)	UN(1983a),xxiv
34				*9)	1980 kerosene price, US cents/US gal.	DOE(1981),48
35				+(27.774*1.099	cons. fuel oils, mil MT, x CuM/MT (F.O.))	UN(1983a),480,503,xxiv
36				*(277+242)/2/42))	'80 med+hvy fuel oil, US cts/bbl/42 gal/b	DOE(1981),48
37				/(13.734*1.351	cons. gasolenes, mil. cubic meters	(line 30, above)
38				+3.600*1.235	cons. kero.+jet fuel, mil. cubic meters	(line 32, above)
39				+27.774*1.099)	cons. fuel oils, mil. cubic meters	(line 35, above)
40				*((885434.2/12.5)	1980 "resource" use, constant US dollars	World Bank (1983),123
41				/(4317088.0/22.951)	1980 "resource" use, current US dollars	World Bank (1983),123
42				*(452721.0/12.5))	1970 "resource" use, current US dollars	World Bank (1983),122
43				/(452721.0/12.5)))	1970 "resource" use, constant US dollars	World Bank (1983),122
44	REFPR	.70167	kg/US$,	55921000 MTon	Tot. petrol. refinery output, all products	UN(1983a),573
45			'69/71	/1148.49	1980 per capita GDP, 1969/1971 US $	(line 28, above)
46			prices	/(69.393*1000)	1980 mid-year population, in thousands	World Bank (1983),123
47	SCR	.00099	BOE/day	5747000 MTCE	Consumption solid fuels	UN(1983a),19
48			/1000	*13.75246	Conversion factor	Annex A, note 9
49			US$	/69393000	1980 mid-year population	World Bank (1983),123
50				/1148.49	Per capita GDP, 1969/1971 US dollars	(line 28, above)
51	EIMPSR	.00226	same	7003000 MT	1980 crude steel production	UN(1983a),692
52				*1.87*13.75246	Energy equiv. in MTCE/MT; conv. factor	Strout(1976); Annex A
53				/1148.49	1980 per capita GDP, 1969/1971 US $	(line 28, above)
54				/69393000	1980 mid-year population	World Bank (1983),123
55	EIMPNSR	.0015	same	((447000 MT	1980 wood pulp production	FAO(1983),261
56				*.99)	Energy equivalent in MTCE/MT	Strout(1976)
57				+(1979000 MT	1980 paper & paperboard produced	FAO(1983),306
58				+.40)+(	Energy equivalent in MTCE/MT	Strout(1976)
59				(753200+195600 MT)	1980 chem fertilizers prod., NPK equiv.	UN(1983b),679,681
60				*.77)	Energy equivalent in MTCE/MT	Strout(1976)
61				+(16398000 MT	1980 hydraulic cement production	UN(1983b),690
62				*.32)	Energy equivalent in MTCE/MT	Strout(1976)
63				+(102400 MT	1980 refined copper production	Metal Stat.(1981),32
64				*4.47)	Energy equivalent in MTCE/MT	Strout(1976)
65				+(184700 MT	1980 refined lead production	Metal Stat.(1981),25
66				*1.1)	Energy equivalent in MTCE/MT	Strout(1976)
67				+(145400 MT	1980 smelter zinc production	Metal Stat.(1981),39
68				*3.0)	Energy equivalent in MTCE/MT	Strout(1976)
69				+(42600 MT	1980 primary aluminum production	Metal Stat.(1981),14
70				*8.97)	Energy equivalent in MTCE/MT	Strout(1976)
71				+(400 MT	1980 primary tin production	Metal Stat.(1981),44
72				*1.42)	Energy equivalent in MTCE/MT	Author's estimate
73				*13.75246	Conv. factor, MTCE to BOE/day/1000 pers.	Annex A, note 9
74				/69393000	1980 mid-year population	World Bank (1983),123
75				/1148.49	1980 per capita GDP in 1969/1971 US$	(line 28, above)
76	EIMPR	.00376	same	EIMPSR+EIMPNSR		(lines 51+55, above)

Annex Table B-3a

Alternative Estimates of Energy Use, Mexico, 1970 and 1980, Assuming Observed Change In Petroleum Prices (i.e. 1980 PPRICE < 1970 PPRICE)

