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THE DIMENSIONS AND DYNAMICS OF TECHNOLOGICAL CHANGE

The Development of a Comprehensive Analytical Model with which to Analyze and Forecast Techno-Economic Development

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CONTENT

ACKNOWLEDGEMENT..... 1

CONTENT..... 2

SUMMARY..... 3

CHAPTER 1: Discovering Technological Change..... 5

CHAPTER 2: Application of Factor Analysis to the Reduction of Variables..... 96

CHAPTER 3: Interpretation and Utilisation of Factor Analysis Results..... 169

CHAPTER 4: Validation of 'National Engine Model'..... 208

CHAPTER 5: The Logistic Growth of Techno Economic Development..... 264

CHAPTER 6: Conclusion..... 290

LIST OF NOTATIONS..... 295

LIST OF FIGURES..... 297

LIST OF TABLES..... 302

STATISTICAL SOURCES..... 304

REFERENCES..... 305

APPENDICES..... appendix 1

THE DIMENSIONS AND DYNAMICS OF TECHNOLOGICAL CHANGE

The Development of a Comprehensive Analytical Model with which to Analyze and Forecast Techno-Economic Development

Summary

The technological state that exists within a socio-economic system ('black-box') can be represented by its efficiency on input-output conversions. Any real improvement in technological state means also an increase in conversion efficiencies. These changes are the results of the total behaviour of a complex socio-techno-economic process rather than being just a technical change within the economic system.

The concept of efficiency is used to build a vector based model from which an analytical model of technological change is developed. International cross-sectional data are used to develop indicators of time-dependent efficiency components, technological gaps between countries, and speeds of development.

An important part of this research is the identification of socio-techno-economic characteristics appropriate to the study of dynamics of technological change. The 'black-box' contains a very complex structure of variables and parameters interacting with each other. A holistic approach must be used to analyze the processes of technological change, its direction, speed of change, and other characteristics. Normally this would entail opening up the 'black-box' and studying all these parameters

individually. However, a method of dimensional reduction by factor analysis is preferred. The result is a representative, comprehensive, and much simplified model of a complex system. This model can then be used for analysis in order to make a simulation-based forecast of the direction and magnitude of techno-economic development. The model can then serve decision makers as a methodological tool and as an aid to decision-making and policy planning.

The research uses an international data sample collected from 100 developed and developing countries over the period 1960 to 1977. The necessary socio-techno-economic indicators are developed from this data. The indicators define the dimensions of a multidimensional space in which the efficiencies of the techno system can be mapped as they vary with time. The relationships between technological, labour and energy conversion efficiencies are derived, and it is shown that technological improvement is a major drive in socio-economic development.

It is demonstrated that:

1. The data reduction method developed produces a powerful and valid technique for forming an analytical model of techno-economic change of any finite dimensionality.
2. The resulting model provides a useful tool with which to study the dynamics of technological change that result from interacting technical, economic, energy and labour factors.
3. The model provides a powerful aid to policy planners considering development strategy or science policy.

CHAPTER 1

Discovering Technological Change

1.1. Introduction..... 7

1.2. Review of the Treatment of Technical Change in Economic Theory

1.2.1. Introduction..... 8

1.2.2. The Classical Economists..... 8

1.2.3. Growth Theory..... 9

1.2.4. Neoclassical Growth Theory..... 11

1.2.5. Evaluation of Economic Approach..... 16

1.3. Review of Logistic Models of Technological Change

1.3.1. Introduction..... 18

1.3.2. Biological Growth Models..... 18

1.3.3. Substitution and Market Penetration Models..... 24

1.3.4. Substitution - Information Growth Models..... 35

1.3.5. Substitution and Innovation Growth Models..... 42

1.3.6. Multilevel Substitution Models..... 45

1.3.7. Energy Substitution Models..... 51

1.3.8. Evaluation of Logistic Growth Models..... 57

1.4. Models of National GNP-Energy Growth

1.4.1. Introduction..... 63

1.4.2. Concept of Energy as a Substitute for Capital in the Growth Models..... 65

1.4.3. Relationship between Energy and GNP growth..... 67

1.4.4. Generalized Production Function..... 68

1.4.4. Discussion..... 72

1.5. Integrated Model of Technological Change

1.5.1. Introduction..... 74

1.5.2. The Engine Model of a Nation..... 79

1.5.3. The Gompertz Logistic Applied to Engine Model.... 81

1.6. General Format of this Research Programme

1.6.1. Introduction..... 85

1.6.2. Research Objectives..... 86

1.6.3. Structure of the Thesis..... 87

1.7. Summary of Results and Claims for New Knowledge

1.7.1. Results..... 91

1.7.2. New Knowledge..... 94

CHAPTER 1.

DISCOVERING TECHNOLOGICAL CHANGE

1.1. Introduction

One of the main problems in measuring the direct contribution of technological change to a socio-techno-economic system is that the dimensionality of the problem is very large indeed. There is an enormous number of socio-economic indicators that can be gathered and most of them are likely to reflect the effects of technological change somehow. Apart from the problem of size, the matter is made even worse by the fact that the variables are highly interrelated to one another in a complex structure. It is almost impossible to account for any change in one indicator without referring to the effects on the others.

Faced with such involved and entangled relationships among the variables, researchers have followed traditionally a conservative empirical path to reduce the dimensionality. First a simple theory is suggested requiring only a limited number of variables. Then the relationships between them are assumed or predicted. Using the two or three variables of the model and analysing the association or correlation between them historical statistical series are analysed to determine empirically an analytical relationship. Example of such a procedure are the growth theories and production functions of economic theory to represent the behaviour of a developing economy.

1.2. Review of the treatment of technical change in economic theories

1.2.1. Introduction

Perhaps the importance of technological change as a factor in understanding better the behaviour of economics and social change starts with the era of classical economics. The significance of production and the factors of production (capital, land, labour) came to the forefront of the economic debate and economists gradually developed the notion of a causal connection between the level of production or output and the quantities of the factors of production. The production function model has developed to relate the level of output to the factors of production at a given state of technical knowledge. An increase in technical knowledge causes a shift in the production function, so that technical change is often identified with the shift in this function.

1.2.2. The Classical Economists

The effects of technological change on economics and society was first observed by James Stuart and Adam Smith early in 1767. According to Stuart, experience shows that new machines bring about improvements and price reductions, although they can bring about temporary unemployment. However employers may offer long term employment (224). Adam Smith taking a somehow different angle of looking at technology, pointed out that the increase in labour productivity is mainly due to the division of labour, and

'the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many', and the invention of machines 'seems to have been originally owing to the division of labour' (215). He further pointed out that it was possible to have more and more divisions of labour in industry, but not in agriculture, and that was the reason productivity in industry increased faster.

Malthus, went even further on 'diminishing return' by saying that it is possible to produce enough capital saving and labour saving in industry, so that the price of goods is 'reduced to the price of production from best machinery', whereas even the most fertile land can not keep up with the 'effective demand of an increasing population' (153). According to Ricardo (189) the economic growth is limited by the size of the land available, which set the price of food and thus the supply of labour. Like Smith, Ricardo believed that economic growth resulted from 'capital accumulation'. But accumulation in turn was a function of profit, which depended on wages, which depended on the price of the food, which depended on the availability of land or food import.

1.2.3. Growth Theory

Early in twentieth century Schumpeter (207) mentioned the importance of technological change in his analysis of capitalism. Yet, although technological change played a central role in his theory-both in accounting for short term instability and for its

dynamic long term behaviour - Schumpeter in a sense kept the phenomenon at arm's length. That is to say, he treated innovative activity as an essentially exogenous force, which had important economic consequences, but no economic causes or antecedents.

It was not until after second world war that the question of economic growth and technological change arose again, initially as a by-product of Keynesian revolution in income theory, and later as economists lifted their attention from Europe and America to less developed countries. Keynes (126) pointed out that income would be stabilized-possibly at less than full employment-where new expenditure for capital investment coming into the system exactly offset saving being taken out. But Sir Roy Harrod (110), a British economist, observed that the full-employment income in period t would not be sufficient in period t+1 because of the additional capacity created by investment in period t. How much more spending would be needed in t+1 could be determined by the relationship between capital and output, ie. capital-output ratio. Since investment in period t is determined at the equilibrium level of national income by the marginal propensity to save, economic growth becomes a function of the marginal propensity to save and capital-output ratio.

Independently Domar (69) worked out using similar model but emphasizing more the enlarged capacity made available for economic growth in t+1 by investment in period t.

However the Harrod-Domar model has failed on empirical grounds. Growth as observed in concrete situations proceeds

faster than can be accounted for by the rate of inputs of capital with a constant capital-output ratio. The weakness of the Harrod-Domar model of growth led the Neo-classical group of economists to explore more complex theories which allowed for changes in capital and labour relative to a given output. Solow (218) was one among the first to work along this line.

1.2.4. Neoclassical Growth Theory

In place of the Harrod-Domar assumption of single production process that imposes a fixed ratio between capital and labour is the assumption of an indefinetely large number of production processes, one shading off from another in a way that permits any combination of labour and capital to be employed. Capital is thus regarded as unique, an abstract agent of production that can be adjusted at any time to absorb into employment a labour force of any size. With the combination of labour and capital capable of varying in this way, it follows that, instead of the fixed ratio between output and capital employed by Harrod and Domar, the output-capital ratio is also capable of varying continuously. Thus, the larger the labour force absorbed into employment with a given stock of capital, the greater will be the output-capital ratio, or the productivity of capital, and the smaller will be the output-labour ratio, or the productivity of labour. Similarly, the smaller the labour force absorbed into employment with a given stock of capital, the lower the productivity of capital and the higher the productivity of labour.

The rate of which the output of the economy grows depends

basically on the rate at which its capital stock, labour force, and technological know-how grow over time. The relationship for any particular period of time may be simply expressed in the form of the following production function:

$$Y = f (K, L, T) \qquad (1.1)$$

where K = Capital

L = Labour

T = State of technology

Y = Output

Both Neoclassical economists as well as Harrod-Domar would say that if both capital (K) and labour (L) increased by 1 percent, output (Y) would also increase by 1 percent. In Harrod-Domar, however, a 1-percent increase in L with no increase in K (and with all the existing K already in full use) would mean no increase in Y because of the fixed proportion between L and K, whereas in Neoclassical theory the same set of conditions would lead to some increase in Y because the enlarged L could be absorbed into employment with an unchanged K.

The production function explored by Solow permitting capital and labour to grow at different rate was the Cobb-Douglas function (55). It can be described as:

$$Y = a K^{b} L^{c} \qquad (1.2)$$

where Y = output

K = capital

L = labour

a = constant for different economic system

b,c = marginal efficiencies for Capital and Labour

In the Cobb-Douglas function the constant b and c add to unity, which means that increase in income are fully equal to the marginal physical productivity of the factors times their respective increases.

The Neo-classical approach has been taken further and generalized by Meade (171). There is one output which can be used for either capital formation or consumption. His model can be represented as:

$$Y = f(K,L,N,t) \qquad (1.3)$$

where N = land

t = time

If land is regarded as constant, we have:

$$\frac{dY}{Y} = \frac{VK}{Y}\frac{dK}{K} + \frac{WL}{Y}\frac{dL}{L} + \frac{dY'}{Y} \qquad (1.3a)$$

where Y' = change in income due to Technology

V = marginal efficiency of capital

W = marginal efficiency of labour

$\frac{dY}{Y}$ = rate of growth

Economic growth is thus the marginal product of capital times the proportionate increase in capital, plus the marginal product of labour times the proportionate increase in labour, plus the proportionate increase output owing to technological change. In

Neo-classical theory the rate of change of income therefore may be dependent to the Technology which is exogonous.

Kaldor (121) objected to both the un-stable nature of the Harrod-Domar model and the escape from it through factor substitution. In his view, ready substitutability of capital for labour was impossible because of the rigidity of technology embodied in machines. To produce a change in technology required new investment. Thus it was impossible to have technological change depend upon time alone.

But while traditional economic theory has found it difficult to incorporate technology into its model in an explicit way, the study of technological change has become a recognised field of research within the broad economic subject. Ruttan (196) defines technological progress as an increase in output per unit of input. In his later article, Ruttan (197) views technological change in a production function context. He further defines it as a change in the parameters of the production function or a creation of a new production function. In other words this view defines technological progress as an upward shift in the production function. Along this line Kutznets (132) conducted empirical studies to find the exact contribution of technology to the production function.

Denison (65) in his pioneering research attempted to quantify the factor sources of American growth. He examined the growth in national income between 1929 and 1957 and, with the aid of some strong assumptions, attempted to quantify the

contribution of each of a number of variables to this growth. In addition to his estimates of the contribution of changes in quantities of capital and labour input, Denison attempted to adjust for quality changes in labour inputs, particularly those attributable to education and the effects of shorter working hours on quality. Moreover, he decomposed the residual into several component parts, the most important of which turned out to be advances in knowledge and economies of scale.

Schultz (205) proposed a non-conventional economist's approach by stating that the ideal input-output formula is one in which the ratio stays close to one. He stressed that technical change is not 'manna from heaven'. In other words, resources must be devoted to improving the quality of inputs, and that we ought to know the costs of, and returns to, producing new technology. Without knowing how much quality improvements in inputs contribute to output, we can not answer this question (206). He cautions that allowing the production function to shift is an all too convenient way of disposing of the problem. Such a procedure in effect treats economic growth as exogenous to the system - something we have no control over, like the weather.

Indeed, one might argue that the use by many economists of the generalized term 'technological change' is an indication that they do not know where at least a part of the output is coming from. Abramovitz (3) summarized this paradox in his article as 'a measure of our ignorance'.

1.2.5. Evaluation of Economic Approach

The drawback of this economist's approach (using theories to select variables for analysis) is that firstly the socio-economic theories are themselves based largely on intuitively grounded concepts. Secondly they are based on limited knowledge of the relationships between a few variables in the past. Thirdly their analysis assumes that all other variables are held constant and that any relations uncovered by these variables are effectively independent of any of the other variables. Certainly the sensitivity of the original simple model to wider influences can be tested, but what validity does the simple model actually have?. To illustrate the danger one may contrast the validity of the great generalized laws of physics (which are of simple form, great clarity and experimentally verifiable) with the "laws of economic theory" which often seem to provide less than a satisfactory explanation when compared with real-world economic behaviour.

This is clearly a system boundary problem. In a small physical system, for example a simple engine, the boundary of the system can be observed quite clearly. We can observe the input (fuel), output (work done), and all the moving components and functions physically. They do not present such a level of difficulty as one finds in a large and complex socio techno economic system. In a system of great complexity with an unknown boundary limit we can not really afford to make selective use only of variables which we assume to be relevant. It is possible that some important and critical indicators are missed just

because, in the past, they were either not perceived or not thought to be relevant. The risk of making wrong decisions is high if decision makers base their judgement only on simple models with only a few variables. There is nothing wrong with a good simple theory or model. But it must be valid and provide satisfactory explanations that allow real world behaviour to be predicted.

So the problem of understanding the dynamics of technological change is one of the inherent complexity of the total socio-techno-economic process. The technical change index in the production function and growth theories of economics are really gross simplifications with little explanatory power. They do not explain what the mechanism of technological change are, not how the detailed interaction between technology, economic and society work to produce the overall behaviour of an industrializing or industrial economy. The paradox is that such an analysis of technical change relevant to an economy requires a **micro-model** as opposed to a macro model. This is the next problem: how to harmonise the micro and macro viewpoint as well as deal with the dimensional problem of complexity.

1.3. Review of Logistic Models of Technological Change

1.3.1. Introduction

Although there have been occasional studies of the process of technological change, e.g., Gillifan's work (90), in-depth analysis of technological change began only in the 1950's. The push came from two groups-the economists and industrialists. Among the former Edwin Mansfield (156) and Zwi Griliches (91) exerted a major influence. The second group emerged from RAND Corporation, a United States Air Force sponsored research centre.

Researchers with an industrial background interpret the dynamic behaviour of technological change in-terms of growth, diffusion, and substitution processes. Their research starts at the micro or industrial level, and it can be argued that this is an appropriate approach because only by appreciating technology at micro level can an understanding be developed of its general overall behaviour at micro level.

1.3.2. Biological Growth Models

Some researchers, in the quest for more rigorous forecasting methods have observed a similarity between the behaviour of biological growth and the growth in performance of technological devices. This similarity, while often only suggestive, indicates that it might be possible to forecast the growth of technology in the same way biologists forecast the growth of organisms and of populations.

Martino (160) writes that the purpose of the analogy is twofold: to justify the use of growth curves for technological forecasting, and to provide a model of the process of technological development so that forecasts may be made with greater accuracy. Lenz (142) has carried out a rather complete development of such an analogy:

table 1.1

ANALOGY BETWEEN CELLULAR GROWTH AND TECHNOLOGICAL PROGRESS

Biological Growth	Technical Improvement
Initial cell	Initial idea or invention
Cell division	Inventive process
Second generation cell	'New' idea or invention
Cell division period	Time required for initial invention to initiate 'new' invention
Nutrient media	Economic support for invention
Cell lifetime	Useful life for invention
Cell death (normal)	Obsolescence of invention
Cell mass	Technical area or machine class
Volume limit of cell mass	Limits of economic demand for invention in a given technical area
Size of cell mass	Total of existing, non-obsolescent inventions in technical area

from: Lenz (142)

table 1.2

BISEXUAL REPRODUCTION ANALOGY

Biological growth	Technical improvement
Male parent, or parent cell	Existing invention or discovery
Female parent	Inventor
Opportunity of fertilisation	Communication of knowledge
Conception	Origination of idea
Embryo	Evidence of growth of idea
Embryonic growth	Development of idea
Gestation period	Period required for invention
Birth	Disclosure of invention
Nutrition	Economic support
Maturition period	Reduction to practice
Maturity	Operational use of invention
Lifetime	Period from disclosure to obsolescence
Death (normal)	Obsolescence
Total male population	Total inventions disclosed minus obsolete inventions
Total work force	Total operational inventions
Total strength of work force	Performance capability

from: Lenz (142)

In summarising the possible applications of these detailed analogies to analytical forecasting, Lenz points out that: "the analogy of cell division to technological improvement may be used for prediction in the following ways:

1. By identification of the average period required for ideas to be generated from prior inventions, and use of this time period as the basis for predicting the doubling of technical progress over each time period.

2. By relating economic growth to invention and to the rate of increase of invention, to show that exponential increase in invention is not likely without exponential increase in the economic support.

3. By indicating the lower rate of progress caused by obsolescence of invention.

4. By projecting the growth curve to 'maturity', with a constantly deminishing rate of increase in progress, where the limits of demand for invention in a given field can be reasonably determined."

No doubt there are some striking similarity between biological growth and technological growth. The question wheather this model can be useful for forcasting technological growth however needs in-depth study of the growth behaviour of individual technology itself.

Regardless of whether the use of growth curves is accepted as a refined form of analogy, or simply as a workable tool without regard to a possible analogy, it is still necessary to project the curve beyond the existing historical data. A

freehand projection of a curve plotted on the graph is not a very satisfactory approach. Instead it is necessary to fit a mathematical function to the historical data, and then project the function.

The relationship between technical improvement and biological growth generates a specific growth curve known variously as the logistic curve, the Pearl-Reed curve, or simply as the Pearl curve. The name refers to Raymond Pearl (1870-1940), American biologist, who made extensive studies on the growth of organisms and of populations (182). He found that the curve described the growth of organism very well. The equation is:

$$y = \frac{L}{1 + a \exp(-bt)} \qquad (1.5)$$

where L = the upper limit to the growth y

t = time

a, b = constants

A typical Pearl curve is presented in figure 1.1 (page 23).

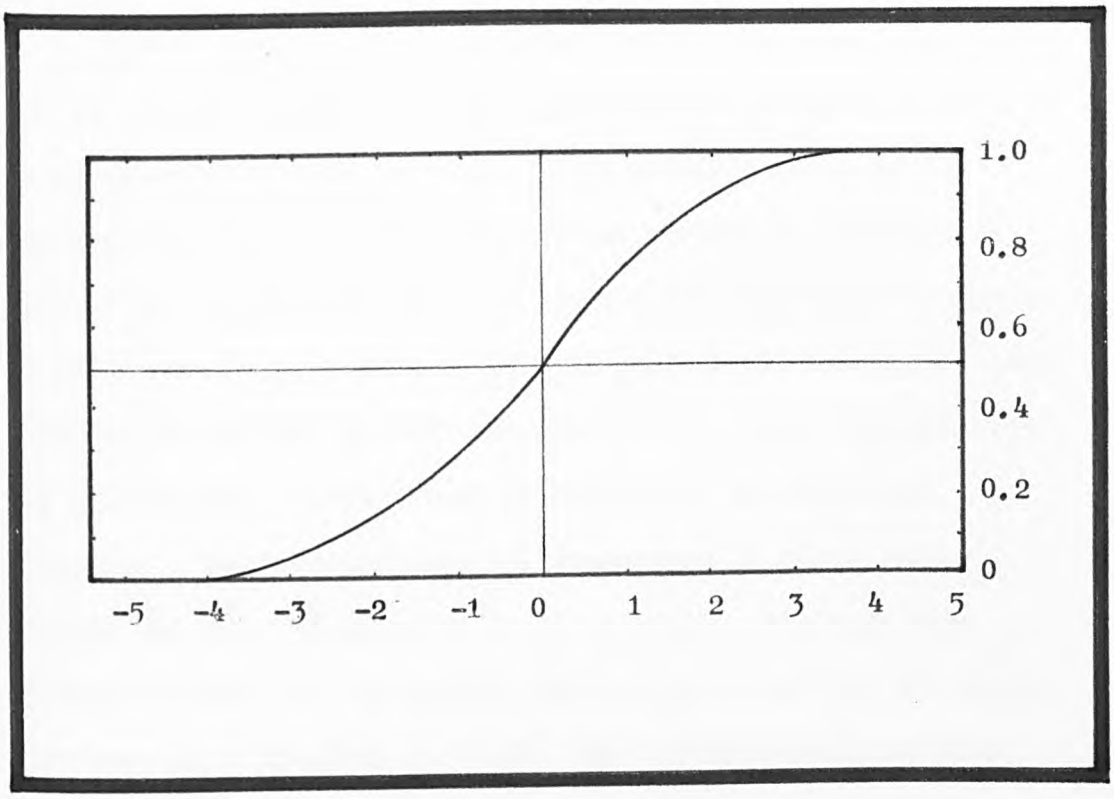


figure 1.1: **Pearl Curve**

Characteristic:

$$y = \frac{L}{1 + a \exp(-bt)}$$

where L = the upper limit to the growth y

t = time

a, b = constants

(1) y = 0 at $t = -\infty$

(2) inflection point at y= 1/2 L or t = (ln (a))/b

(3) curve is symmetrical about its inflection point

1.3.3. Substitution and Market Penetration Models

Fisher and Pry (78) were among the first researchers to look at the growth behaviour of new technological products in terms of a market substitution process. This model is based on the assumptions that: (1) the substitution process is competitive, (2) if the penetration of a new product has progressed as far as a few percent of the market, it will progress to a complete take over of the market, and (3) the rate of fractional substitution is proportional to the extend of additional substitution possible. These assumptions are summarised in (1.6), which yields the solution given in (1.7) or (1.8). The time that elapses between the 10% market takeover point and the 90% market takeover point is given by (1.9). On fitting normalized data from 17 cases of substitution they were able to show that the rate of substitution of a new product or process is proportional to the fraction of the old one still in use.

$$\frac{1}{f}\frac{df}{dt} = 2a(1-f) \qquad (1.6)$$

$$f(t) = \frac{1}{2}\left(1 + \tanh a(t-t_0)\right) \qquad (1.7)$$

$$\frac{f}{(1-f)} = \exp\left(2a(t-t_0)\right) \qquad (1.8)$$

$$dt = t_{0.9} - t_{0.1} = \frac{2.2}{a} \qquad (1.9)$$

where f = the fraction of the market captured by innovation.

a = 1/2 of the annual fractional growth in early

(initial) years

t_0 = time (t) at which f = 1/2

On integration (1.6) yields the well known logistic equation:

$$f = \frac{1}{1 + \exp b\,(t - t_0)} \qquad (1.10)$$

where t_0 = time at which the fractional substitution reaches its mid point.

b = constant

Equation (1.8) is conveniently drawn in linear form on semilog paper. Fisher and Pry' results are presented in figure 1.2 and 1.3 (page 34).

Mansfield (156) attempted to establish an empirical form for technological growth by comparing his model's predictions with historical technological substitutions that occured in four industrial sectors. Using regression analysis he develop an empirical expression for the substitution rate a.

$$a = (Z) + 0.53\,p - 0.27\,s \qquad (1.11)$$

where Z = a constant representative of a given industry

p = a profitability index

s = an investment index

If the economic characteristics of historical technological innovation are known, and if estimates of p and of s can be made based upon this historical data, and in addition if a value of a

is known from historical substitution rates, then an estimate of the value of Z can be found.

Blackman (27) support Mansfield's idea by further classifying two independent catagories of factors for technological change; those related to the industry and those related to the innovation. He believed that the motivating force behind the creation of technology innovation is the economic reward perceived to result from successful innovation. The extent of investment in technological innovation is, therefore, related to the perceived rate at which a market will develop for the new technology. The rate of market development is, in turn, a function of the dynamics of technological substitution. Blackman applied his model to describe the dynamics of innovation of commercial jet engine market and in the electric utility and automotive sectors (26).

$$\ln\left(\frac{m}{L-m}\right) = -\ln\left(\frac{L}{N_0} - 1\right) + a\,(t - t_1) \qquad (1.12)$$

m = market captured at time t by new innovation.

L = upper limit of market share which the new innovation can capture in the long run.

N_0 = market share captured when $t = t_1$

a = const. which governs the substitution rate.

or in general form:

$$\ln\left(\frac{m}{L-m}\right) = c_1 + c_2\,(t-t_1) \qquad (1.13)$$

where c_1, c_2 = constants

t_1 = year in which the new technology product first captures a portion of the market.

In his work on the commercial jet engine market, Blackman (27) presented a more detailed development of Mansfield's model (eqn. 1.1). The change of market share in time (dt) is defined by:

$$(dt) = \frac{m(t+1) - m(t)}{L - m(t)} \qquad (1.14)$$

where m(t) = market share at time t.

L = upper limit on the market share.

He also assumed that

$$d(t) = f\left(\frac{m(t)}{L}, P, S\right) \qquad (1.15)$$

where P = Profitability of employing new products

S = Size of the investment to produce new products

If an estimate can be made of L and if historical data are available which give market share captured by the product of the new technology as a function of time, values for constant c_1, c_2 in (1.13) can be estimated using regression analysis. If an adequate historical data base exists, the model can be used to forecast the rate at which substitution will occur in future. It is not necessary that the database be extensive. In fact, it is demonstrated by Lenz and Lanford (141) that the prediction of substitution may be made when a new technology product is

substituted for as little as 2% of the total market.