I. Assumed Values of Independent Variables (source: Annex Table B-2 for 1980, B-4 for 1970)

	1970	1980		1970	1980
GDPek	682.2	1148.5	SCR	.00101	.00099
LGDPekSQ	42.57984	49.6491	EIMPR	.00448	.00376
PPRICE	13.817	8.919	EIMPSR	.00274	.00226
REFPR	.68999	.70166	EIMPNSR	.00174	.0015
			TMPI	1	1

II. Estimated Values of Dependent Variables, 1980 and 1970

Based Upon Equation				Independent Variables: LGDPek, LGDPekSQ, LPPRICE, LTMPI			Independent Variables: LGDPek, LPPRICE, LTMPI LREFPR, LSCR, LEIMPR, LEIMPSR, LEIMPNSR			"Actual" Value of Dependent Variable (from Annex Tables B-2 or B-4)
Number (Table B-1)	From Period	Dependent Variable	Year	Unad-justed	Ad-justed*	Actual/ Adj.	Unad-justed	Ad-justed*	Actual/ Adj.	
1,11	0	ENA	1980	23.73	27.24	.89	27.65	29.69	.817	24,255
2,12	1	ENA	1980	20.63	27.60	.879	29.94	29.05	.835	
3	0	ENA	1980	30.28	32.79	.74				
4,13	0	ENB	1980	23.78	25.85	.95	24.31	25.50	.963	24.549
5,14	1	ENB	1980	25.65	26.06	.942	25.79	25.84	.95	
6,15	0	PC	1980	17.24	16.53	.987	25.35	21.14	.771	16.307
7,16	1	PC	1980	15.80	16.80	.971	28.51	19.82	.823	
8	1	PC	1980	33.13	20.87	.781				
9,17	0	ELEC	1980	1316.86	1160.15	.838	1243.13	984.56	.988	972.43
10,18	1	ELEC	1980	1495.25	1121.43	.867	1374.32	971.64	1.001	
					Actual/Estimated			Actual/Estimated		
1,11	0	ENA	1970	13.45		1.148	15.96		.968	15.446
2,12	1	ENA	1970	11.54		1.338	17.36		.89	
3	0	ENA	1970	14.26		1.083				
4,13	0	ENB	1970	14.51		1.087	15.04		1.049	15.774
5,14	1	ENB	1970	15.52		1.016	15.75		1.002	
6,15	0	PC	1970	9.64		.959	11.09		.834	9.244
7,16	1	PC	1970	8.70		1.063	13.30		.695	
8	1	PC	1970	14.68		.63				
9,17	0	ELEC	1970	640.07		.881	712.39		.792	563.88
10,18	1	ELEC	1970	751.41		.75	797.07		.707	

*Ajusted = undajusted x "actual/estimated" ratio from 1970.

Annex Table B-3b

Alternative Estimates of Energy Use, Mexico, 1970 and 1980, Assuming No Change In Petroleum Prices (i.e. 1980 PPRICE = 1970 PPRICE)

I. Assumed Values of Independent Variables (source: Annex Table B-2 for 1980, B-4 for 1970)

	1970	1980		1970	1980
GDPek	682.2	1148.5	SCR	.00101	.00099
LGDPekSQ	42.57984	49.6491	EIMPR	.00448	.00376
PPRICE	13.817	8.919	EIMPSR	.00274	.00226
REFPR	.68999	.70166	EIMPNSR	.00174	.0015
			TMPI	1	1