In his work, Blackman assumes that equation 1.15 (page 27) can be approximated by a Taylor series expansion that drops third and higher order terms as shown in (1.16). Substituting (1.14) in (1.16) yields (1.17) where, because of information obtained by Mansfield (157), the coefficienta of the $(m(t)/L)^2$ terms are set equal to zero. For a very small time increment, (1.18) can be written as (1.19) which has the solution given by (1.20). As the time moves backwards towards the date of introduction, the market share of the innovation must tend toward zero. According to Blackman, this requires that a set of constants represented by Q (the sum of all the terms in (1.17) that do not include the ratio of the market share at time t to the ultimate market share) be set equal to zero, yielding (1.21). The next step is the replacement of variable t by the variable t' given by (1.22).

$$dt = f\ (\ m(t)/L,\ p,\ s\ ) \tag{1.16}$$

$$dt = C_1 + C_2\ m(t)/L + C_3\ p + C_4\ s + C_5\ pm(t)/L + C_6\ sm(t)/L + C_7\ ps + C_8\ p^2 + C_9\ s^2 + C_{10}\ (m(t)/L)^2 \tag{1.17}$$

$$m(t+1)-m(t) = (L-m(t))(C_1 + C_2\ m(t)/L + \ldots\ldots + C_9\ s^2 + C_m \tag{1.18}$$

$$m(t+1)-m(t) = \frac{dm(t)}{dt} = (L-m(t))\ (Q+am(t)/L) \tag{1.19}$$

where Q = sum of all terms in (1.17) that do not contain m(t)/L

a = sum of all terms in (1.17) that do involve m(t)/L

Following Blackman, the equation above becomes;

$$m(t) = L\,(\exp(q+(Q+a)t)-Q/a) \;/\; (1 + \exp(q+(Q+a)t)) \qquad (1.20)$$

where q = a constant of integration

$$m(t) = L\,(1 + \exp -(q+at))^{-1} \qquad (1.21)$$

$$t' = t - t_1 \qquad (1.22)$$

where t_1 = year in which the first market penetration occurs

$$\text{if } m(t_1) = N_0 \qquad (1.23)$$

where N_0 = market share obtained by the product innovation at the end of its first year on the market

then substituting (1.22) and (1.23) into (1.21) yields (1.24), which can be conveniently rewritten as (1.12).

$$m(t-t_0) = L\left(1 + \left(\frac{L}{N_0} - 1\right) \exp -a(t-t_1)\right)^{-1} \qquad (1.24)$$

Notice that using the definition of a as the sum of all terms in (1.17) that do involve the ratio of the market share to the ultimate market share yields (1.25), which is just another form of equation (1.11).

$$a = C_2 + C_5\, p + C_6\, s \qquad (1.25)$$

Floyd (79) attempted to both explain technological "growth" and to forecast growth trends in improved functional capability. This capability is translated as a "figure of merit" which serves as the dependent variable. Out of a number of techniques

available, to implement a new development Floyd assumed that only a fraction of these will be successful. He also imposes an upper limit to this functional capability, which is summarized as:

$$P(f,t) = 1 - \exp\left(\frac{-0.6931\ (at+b)}{Y + \ln(Y-1) + b}\right) \qquad (1.26)$$

where $Y = (1-f_c/F) / (1-f/F)$

$P(f,t)$ = probability of achieving figure of merit level f by time t

F = limiting value of figure of merit.

f = level of figure of merit for new technology.

f_c = level of figure of merit for competitive technology.

a,b = constant

t = time.

In this model Floyd assumes that there is a fixed number of techniques that can be tried to accomplish a specified goal and that only a fraction of these will be 'successful'. There is an upper limit to the functional capability, which will be reached only after all possible techniques have been tried. However the practicality of his model is questionable by the difficulty to measure the limit of techniques that can be imagined.

Sharif and Kabir (211) observed the close similarity between Blackman (27), Fisher and Pry (78) and Floyd's model (79). Floyd's model was observed to underestimate a forecast, while Blackman and Fisher Pry models give an overestimate of a

forecast. Since it is likely that the correct estimation lies between these two extremes, Sharif and Kabir suggest that the models of Floyd and of Blackman be linearly combined (1.27). When s = 1, we have Floyd's model, for s = 0, we have Blackman's model,and for s = 0 and F = 1, we have Fisher - Pry model. If we take F = 1, equation (1.27) can be simplified to (1.28). By treating s as a parameter with possible value between 0 and 1, a set of smooth S-shaped curves can be obtained by a decision maker ranging from most optimistic to most pessimistic forecast.

$$(1+s)\ln(f/(F-f))+(s)\ln(f/(F-f)+F/(F-f)= a + bt \qquad (1.27)$$

$$\ln (f/1-f) + s\ (1/1-f) = a + bt \qquad (1.28)$$

where s = delay coefficient.

a, b = constants.

In order to determine an appropriate value for s to be used in the general model given by equation (1.28), many factors need to be considered. Sharif and Kabir stated s is a function of:

$$s = f\ (DS, DE, f1, ELS) \qquad (1.29)$$

where DS = data scatterness

DE = data extent

f1 = last value of f (market share at the time of forecast)

ESL = effective life span (time required for f to go from 0.1 to 0.9)

The value of market share at the time of forecast influences the trend of the substitution curve quite significantly when the

number of historical data is small. The influence decreases with the increase in data points. However, use of data points corresponding to a very early stage of substitution is likely to produce a pessimistic forecast when the market share at the time of forecast is also relatively small.

The accuracy of a forecast is highly dependent on the effective life span. For a very short effective life span, full substitution forecast is likely to be less accurate compared with the case when the effective life span is relatively long.

According to Jantsch (119), Ridenour (1951) was among the first to look for a mechanism which would describe the utilisation of technology. He assumed that the rate of public acceptance of a new product, service or technique follows a "law of social change" which is proportional to the number of users (customers) who have been exposed to it. Thus the incremental increase of this number is proportional to the number of people having already accepted, that is:

$$dN / dt = k N \qquad (1.30)$$

where k = index of proportionality (constant)

N = number of people exposed to the new technology

However he imposes an upper limit (L) to the number of such potential users, such that:

$$k = b (1-N/L) \qquad (1.31)$$

where b = constant

therefore (1.30) becomes,

$$dN / dt = b(1-N/L)\ N \qquad (1.32)$$

or on integration:

$$N(t) = \frac{1}{1 + (L/N - 1)\exp(-bt)} \qquad (1.33)$$

This equation is equivalent to Pearl's model (78).

figure 1.2

Fisher and Pry curve

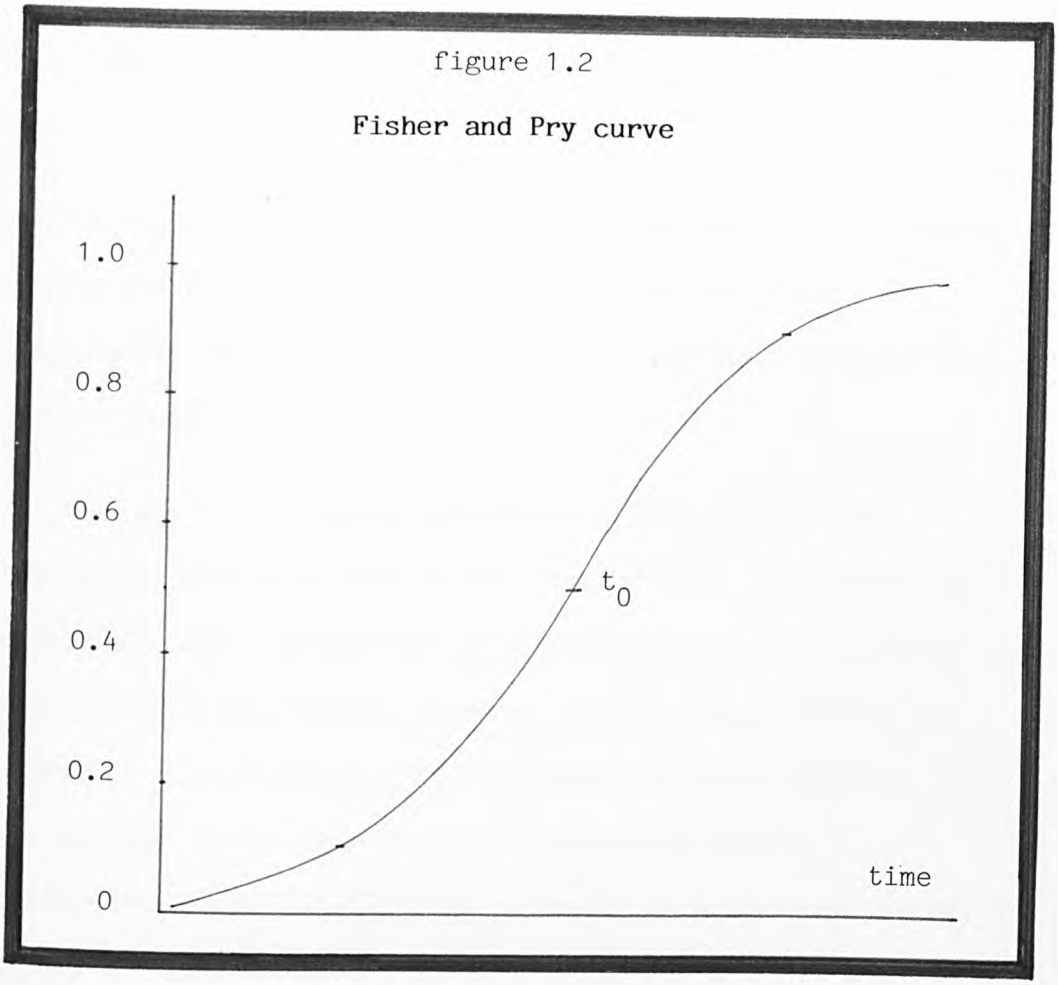
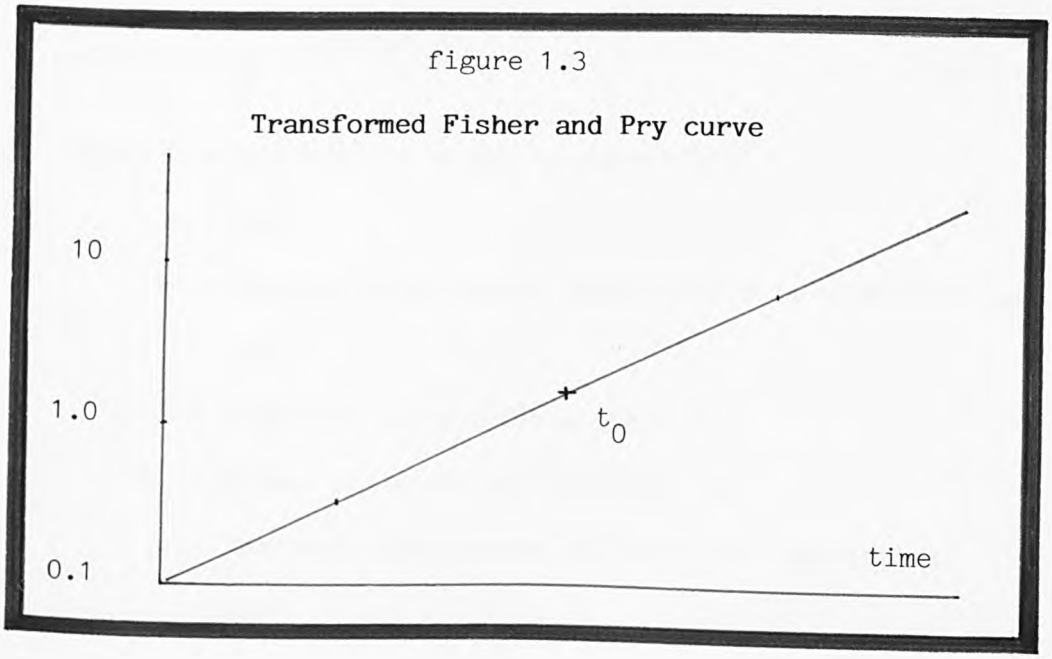


figure 1.3

Transformed Fisher and Pry curve



1.3.4. Substitution - Information Growth Models

The basis of technology is knowladge and information. This area of research is generally scattered and basically unrelated to substitution-growth models described earlier. For completeness and background reason, some basic findings in this area are presented here.

Isenson (118) assumes dependence of the incremental information gain over time on two factors only, the number of researchers and a recognized upper limit growth. A third factor, which he calls the "inter-scientist communication factor" is assumed to depend entirely on the number of investigators. For the approach to an upper limit L, Isenson introduces a "connection factor" (1-I/L); which leads to an S-shaped curve for the state of knowledge

$$dI/dt = q\, N_0\, e^{ct((L-I)/L))} \qquad (1.34)$$

where I = Information (state of knowledge)

t = Time

q = Average productivity factor per scientist and time unit

N(t) = Number of scientists at time t

N_0 = Number of scientists at time t=o

c = Constant (coefficient of curve in logarithmic plot)

On integration the equation (1.34) yields the "state of knowledge", which is implicitly assumed to be proportional to the

value of a functional technological capability or any other numerical characteristic:

$$I = q\,N_0 \int_0^T e^{ct}\,dt = \frac{q\,N_0}{c}\,(e^{cT} - 1) \qquad (1.35)$$

where T = time span of evaluation

For the approach to an upper limit L, Isenson introduces a correction factor (1-I/L), so that the equation (1.34) now also becomes dependent on the level of I, and brings it closer to Hartman's model (1.38):

$$\frac{dI}{dt} = q\,N_0\,e^{ct}\,\frac{L - I}{L} \qquad (1.36)$$

which leads to an S-shaped curve for the state of knowledge (figure 1.4, page 40). Thus,

$$I = L\,(1 - e^{-\frac{qN_0}{cL}\,e^{ct}}) \qquad (1.37)$$

The only explanation which this model seems able to furnish is that of the general rise of total scientific and technical knowledge, a value which is no longer measurable by single indices but which may be roughly proportional to the number of scientists in the world. The laws which govern typical team work today - often carried out with a constant number of people during the critical period - are obviously not represented by Isenson's model.

Hartman, in Jantsch (119), derives his model from a simple

analogy with reaction processes in a gas. The information gain, in this model, depends on the amount of information already available - thus basically differing from Isenson's model, and conforms, in this respect, more closely with our general thinking on the production of scientific and technological results.

Hartman imagines a "gas," the molecules of which are scientists and pieces of information, both occuring at a given volume density (eg. N scientists per cubic metre, etc). The scientist "molecules" S do not move significantly, whereas the information "molecules" I move with assumed constant velocity v in random direction. A useful reaction (i.e. the generation of new information) is supposed to occur when the scientist "molecules" S have a "reaction cross section" q on being hit by the information "molecules" (figure 1.5, page 41).

The incremental information gain (the generation of new information "molecules" per volume unit) is then:

$$\frac{dI}{dt} = kvNqI(t) \qquad (1.38)$$

where k = constant

v = speed of information "molecules"

N = number of scientists (volume density of scientists "molecules")

q = reaction cross section (target area) of scientists for the generation of new information through collision between the two types of "molecules"

I(t) = amount of information at time t (volume density of information "molecules")

Taking N as constant one may arrive at a reasonable model for small or medium-scale team work at early stages (when each "collision" between a scientist and and a piece of information can be expected to give rise to the production of new information). Integration between t=0 and t=T yields an exponential increase of information:

$$I = I_0 (e^{bT} - 1) \qquad (1.39)$$

where I_0 = amount of information at time t = 0

b = kvNq = constant

If N, too, is taken to rise exponentially: $N=N_0 e^{ct}$, as in Isenson's model, one may come close to arriving at a model for a new breakthrough field, where the number of investigators increases exponentially while "collision" between scientists and available information will still trigger the production of new information - a situation which, however, will not prevail very long. The equation (1.37) then becomes:

$$\frac{dI}{dt} = kvN_0q\, e^{ct}\, I(t) \qquad (1.40)$$

Integration yields a double-exponential growth curve:

$$\ln (\ln (I)) = ct + \text{const.} \qquad (1.41)$$

or, in explicit terms

$$I = I_0 \left(e^{\frac{kvN_0q}{c} e^{cT}} - 1 \right) \qquad (1.42)$$

Such a growth characteristic, represented by a straight line in a double-logarithmic plot, can indeed be encountered in several fields. Isenson (118) gives the example of papers published in laser/maser technology which closely follows a double-exponential curve.

For the approach to a limit L, Hartman introduces the same correction factor as Isenson, so that the equation (1.38) becomes

$$\frac{dI}{dt} = (kvNq)\, I \frac{L-I}{L} = b\, I \frac{L-I}{L} \qquad (1.43)$$

which again results in an S-shaped curve for information gain:

$$I = \frac{L}{1 + \left(\frac{L}{I_0} - 1 \right) e^{-bT}} \qquad (1.44)$$

In criticising Hartman's model, the basic assumption that the information gain is proportional to the amount of existing information (dI/dt = (const.) x I) holds only where: (a) ideal communication between all investigators and all pieces of information can be assumed, and (b) where every new opportunity presented by this communication can in fact be exploited. Both assumptions certainly do not hold for scientific and technological growth (where communication is not ideal and where - in the present situation - far more opportunities for the production of new information exist than can be followed up).

figure 1.4

Isenson's Information Growth Curve

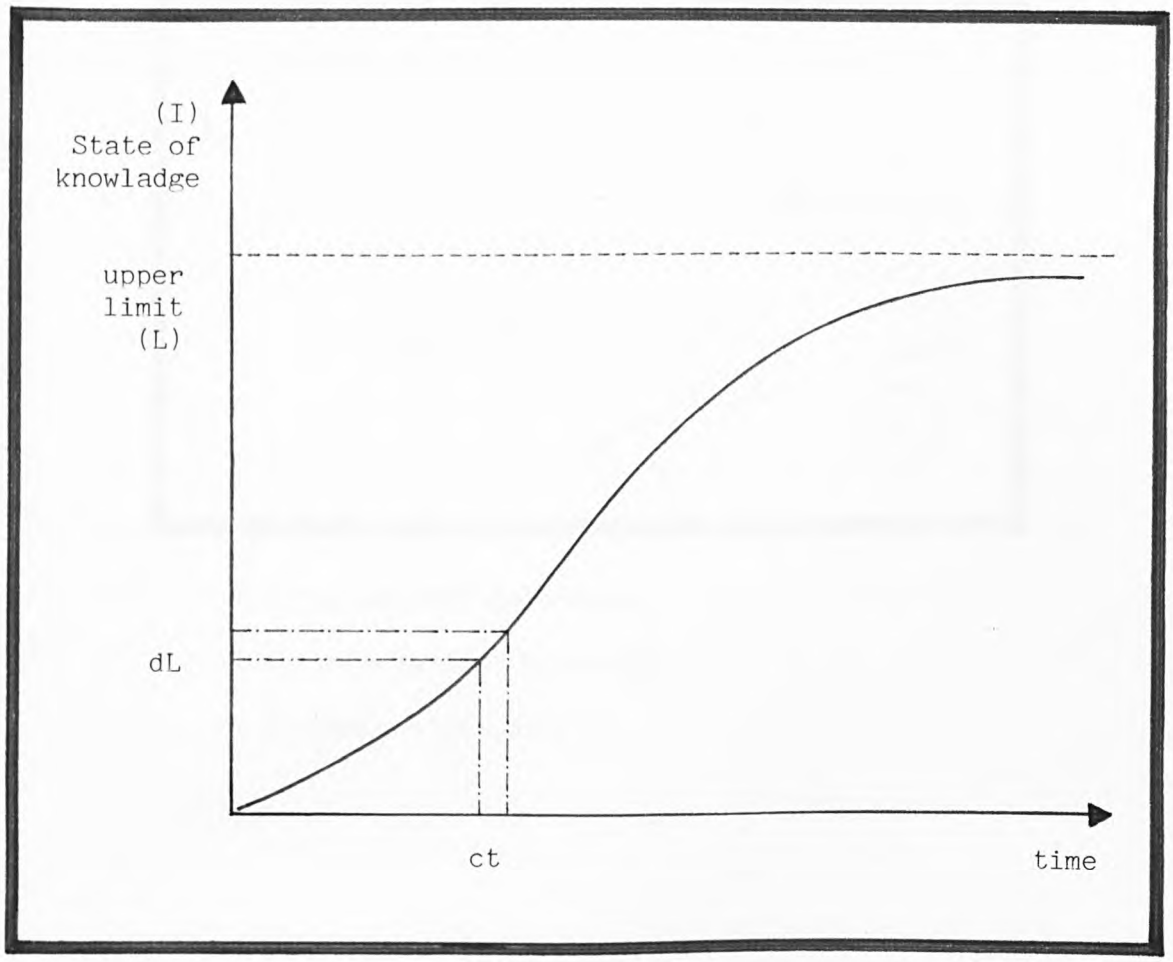
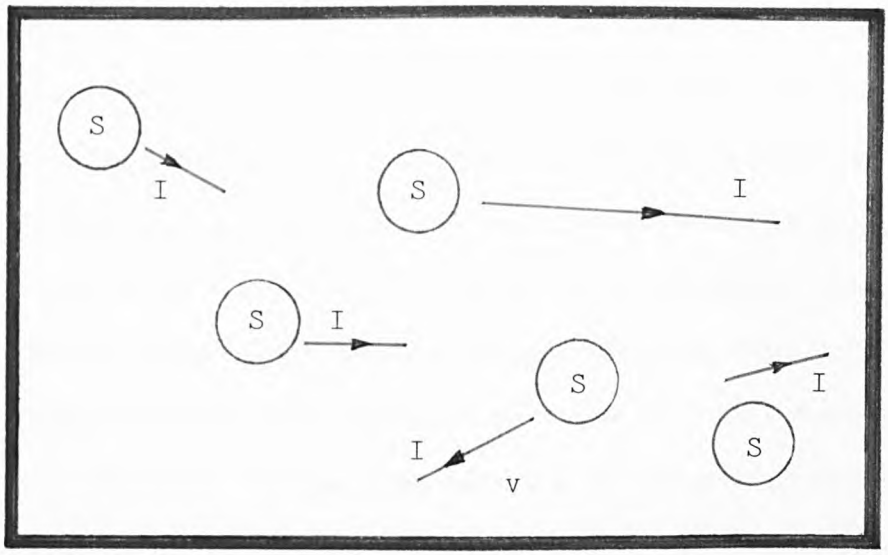


figure 1.5

Hartman Information Growth Model



S = 'scientist' molecules

I = 'information' molecules

v = constant velocity

1.3.5. Substitution and Innovation Growth Models

Blackman et al (30) develop an innovation index which measures the relative tendency of various industrial sectors to innovate. The index is derived from various input variables which reflect the extent to which resources are allocated to innovation, and output variables which measure the extent to which new product and process innovation is achieved. Blackman (27) using Mansfield's model (155) hypothesized that a relationship might exist between the value of Z (a constant representative of a given industry) for an industrial sector and the value of an innovation index for that sector. To test this hypothesis the Z values for the steel and food and kindred product sectors were obtained from Mansfield's work (155) and Z values for aerospace and for auto and electrical mechinary, from Blackman's work (26). He found a high correlation (0.92) between these values and the values of the innovation index.

$$Z = 0.2221\ (I) - 0.3165 \qquad (1.45)$$

where I = innovation index

Blackman has also hypothesized that the propensity to innovate, Z, is directly related to the risk characteristics of the industry. The possibility exists that Z values might be estimated from the variance (used as a measured of risk) in the rate of return among firms in an industry.

Blackman (28) went on relating investment to the

technological substitution. The profitability index, p, can be expressed as:

$$p = \frac{ROR}{ROR_{req}} \tag{1.46}$$

where ROR = rate of return associated with the innovation

ROR_{req} = minimum rate of return required for investments

If p is greater than 1, the product substitution is considered profitable. Equating capital investment to the present value of net benefit he obtains:

$$Y_0 = \sum_{k=1}^{j} \frac{B_{0,k}(1-T)}{(1+ROR_{req})^k} - \sum_{k=1}^{j} \frac{(E_{0,k}+D_{0,k})(1-T)}{(1+ROR_{req})^k} + \sum_{k=1}^{j} \frac{D_{0,k}}{(1+ROR_{req})^k} \tag{1.47}$$

where Y_0 = Initial purchase price of old product.

B_0 = Annual benefit to users of old product.

T = Tax rate.

E_0 = Annual expenses using the old product.

D_0 = Depreciation expense of old product.

J = Life of product in years.

Based on a known initial purchase price, life cycle expense, and tax rate, equation (1.47) can be used to determine the annual benefit received from the old product (B_0). Assuming that the annual benefit of the new product must equal the benefit of the old product and that the initial cost (Y_N), annual operating expenses (E_N), and depreciation (D_N) of the new product are known

(or can be estimated), the ROR of the new product can be determined from

$$Y_0 = \sum_{k=1}^{j} \frac{B_{0,k}(1-T)}{(1+ROR_{req})^k} - \sum_{k=1}^{j} \frac{(E_{N,k}+D_{N,k})(1-T)}{(1+ROR_{req})^k} + \sum_{k=1}^{j} \frac{D_{N,k}}{(1+ROR_{req})^k} \quad (1.48)$$

Blackman then introduced investment index S, which is determined by estimating the average initial investment in new product and then estimating the total assets of an 'average' firm; i.e.,

$$S = \frac{\text{initial investment x 100}}{\text{total assets of an average firm}} \quad (1.49)$$

Blackman's model provides insights into the causes of inter- and intra-industry differences in the dynamics of market growth of new products based on new technology. The concept of profitabilty and investment index should also be useful in establishing the criteria for selecting new products which can be expected to achieve high rates of market growth in the future.

1.3.6. Multilevel Substitution Models

Sharif and Kabir (211) state that existing mathematical models of trend extrapolation for forecasting technological change deal primarily with cases where a new product or technology replaces the old one over a period of time, in at least some portion of the market. However in the present era of rapid technological change, one can think of many examples where a particular product or technology is replacing an older one, while at the same time being replaced by a newer one. According to them this is a multilevel substitution process.

Figure 1.6 (page 49) illustrates different phases of a technological substitution process. If there are N products in the market at time t to satisfy a particular consumer need with the products moving into the market in a definite order starting from P_1 to P_N corresponding to the stages of technological development, then the principles of substitution can be stated as follows:

1. The oldest product in the market P_1 being technologically least advanced will lose its market share to all other products (P_2 to P_N).
2. The newest product in the market P_N being technologically most advanced will substitute over a period of time all other products (P_1 to P_{N-1}).
3. Any intermediate product P_X (where $2 =< X =< N-1$) will substitute older products (P_1 to P_{X-1}) while at the same time being substituted by newer products (P_{X+1} to P_N).