II. Estimated Values of Dependent Variables, 1980 and 1970

Based Upon Equation: Number (Table B-1)	Based Upon Equation: From Period	Dependent Variable	Year	Independent Variables: LGDPek, LGDPekSQ, LPPRICE, LTMPI — Unadjusted	Adjusted*	Actual/Adj.	Independent Variables: LGDPek, LPPRICE, LTMPI LREFPR, LSCR, LEIMPR, LEIMPSR, LEIMPNSR — Unadjusted	Adjusted*	Actual/Adj.	"Actual" Value of Dependent Variable (from Annex Tables B-2 or B-4)
1,11	0	ENA	1980	23.73	27.24	.89	27.65	26.76	.906	24.255
2,12	1	ENA	1980	20.63	27.60	.879	29.94	26.65	.91	
3	0	ENA	1980	25.73	27.86	.871				
4,13	0	ENB	1980	23.78	25.85	.95	24.31	25.50	.963	24.549
5,14	1	ENB	1980	25.65	26.06	.942	25.79	25.84	.95	
6,15	0	PC	1980	17.24	16.53	.987	19.91	16.60	.982	16.307
7,16	1	PC	1980	15.8	16.80	.971	23.57	16.38	.996	
8	1	PC	1980	25.71	16.20	1.007				
9,17	0	ELEC	1980	1316.86	1160.15	.838	1243.13	984.56	.988	972.43
10,18	1	ELEC	1980	1495.25	1121.43	.867	1374.32	971.64	1.001	
						Actual/Estimated			Actual/Estimated	
1,11	0	ENA	1970	13.45		1.148	15.96		.968	15.446
2,12	1	ENA	1970	11.54		1.338	17.36		.89	
3	0	ENA	1970	14.26		1.083				
4,13	0	ENB	1970	14.51		1.087	15.04		1.049	15.774
5,14	1	ENB	1970	15.52		1.016	15.75		1.002	
6,15	0	PC	1970	9.64		.959	11.09		.834	9.244
7,16	1	PC	1970	8.70		1.063	13.30		.695	
8	1	PC	1970	14.68		.63				
9,17	0	ELEC	1970	640.07		.881	712.39		.792	563.88
10,18	1	ELEC	1970	751.41		.75	797.07		.707	

*Ajusted = undajusted x "actual/estimated" ratio from 1970.

Annex Table B-3b

Alternative Estimates of Energy Use, Mexico, 1970 and 1980, Assuming No Change In Petroleum Prices (i.e. 1980 PPRICE = 1970 PPRICE)

I. Assumed Values of Independent Variables (source: Annex Table B-2 for 1980, B-4 for 1970)

	1970	1980		1970	1980
GDPek	682.2	1148.5	SCR	.00101	.00099
LGDPekSQ	42.57984	49.6491	EIMPR	.00448	.00376
PPRICE	13.817	8.919	EIMPSR	.00274	.00226
REFPR	.68999	.70166	EIMPNSR	.00174	.0015
			TMPI	1	1

II. Estimated Values of Dependent Variables, 1980 and 1970

Based Upon Equation: Number (Table B-1)	Based Upon Equation: From Period	Dependent Variable	Year	Independent Variables: LGDPek, LGDPekSQ, LPPRICE, LTMPI: Unadjusted	Adjusted*	Actual/Adj.	Independent Variables: LGDPek, LPPRICE, LTMPI LREFPR, LSCR, LEIMPR, LEIMPSR, LEIMPNSR: Unadjusted	Adjusted*	Actual/Adj.	"Actual" Value of Dependent Variable (from Annex Tables B-2 or B-4)
1,11	0	ENA	1980	23.73	27.24	.89	27.65	26.76	.906	24.255
2,12	1	ENA	1980	20.63	27.60	.879	29.94	26.65	.91	
3	0	ENA	1980	25.73	27.86	.871				
4,13	0	ENB	1980	23.78	25.85	.95	24.31	25.50	.963	24.549
5,14	1	ENB	1980	25.65	26.06	.942	25.79	25.84	.95	
6,15	0	PC	1980	17.24	16.53	.987	19.91	16.60	.982	16.307
7,16	1	PC	1980	15.8	16.80	.971	23.57	16.38	.996	
8	1	PC	1980	25.71	16.20	1.007				
9,17	0	ELEC	1980	1316.86	1160.15	.838	1243.13	984.56	.988	972.43
10,18	1	ELEC	1980	1495.25	1121.43	.867	1374.32	971.64	1.001	
						Actual/Estimated			Actual/Estimated	
1,11	0	ENA	1970	13.45		1.148	15.96		.968	15.446
2,12	1	ENA	1970	11.54		1.338	17.36		.89	
3	0	ENA	1970	14.26		1.083				
4,13	0	ENB	1970	14.51		1.087	15.04		1.049	15.774
5,14	1	ENB	1970	15.52		1.016	15.75		1.002	
6,15	0	PC	1970	9.64		.959	11.09		.834	9.244
7,16	1	PC	1970	8.70		1.063	13.30		.695	
8	1	PC	1970	14.68		.63				
9,17	0	ELEC	1970	640.07		.881	712.39		.792	563.88
10,18	1	ELEC	1970	751.41		.75	797.07		.707	

*Ajusted = undajusted x "actual/estimated" ratio from 1970.

Annex Table B-4

Calculation of Variables for Use With Cross-Country Estimating Equations,
Energy Use in Mexico, 1969-1971 (3-yr means)

Line	Variable	Estimated Value	Units	Equals:	Line-by-line Description	Source/page no.
I.	DEPENDENT VARIABLES (1970)					
1	ENA	15.446	BOE/D/	(53130000 MTCE	Primary energy consumption, UN def.	UN(1983a),19
2			1000	+(1864000 MTCE	Primary electricity consumption, UN def.	UN(1983a),19
3			persons	*((1/.30)-1)))	Thermal fuel equivalent of primary	Working
					electricity cons. at 30% efficiency	assumption
4				*13.75246	Conversion factor, MTCE/yr to BOE/day	Annex A, note 9
5				/51176000	Mid-year population	World Bank (1983),122
6	ENB	15.774	Same	15.446	Adjusted primary energy use/person (ENA)	(line 1, above)
7				+((2566	Conifer fuelwood prod'n, '000 Cubic M	FAO(1983),84
8				*.26)	Est'd MTCE per cubic meter, conifers	Author's estimate
9				+ ((0 - 1	Fuelwood imports - fuelwood exports	FAO(1983),87,89
10				+ 1791)	Nonconifer fuelwood prod'n, '000 CuM	FAO(1983),85
11				*.31))*13.75246	Est'd MTCE/CuM of nonconifers x conversion	Author's estimate
12				/51176	factor, divided by '80 pop. in thous.	World Bank (1983),122
13	PC	9.244	Same	34399000 MTCE	Primary liquid fuel consumption	UN(1983a),19
14				*13.75246	Conversion factor, MTCE/yr to BOE/day	Annex A, note 9
15				/51176000	Mid-year population	
16	ELEC	563.88	Kwatt-hrs	28857	Elec. consumption, mil. kilowatt-hr.	UN(1983),717
17			/person	/51.176	Mid-yr population, millions	World Bank (1983),122
II.	INDEPENDENT VARIABLES (means of 1969-1971)					
18	GDP	682.2	US$/per-			
19			son, in			
20			1969/71			
21			prices	((374900/12.5)	'69 GDP in cur. prices/'69 exch rate	World Bank
22				+(444271.4/12.5)	'70 GDP in cur. prices/'70 exch rate	World Bank (1983),122
23				+(490011.0/12.5))	'71 GDP in cur. prices/'71 exch rate	World Bank (1983),122
					(where GDPs in mil. units dom. currency)	
24				/3/51.176	no. yrs/1980 population, in millions	World Bank (1983),122
25	KGDPest	1984.3	same, in	EXP(1.3503*ln(GDP)	Equation for estimating Kravis-$ per	Eq. 4, text, p. 46
26			1975 US$	-.0485*(ln(GDP)^2)	capita GDP, in 1975 US$, from nominal	GDP = 682.2 (from
27				+.847)	over-time per capita GDP (as in line 18	line 18, above)
28	GDPek	682.2	same, in	EXP((-1.3503	Equation for estimating nominal-over-time	Eq. 4, text, p.46
			1969/71	+SQRT((1.3503^2)	per capita GDP, in '69/'71 US$, from	KGDPest=1984.30
			US$	-4*(-.0485)*(.847	Kravis-dollar per capita GDP (=KGDPest),	(from line 25,
				-LN(KGDPest))))/	in '75 US$	above)
				/(2*(-.0485)))		
29	LGDPekSQ	42.580	---	ln(682.2)	ln GDPek, squared	(line 28, above)
				*ln(682.2)		

Annex Table B-4, Continued

Calculation of Variables for Use With Cross-Country Estimating Equations, Energy Use in Mexico, 1970, Continued