A market in which multilevel substitution is taking place can be represented as follows; the oldest product in the market, being technologically least advanced, will lose its market share to all other products. The newest product in the market, being technologically more advanced, will substitute over a period of time for all other products, while at the same time being substituted for by new products. Using combined Blackman, Fisher & Pry and Floyd's model,

$$\ln \frac{f}{(1-f)} + s \frac{f}{(1-f)} = a + bt \qquad (1.50)$$

hence the rate of substitution:

$$\frac{df}{dt} = \frac{b\, f\, (1-f)^2}{sf + (1-f)} \qquad (1.51)$$

where s = delay coefficient

If we consider parameter b to be a time dependent function designated by $b_1(t)$ and if we also assume that s is the time dependent parameter designated by a(t), the rate of substitution becomes:

$$\frac{d\, f(t)}{dt} = \frac{b_1(t)\, f(t)\, (1-f(t))^2}{a(t)\, f(t) + (1-f(t))} \qquad (1.52)$$

The dynamic coefficient a(t) will determine the path of the substitution curve under the influence of exogeneous factors. According to them a(t) should lie between 0 and 1. The proper functional form of $b_1(t)$ can be determined mathematically by

identifying the trend b using historical data up to different points in time with selected values of s. To forecast the effect of market share due to the technological change of any intermediate products, the model must be converted into an equivalent three-product system. All products earlier than the particular product in question are grouped together and treated as a single product. We can then forecast the market share of this complex product. Similarly all products newer than the product in question are grouped together and forecast in the same manner. The market share of the product in question, then, is 1 less the estimated market share of the group of old products less the estimated market share of the group of new products.

Figure (1.7), (page 50) shows a simplified diagram for three products multilevel substitution situation. The three products, P_1, P_2, and P_3 (in order of their appearance in the market) are shown as 'levels'. $R_{x.y}$ indicates the 'rate' at which the older product x is being substituted by the newer product y, and the arrows indicate the direction of gain in market share. The corresponding rate of equation can be written as:

$$R_{x.y} = \frac{b_{x.y}\, f_y\, (1-f_y)^2}{s_{x.y}\, f_y + (1-f_b)} \qquad (1.53)$$

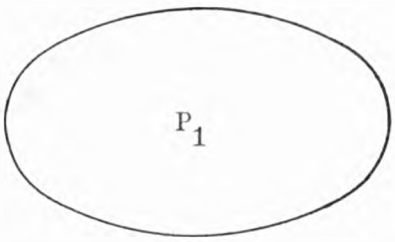
where $R_{x.y}$ = rate at which the older product x is being substituted by newer product y

Sharif and Kabir used a system dynamic computer program DYNAMO to simulate the rate of substitution of piston by turbo-

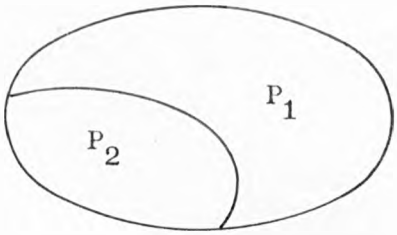
jets, and piston by turbo-props. The result indicates that irrespective of the number of products that are competing in the market simultaneously, the oldest product will lose its market share to all other newer products and the newest products will gain market share from all other older products. More interestingly their substitution process follow the familiar S-shaped logistic curve.

figure 1.6

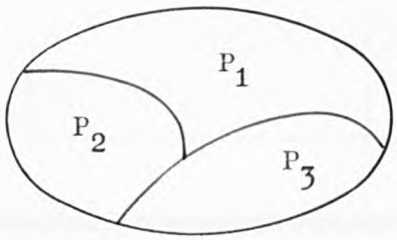
Schematic diagram of the Process of Multilevel Substitution



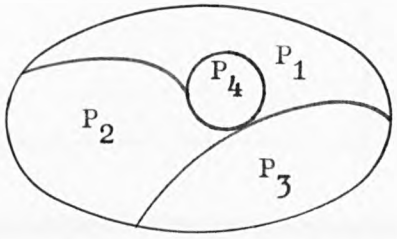
$t = t_1$: A single product P_1 is satisfying a particular consumer need



$t = t_2$: A second product P_2 is substituting the older product P_1. (one to one substitution)



$t = t_3$: A third product P_3 is substituting older products P_1 and P_2; P_2 is substituting older product P_1 but also being substituted by newer product P_3; P_1 is being substituted by later products P_2 and P_3.
(Multilevel substitution)

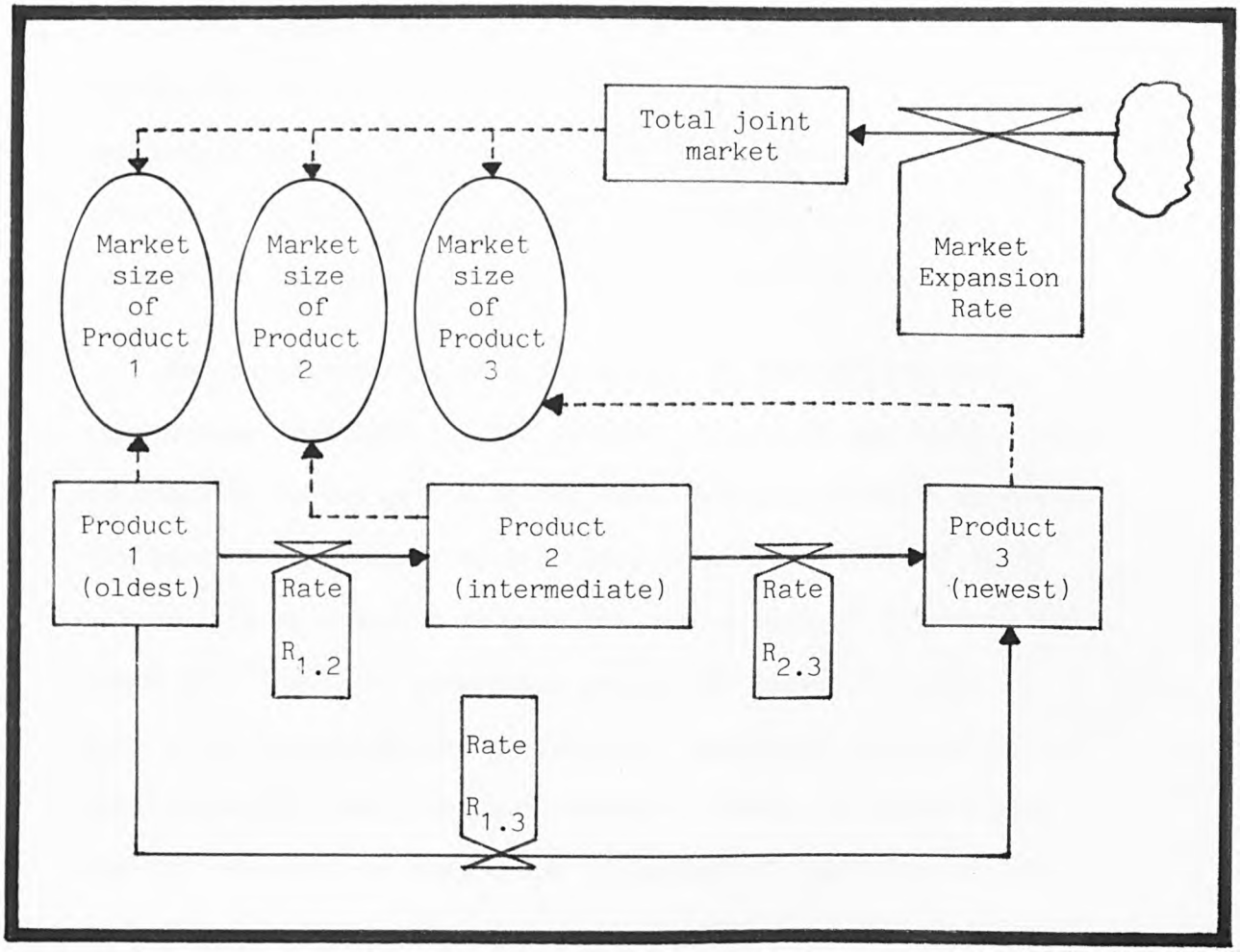


$t = t_4$: A fourth product P_4 is substituting P_1, P_2, and P_3; P_2 is substituting P_1 but being substituted P_3 and P_4; P_3 is substituting P_1 and P_2 but being substituted by P_4; P_1 is being substituted by P_2, P_3, and P_4.
(Multilevel substitution)

from: Sharif and Kabir (211)

figure 1.7

Simplified basic structure of the Multilevel Substitution Model



from: Sharif and Kabir (211)

1.3.7. Energy Substitution Models

Marchetti (159) in his energy-strategy research looked at the past history of energy consumption to see whether stable patterns and trends could be detected, in order first to use them as inputs for extrapolations, and second to cross-check scenarios and models over them. The data show that a good part of the growth of fossil fuels is due not to an increase in energy consumption but to substitution of fossil fuel by non-fossil fuel.

Marchetti reported that the growth of the world's fuel consumption from 1860 to 1950 is about 2 percent per annum. This is compared to the growth of the world population which is about 1.5 percent per annum. On the other hand United States' fuel consumption is reported to have grown at a rate of 3 percent per annum with 2 percent population growth per year. In order to make a methodological energy-forecast, Marchetti observed the conversion-efficiency at which energy is used. He cited Fisher and Pry' research on market and technological substitution (78), and looked at the growth of mechanical efficiency from 1700 to around 1960 and used a time dependent growth in efficiency of ammonia production from Slesser (212). The typical pattern of efficiency growth is shown in figure 1.8, page (53).

Marchetti shows that there is a similar behaviour pattern between the growth of primary energy consumption and substitution process. His conclusive results indicated that using data before 1935, he was able to forecast the fractional market share of oil in the United States up to 1970 with a precision better than one

percent. This is shown in figure (1.9), page (54).

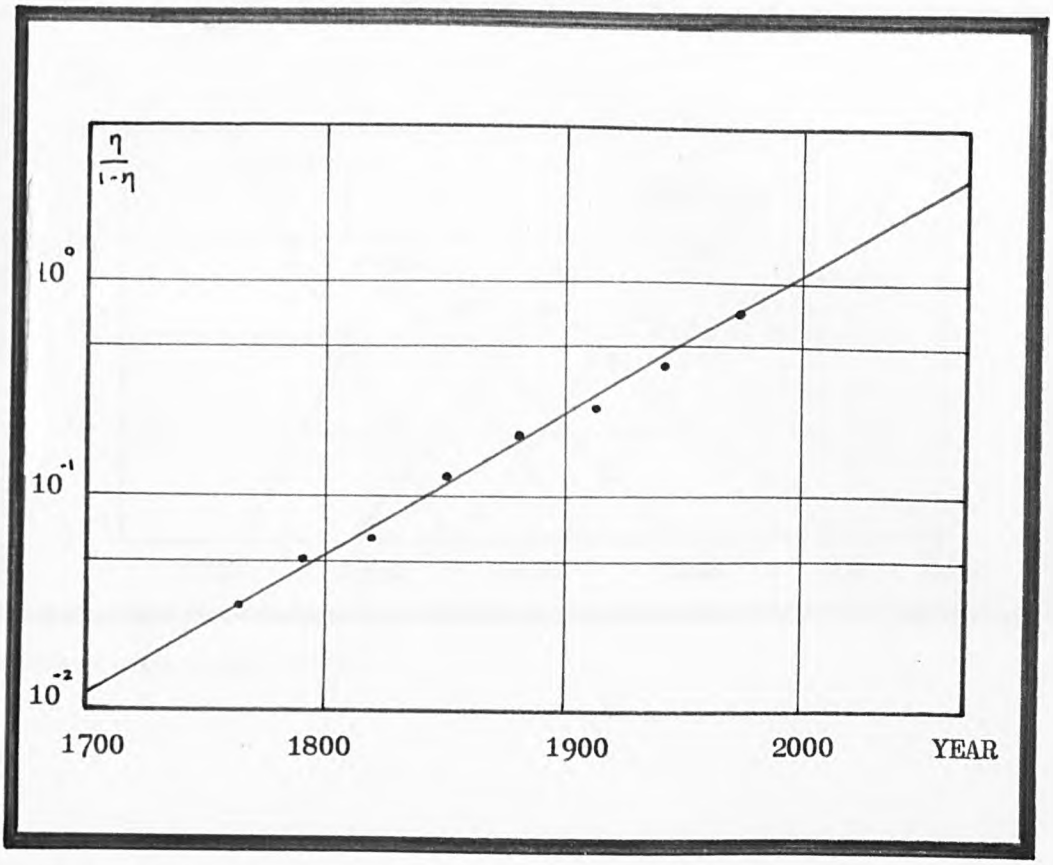
Marchetti argues that if a 'new' coal industry were started now, it effect would not be to stop the growth of nuclear industry now but at some distant time, probably about a century from now. If that is the result of a new thrust in the coal industry, is it worth it?. It certainly is not the objective in mind by those who point to the immense reserves of the coal as a way of avoiding nuclear power. In his analysis he points out that only way to curb the nuclear industry (if one wants to) is to start a new energy sector, which he calls SOLFUS (Solar and Fusion).

Marchetti looked at how SOLFUS affects both the United States as well as world energy consumption. His result is presented in figure (1.10), and figure (1.11) page (55 and 56). Assuming that there would be new SOLFUS at around the year 2000 in U.S.A., the gas consumption is reduced by the amount shown by dotted line. Similarly the world market consumption of oil and gas could have been reduced by speeding up the neuclear program.

The very stable trends he shows, and in particular that of primary energy substitution, with its broad base of parallel example in the market at large, appear to go unscathed through economic depressions, wars and central planning. His result certainly brings a new dimension on long range energy planning. His substitution model clearly shows that there is a certain advantage in coming late, because doubling occurs at shorter time intervals as the new industry tends to be more brisk and aggressive than the old.

figure 1.8

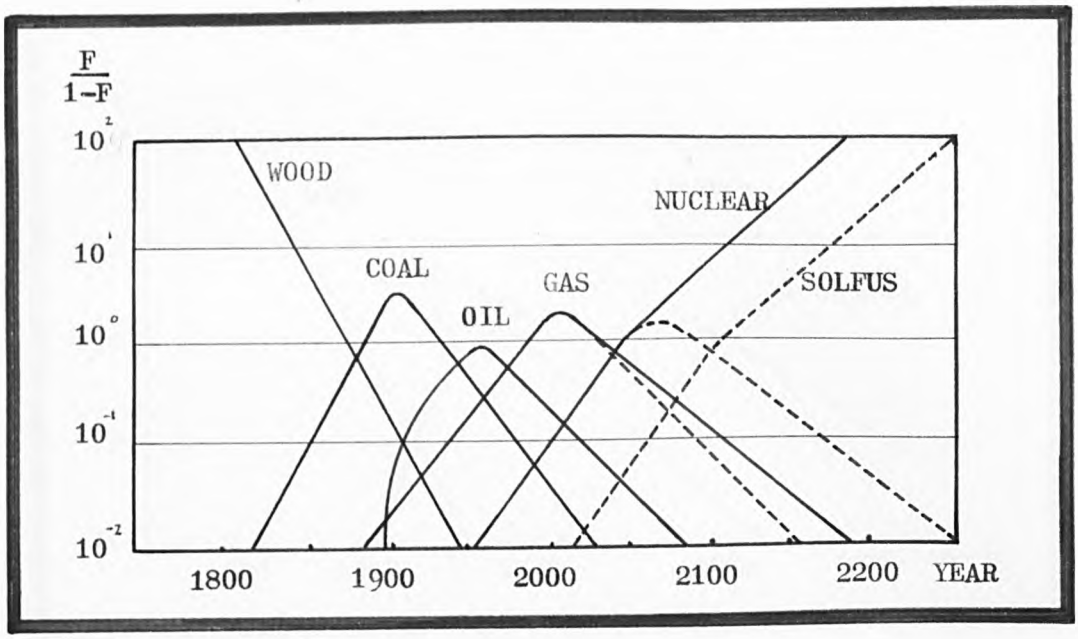
Efficiency of Prime Movers



source: Marchetti (158)

figure 1.9

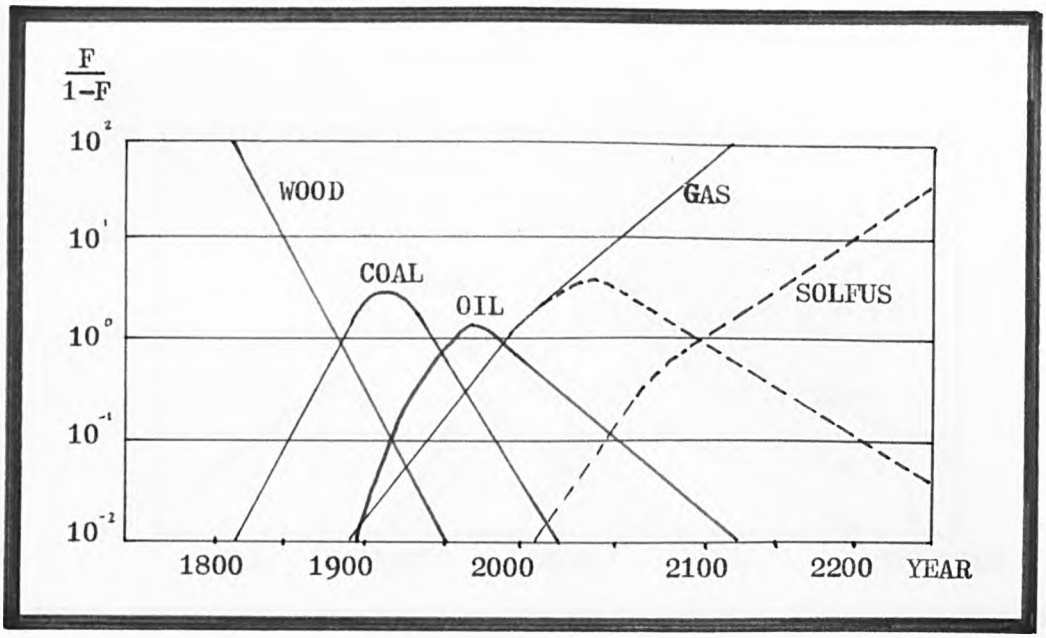
U.S. Energy Consumption



source: Marchetti (158)

figure 1.10

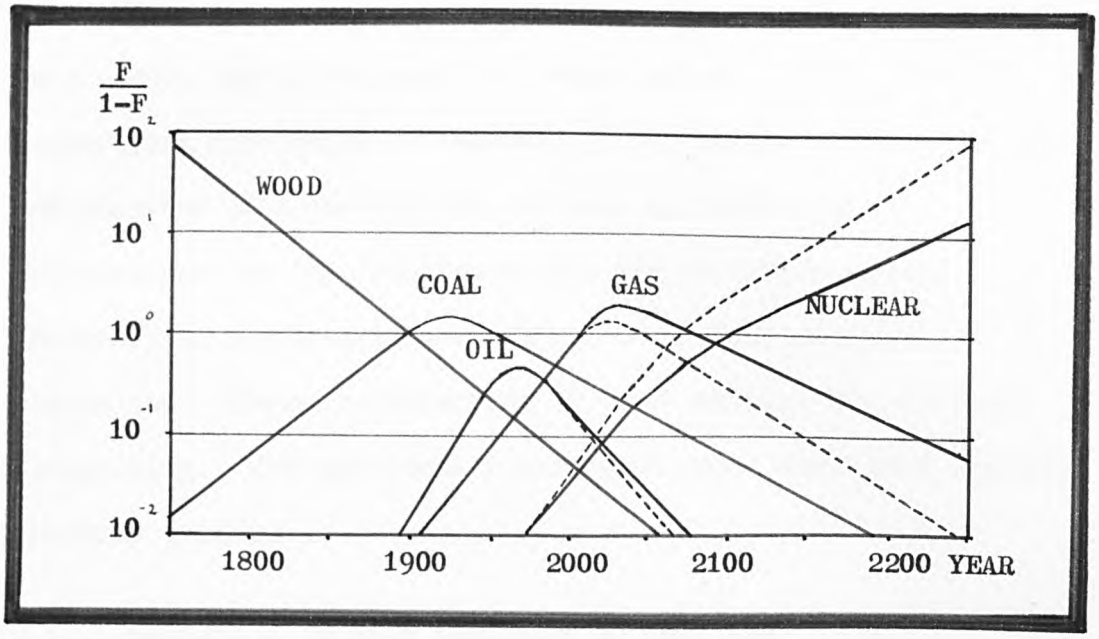
No Nuclear Energy and New Coal at year 2000 for U.S.



source: Marchetti (158)

figure 1.11

The Effects of Speeding up World Neuclear Program



source: Marchetti (158)

1.3.8. Evaluation of Logistic Growth Models

Table (1.1), page (59) summarises the logistic models which are widely applied to describe technological growth. The underlying hypothesis of logistic growth models is that the rate of adoption of a new product, process or technology is proportional to the fraction of the old one still in use. Secondly this method is basically a trend extrapolation technique. The main attraction of these methods lies in their simplicity. They are ideally suited to cases where data are not readily available.

However, it is very important to note that forecasting based on these simple methods (i.e. trend extrapolation) implies the cetaris paribus assumption. This can be a serious handicap in the case of a significant change in the exogenous factors that influence the course of substitution. What is needed therefore is a model that is both dynamic and adaptive in nature.

Much of the literature on technological change and substitution focusses on how they behave through time. This can be represented by an input-output black-box diagram as shown in figure (1.12), page (62). The question why the change should continue in the first place has been generally neglected. It is one of the most commonly noted empirical regularities that the diffusion of technology follows an S-shaped pattern. However, no attention has been paid to the question of the mechanisms inside this black box. This is therefore the area which urgently needs

to be explored in order to provide a better understanding on the nature of technological change.

Although the substitution model is a very powerful tool, most of the substitution models only deal with one technology or account for technological behaviour only at a micro level. Marchetti was the first to attempt to use this technique at a higher level (energy industry in general). Obviously the application of this technique at a macro level is much more complex and demands a global approach to the problem. One way of overcoming this problem is by the modelling and reduction method as described later (section 1.5).

table 1.3

SUMMARY OF LOGISTIC AND SUBSTITUTION MODELS

Model	Variables and constants	Main Characteristics and Applications
Pearl $\frac{1}{f}\left(\frac{df}{dt}\right) = c\,(1 - f)$ ref. (182)	f = proportion of yeast at time t c = constant	-Biological growth in a fixed environment. -Basic form of logistic equation
Fisher & Pry $\frac{f}{1 - f} = \exp 2c\,(t - t_0)$ ref. (78)	f = market share at time t t_0 = time at which substitution is half complete c = constant	-Market substitution over wide range of cases -17 cases of market substitution -Assume fixed upper limit -Could give over-estimate forecast
Blackman $\ln \frac{f}{F - f} = c_1 + c_2\,t$ ref. (27)	f = market share of a product at time t F = upper limit of market share c_1, c_2 = constants	-Market substitution over 12 innovations -Consider of profitablity factor -Could give over-estimate forecast
Floyd $\ln \frac{f}{F - f} + \frac{F}{F - f} = c_1 + c_2\,t$ ref. (79)	F = upper limit of market share f = market share at time t c_1, c_2 = constants	-Logistic growth in improved functional capability -Assume upper limit of functional capability -Probabilistic approach -Case study on maximum speed of propeler driven aircraft -Could give underestimate forecast

SUMMARY OF LOGISTIC AND SUBSTITUTION MODELS

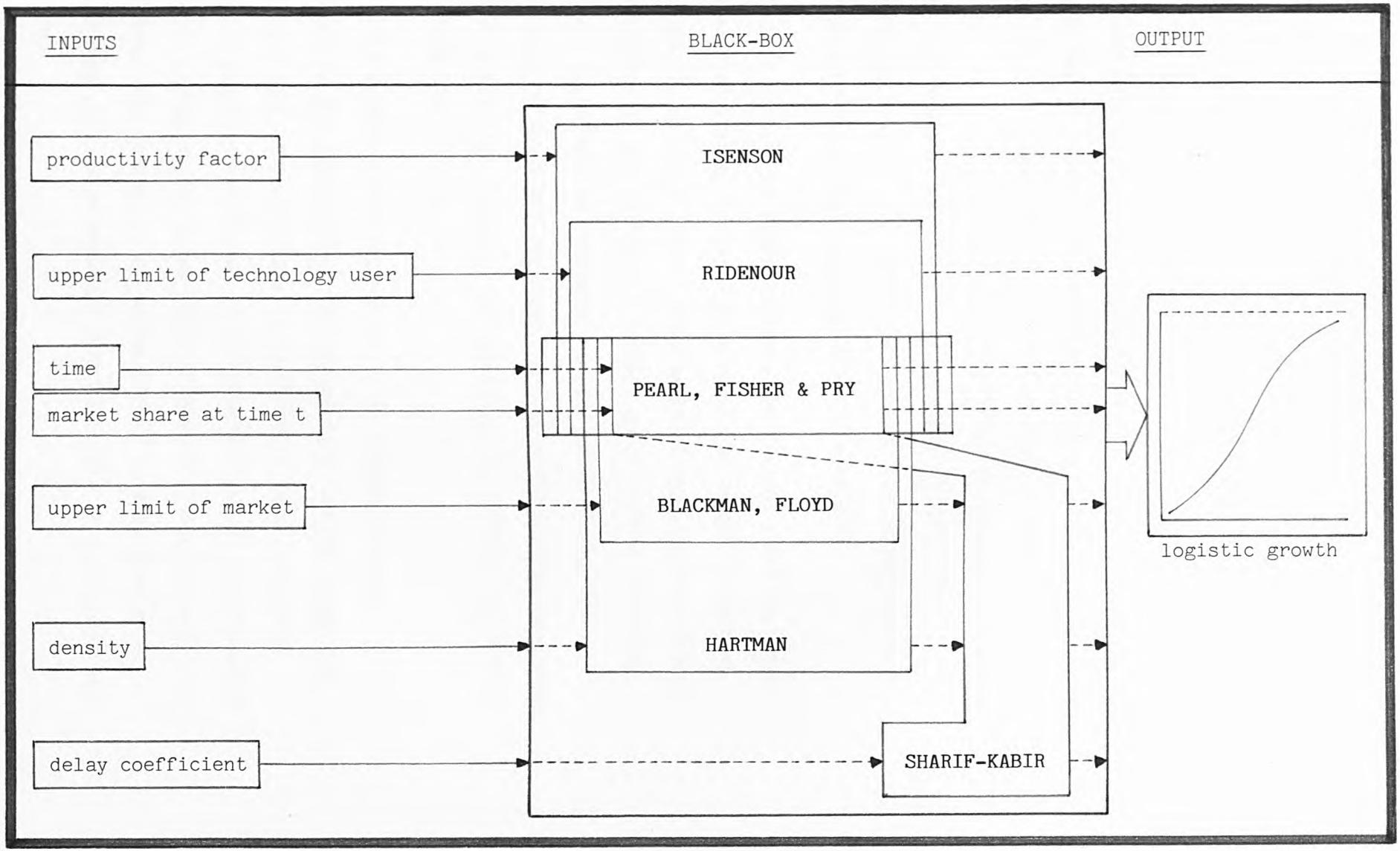
Model	Variables and constants	Main Characteristics and Applications
Sharif & Kabir $\ln\left(\frac{f}{1-f}\right) + s\left(\frac{1}{1-f}\right) = c_1 + c_2 t$ ref. (211)	f = market share of product at time t s = delay coefficient c_1, c_2 = constants	-Correction on Blackman, Fisher and Pry's model (under-estimation) and Floyd's model (over-estimation) -Case study on substitution of power for sail in marine market, diesel and electric for steam locomotives, and metal for wood -Subjective valuation for delay coefficient
Ridenour $N(t) = \frac{1}{1 + \left(\frac{L}{N} - 1\right) e^{-bt}}$ ref. (119)	$N(t)$ = number of people exposed to the new technology at time t L = upper limit to the potential technology users b = constant	-Model of technological utilisation -Assume fixed upper limit to technology
Isenson $I = L\left(1 - e^{-\frac{qN_0}{cL} e^{ct}}\right)$ ref. (118)	I = amount of information (state of knowledge) t = time q = average productivity factor per scientist and time unit N_0 = number of scientists at time $t = 0$ c = constant L = upper limit of information I	-Model of information growth -Case study on papers published on laser - maser technology and commercial computers -Ability to measure information gain without assuming its upper limit