Line	Variable	Est.Value	Units	Equals:	Line-by-line Description	Source/page no.
II.	INDEPENDENT VARIABLES, continued					
30	PPRICE	13.817	US cents	((6.232*1.351	Cons. gasolines, mil. MT, x CuM/MT (gaso.)	UN(1983a),391,412,xxiv
31			/gallon,	*(24.2+30.3)/2)	mean '70 price reg.,prem. gasoline	World Bank
32			'70 price	+(2.064	cons. kerosene + jet fuel, mil. MT,	UN(1983a),437,459
33				*1.235	Cubic Meters/MT (kerosene)	UN(1983a),xxiv
34				*10.3)	'70 kerosene price, US cents/US gal.	World Bank
35				+(10.632*1.099	cons. fuel oils, mil MT, x CuM/MT (F.O.)	UN(1983a),480,503,xxiv
36				*(206)/42))	'70 hvy fuel oil, US cts/bbl/42 gal/bbl	World Bank
37				/((6.232*1.351)	cons. gasolenes, mil. cubic meters	(line 30, above)
38				+(2.064*1.235)	cons. kero.+jet fuel, mil. cubic meters	(line 32, above)
39				+(10.632*1.099))	cons. fuel oils, mil. cubic meters	(line 35, above)
40						
41						
42						
43						
44	REFPR	.68999	Kg/US$,	24089000 MT	Tot. petrol. refinery output, all product	UN(1983a),573
45			'69/71	/682.2	1969/71 per capita GDP, 1969/1971 US $	(line 28,above)
46			prices	/51176	1970 mid-year population, in thousands	World Bank (1983),123
47	SCR	.00101	BOE/day	2570000 MTCE	Consumption solid fuels	UN(1983a),19
48			/1000	*13.75246	Conversion factor	Annex A, note 9
49			US$	/51176000	1970 mid-year population	World Bank (1983),122
50				/682.2	Per capita GDP, 1969/1971 US dollars	(line 28,above)
51	EIMPSR	.00274	same	3723000 MT	1969/71 crude steel production	United Nations
52				*1.87*13.75246	Energy equiv. in MTCE/MT; conv. factor	Strout(1976); Annex A
53				/682.2	1969/71 per capita GDP, 1969/1971 US $	(line 28,above)
54				/51176000	1970 mid-year population	World Bank (1983),122
55	EIMPNSR	.00174	same	((304000 MT	1969/71 wood pulp production	FAO
56				*.99)	Energy equivalent in MTCE/MT	Strout(1976)
57				+(874333 MT	1969/71 paper & paperboard produced	FAO
58				*.40)+(	Energy equivalent in MTCE/MT	Strout(1976)
59				(587000 MT)	1969/71 chem fertilizers prod., NPK equiv	United Nations
60				*.77)	Energy equivalent in MTCE/MT	Strout(1976)
61				+(7191667 MT	1969/71 hydraulic cement production	United Nations
62				*.32)	Energy equivalent in MTCE/MT	Strout(1976)
63				+(54433 MT	1969/71 refined copper production	Metal Stat.
64				*4.47)	Energy equivalent in MTCE/MT	Strout(1976)
65				+(171667 MT	1969/71 refined lead production	Metal Stat.
66				*1.1)	Energy equivalent in MTCE/MT	Strout(1976)
67				+(83733 MT	1969/71 smelter zinc production	Metal Stat.
68				*3.0)	Energy equivalent in MTCE/MT	Strout(1976)
69				+(35433 MT	1969/71 primary aluminum production	Metal Stat.
70				*8.97)	Energy equivalent in MTCE/MT	Strout(1976)
71				+(1100 MT	1969/71 primary tin production	Metal Stat.
72				*1.42)	Energy equivalent in MTCE/MT	Author's estimate
73				*13.75246	Conv. factor, MTCE to BOE/day/1000 pers.	Annex A, note 9
74				/51176000	1970 mid-year population	World Bank (1983),122
75				/682.2	1969/71 per capita GDP in 1969/1971 US$	(line 28,above)
76	EIMPR	.00448	same	EIMPSR+EIMPNSR		(lines 51+55, above)