SUMMARY OF LOGISTIC AND SUBSTITUTION MODELS

Model	Variables and constants	Main Characteristics and Applications
Hartman $I = \dfrac{L}{1 + \left(\frac{L}{I_0} - 1\right) e^{-bt}}$ ref. (119)	I = amount of information (volume density in information molecules) I_0 = information at time $t = 0$ L = upper limit of information I	-Analogy of technological growth to reaction process is a gas -Weak assumption on: 1. Ideal communication between all scientist - investigators 2. Every oportunity can in fact be exploited -Similar to Isenson's model

figure 1.12

BLACK-BOX MODEL OF LOGISTIC GROWTH MODELS



1.4. Models of National GNP-Energy Growth

1.4.1. Introduction

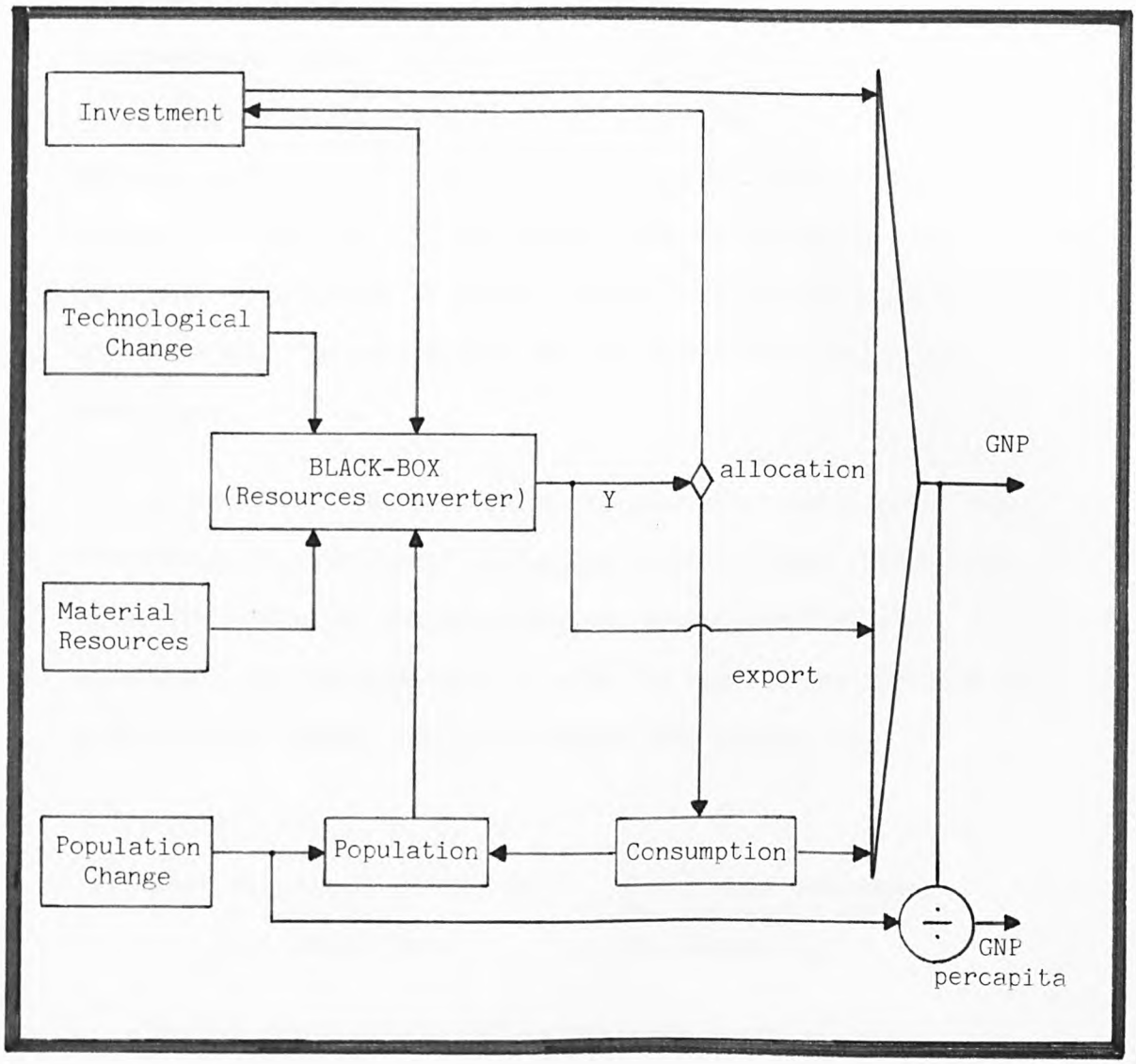
The relationship between GNP and primary energy consumption has been well known. This is surveyed in section 1.4.2. The nation may be viewed as a resource converter, that is a 'black-box' which consumes inputs in order to produce outputs. To the economists this 'black-box' is a converter of labour, capital, and other economic variables into monetary output. The engineers, however, are interested more on the mechanisms and performanceof national resource-converting machine.

This machine is represented by the capital stock to which new machinery is being added as a result of annual investment (figure (1.13), page (64)). The result of the labour-machinery combination is the net output Y (GNP) which is then allocated between investment and consumption, the latter being the enjoyment of goods and services. A production system, of course, requires material resources to operate on to produce the outputs of goods and services.

The modern industrial nation is so technologically structured and dependent on technologically derived goods and services that it is possible to think of it as a conversion process subject to the laws of thermodynamics. We can therefore look on energy as the prime mover of modern industrialised nations. The importance of energy should be even greater as technology plays more and more important role in this conversion system.

figure 1.13

Production process of the nation



1.4.2. Concept of energy as a Substitute for Capital in the Growth Model

Chenery (52) in his paper wrote; 'To the economist, production means anything that happens to an object or set of objects which increases its value. Usually this results in a change in form, but it may be merely a change in space or time. The basic physical condition necessary to effect any of these changes (except the last) is that the energy must be applied to the material. Application of energy in some form is one element common to both the economist's and the engineer's concept of production.

To economists the production function provides a useful way of reducing the factors of production to their basic components. Using the concept of the neo-classical production function (equation 1.1), and combining it with the engineering approach to technological change, Georgescu-Roegen (88) suggested;

$$y(t) = f\ (\ K, L, E, M, T) \qquad (1.54)$$

where y = output at time (t)
K = capital
L = labour force
E = energy consumption
M = material resources
T = technology

Capital can be considered as the money spent on land, equipment, and plant. Plant, equipment and machinery must be made available somewhere, using prior production process. This process of networking back to the primary inputs reveals that capital in a physical sense is no more than the accumulation of prior inputs of labour, material, energy and technology.

Labour is reproducible (procreation), trainable, and flexible. It is a renewable resource which can be upgraded to cope with the existing level of technology. On this basis we can classify the labour force as manual labour, skilled labour and decision makers. Historically manual labour provided the energy input to the production system. However in most industrialised countries now external energy has almost completely taken over this function.

Material resources have a special role in the production system, for they are never consumed, only transformed (Law of conservation of matter). For example when iron ore is turned into iron, and then into steel, and then into, say, a car, it is still in the form of iron, and remains so even when finally the car finds its way to the scrapyard. Material resources therefore may be redistributed, change form, be discharged as waste products, but they are not consumed (except for nuclear process involving conversion between energy and matter).

In an advanced industry the level of energy consumptionis a measure of the scale of industrial, commercial and domestic activity as all capital plant is converted material via the application of energy, and most industrial, transport, commercial and service activities use energy in some form to generate the activity. Thus the capital stock of an industry represents "stored energy", and the activities generating new capital also require energy. Consequently the energy consumption of a national industry (E) can be used as an indicator of the aggregate and change in capital stock K.

1.4.3. Relationship between energy and GNP growth

Recently many researchers have taken a greater interest in the overall causal relationship between the economic and technical development. Perhaps this engineering perspective began to seem a more promising approach to the management of technological change since the discovery of a strong indication of the relationship between GNP and energy consumption. Olson (180) experimented in 1948 with a formulation of the Cobb Douglas production function that substitutes energy for capital. He concluded that energy is an index of a certain kind of capital, namely energy consuming capital of all kinds measuring different ways of the productive apparatus of society. Mason (168) concluded that no country can enjoy a high per capita income without becoming an extensive consumer of energy. A year later Robinson and Daniel (191) not only successfully related per capita income with per capita consumption 1949, but also related the changes in primary fuel consumption and manufacturing production, 1939-1950, for selected countries in North America and Western Europe.

In addition a number of other scientists have attempted to make broad estimates of the relationship between per capita GNP and per capita energy consumption. For instance, Kindleberger (128), suggests that the rate of energy consumption accelerates as development gets beyond $ 200 per capita income. At the other end of the scale Graham (99) states that 'as consumption rises above about 4 TCE per capita the rate of (energy) growth is invariably slower'.

A particularly interesting idea was the use of energy consumption as a proxy variable for capital. Frankel (85) suggested the use of horsepower / worker ratio to provide a substitute for the lack of capital data for these comparisons.

Frank (84), using measures of capital data available for USA and UK between 1880-1948, correlated energy consumption and the industrial capital stocks for these two countries. In both cases he found a very high correlation as well.

1.4.4. Generalized Production Function

Millendorfer and Gaspari in their paper 'Formulation of a General Production Function' (174) attempted to explain the residual factor in production function by looking at the quality of labour, education and investment in intelectual capital.

According to Millendorfer and Gaspari, the most important factors in determining any country's performance are capital, education and structure. In cybernetic terms this can be interpreted as: a country's economic output is determined by its energy (capital) and information (education) processing capacity and by the way the system is organized and the goals it is heading for.

The relationship between percapita income (output) and its capital (energy consumption percapita) can be summarised as:

$$y = k_1 \, m^{1/2} \qquad (55)$$

where y = percapita income

k_1 = constant

m = electricity consumption percapita

Fitting world data between 1951-1965 on the above model, they observed a very good correlation (0.9385).

They also observed the empirical relationship between percapita income and literacy rate (as an indicator for education). This relationship can be described as:

$$y = k_2 \, e^{cb} \tag{56}$$

where y = percapita income

c, k_2 = constants

b = literacy rate (indicator for education)

In their experiment, they divide the world into groups of countries. The result on fitting the equation (56) into these data is described in table (1.2), (page 71).

Through the two models above Millendorfer and Gaspari were able to to show the difference in each country's capability to use capital and education for the purpose of producing economic output. They observed that the most efficient countries seemed to comprise mainly Protestant countries (North Western Europe), followed by essentially Catholic, Orthodox, and former Christian countries of the Middle East and North Africa, the least efficient being Hinduistic and Buddistic countries such as South East Asia.

They conclude that the national economic structure seems to

be strongly influenced firstly by differences in the behaviour patterns, the values, the motivation of the people, and secondly by the way the society is organized. Thus the structure reflects the goals the societal system is aiming at and the way it is organized. Combining the two models ((55) and (56)), Millendorfer and Gaspari summarize the Generalized Production Function:

$$y = p_z \, m^c \, e^{kb} \qquad (57)$$

where y = income percapita

p_z = efficiency parameter

m = energy consumption percapita

b = education indicator

c, k = constants

A very high correlation between the observed and the calculated income percapita (**y**) was demonstrated. This is summarised in table (1.3), (page 71).

table 1.4

Table of Education - GNP result from Millendorfer-Gaspari

model : $y = k\, e^{cb}$

y = income percapita

b = literacy rate (indicator of education)

Groups	k	c	Countries
1	125	1.9	East Europe and South Europe
2	130	2.0	North Africa, West Asia
3	105	1.8	Central America, South East Asia, South West America
4	500	2.4	East Asia, South West Pacific.

table 1.5

Empirical Result from Generalized Production Function

model $y = p_z\, m^c\, e^{kb}$

where y = income percapita

p_z = efficiency parameter

m = energy consumption percapita

b = education indicator

Countries	p_z	c	k	corr. coef.
South East Europe	57.5	0.33	0.95	0.984
Central America South East America	52.0	0.22	0.78	0.975
Europe	62.2	0.22	0.82	0.99
South America	52.6	0.22	0.82	0.99

1.4.5. Discussion

Although there are many strong indications between energy and GNP relationship, there are a number of things which are unsatisfactory. Firstly some nations seem to be more efficient in energy utilisation than others. From the GNP - Energy relationship alone one cannot decide whether higher productivity is a function of having more energy or whether higher energy consumption arises from increased production. Some economists even question whether there is any causal relationship at all !.

Of all the primary inputs to the economy, energy is perhaps the one about which we have least certainty as to its future prices. Yet the direction of the future prices of energy, in real term and relative terms is fundamental to our economic planning. One simply cannot get a satisfactory solution by methods of trend extrapolation of regression analysis of historic GNP-Energy relationship.

The GNP-Energy models all assume that no matter what energy costs the production system has no other option but to consume fuel (energy). Surely there is an urgent need to look closely at the validity of the above assumption and its implications. The Generalized Production Function proposed by Millendorfer and Gaspari provide a significant step foreward in the right direction. They combined the concept of the engineering approach (GNP-Energy) and the economist's approach (GNP-Education). The fact that there is an education factor in the economist's

residual (technical change) shows that it is the path along which the problem of technological change can be exploited.

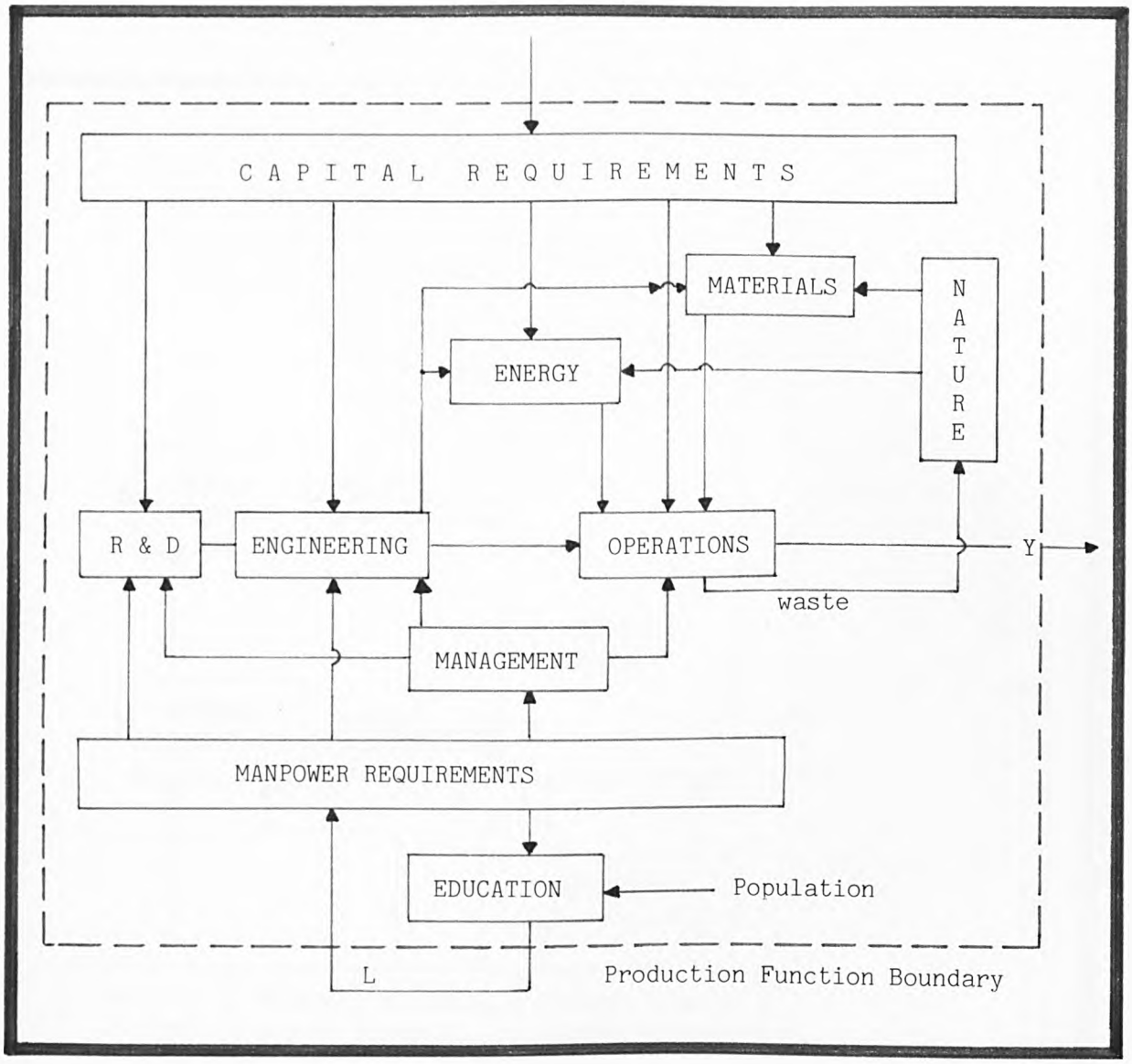
1.5. Integrated Model of Technological Change

1.5.1. Introduction

During 1976, Prof. M'Pherson started a program to study mechanism of Technological Change while working at IIASA, Austria, where he met Marchetti, Millendorfer, and Peterka (two are reviewed in this thesis). M'Pherson's objective was to break up the production function into a fine detail dynamic model that would represent the socio-economic-technological process called Technological Change (TC) (164). The basic structure of the model starts from an internalisation of the production function (figure (1.14), page (75)), and develops into a model of the "system of technological change", figure (1.15), page (76), called the Integrated Model of Technological Change (IMTC). The relationship between IMTC and economic model may be described in figure 1.16 (page 77). Thus IMTC is complementary to an economic model because it uses economic inputs and it may be used as the input to economic planning models. To deal with a very high dimensionality in such a model Prof. M'Pherson introduced the concept of a technological vector in an Euclidean technological space. This provided the essential basis for the efficient manipulation of as many variables as necessary. Furthermore the variables of technological and other related factors can be normalised to a scale of 0-1 by introducing a generalised basis of the efficiency of energy, material, and labour conveniently in in a technological sector, and hence by projection into the national technology (figure (1.17), page (78)).

figure 1.14

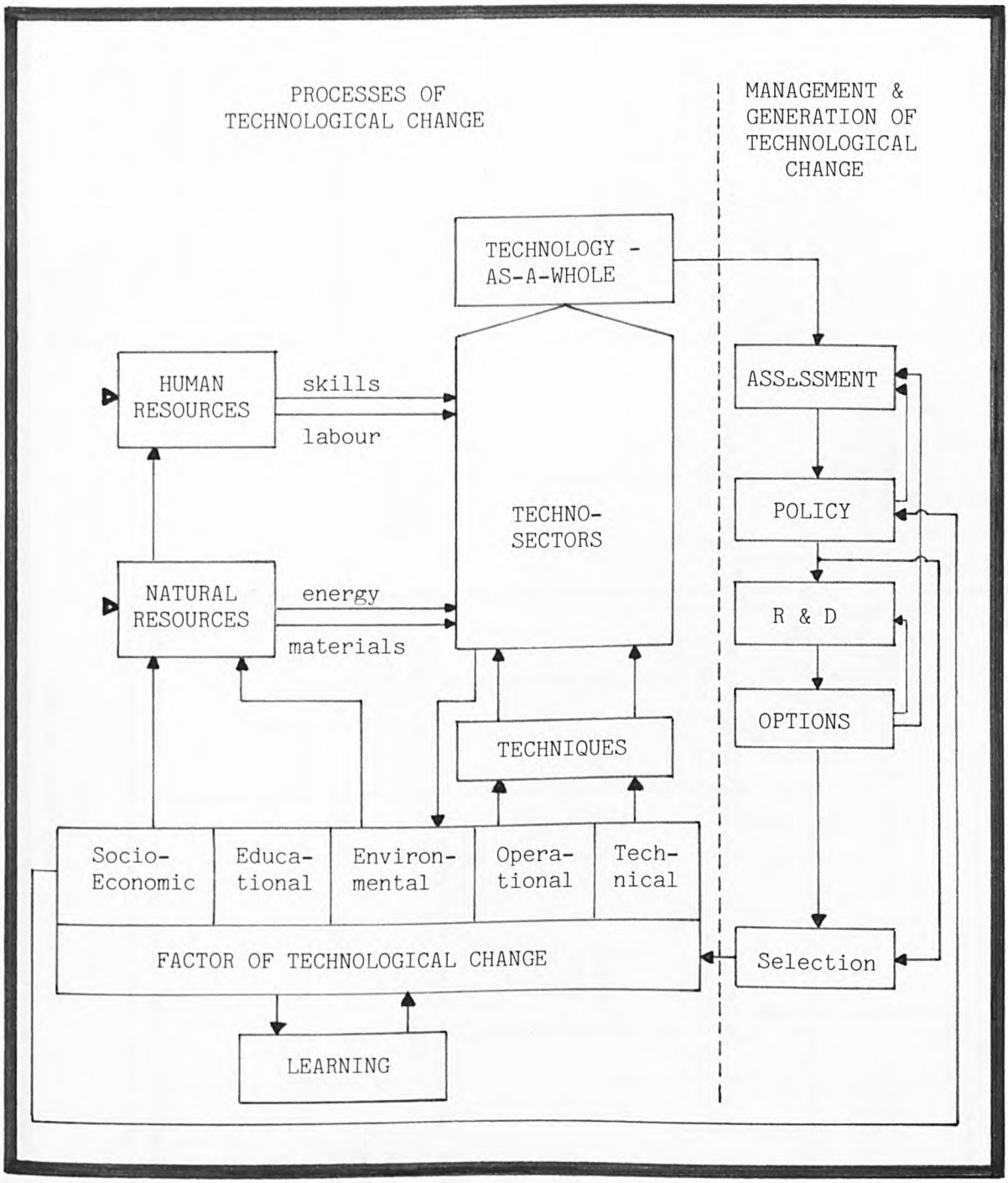
Internal Processes of the Production Function



source: M'Pherson (164)

figure 1.15

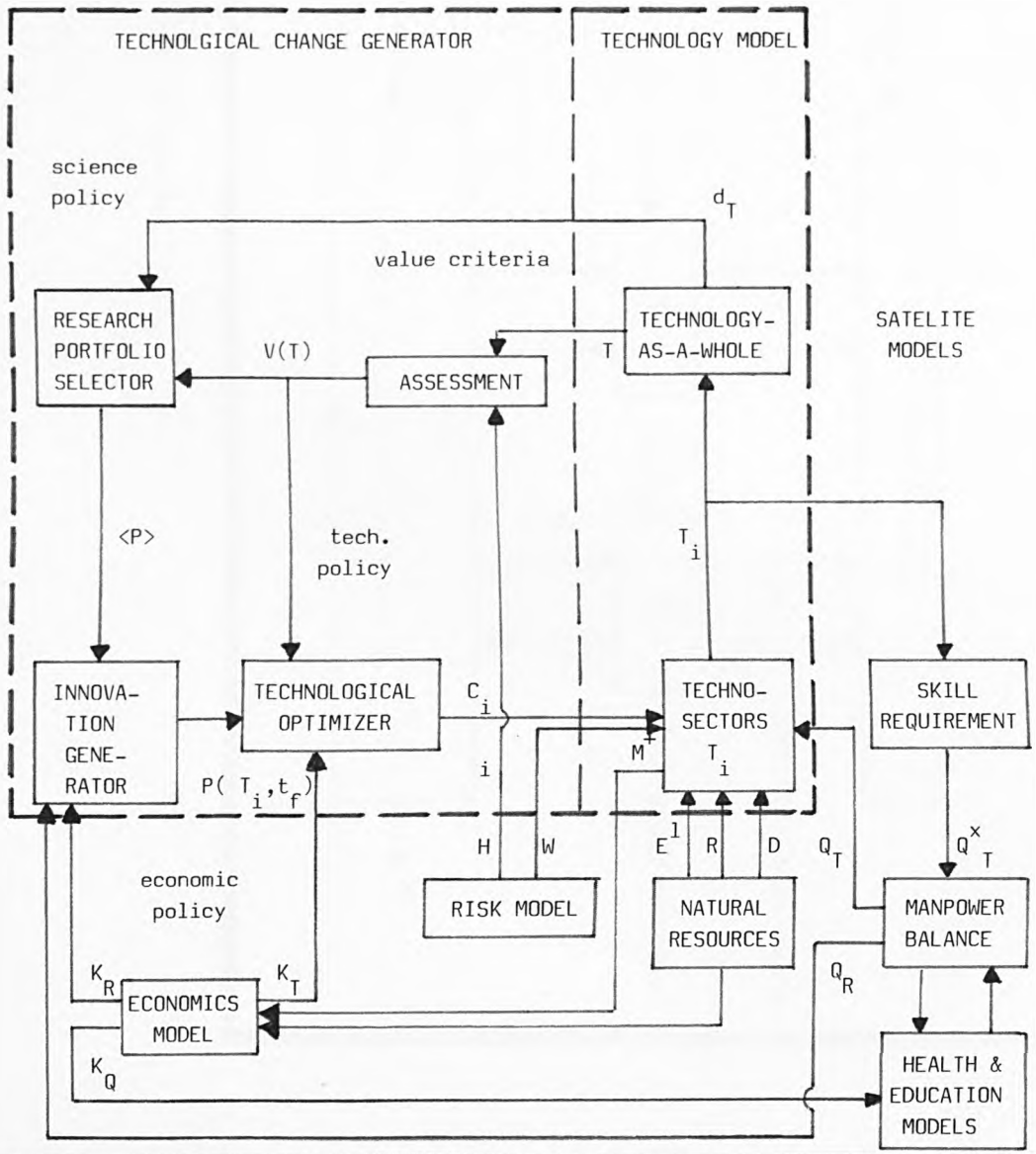
System of Technological Change



source: M'Pherson (164)

CORE MODEL OF IMTC

figure 1.16



NOTATION

TECHNOLOGY

$T_i = \langle {}^{k}_{i} \rangle$, sectoral technolgy vector with efficiency elements

${}^{k}_{i}$ = efficiency of sector i with respect to resource k

$T = \langle T_i \rangle$, Technology State Vector

d_T = distance of T from ideal T*

$M+$ = upper production limits of sectors

W = waste from sectors

TECHNOLOGICAL CHANGE GENERATOR

$V(T) = f(T,H\ V)$ = value of technolgy

$\langle P \rangle = f(SP, V(T), d_t)$ = optimal research portfolios

$p(T_i, t_f)$ = probability of improvement in sector i by time t_f

$C+_i$, $+_i$ = inserted new upper capability & efficiency limits for sector i

SATELITE MODELS

E^1 = primary energy vector

R = primary material vector

D = vector of depletion functions

K_T, K_R, K_Q = capital allocations to techn. research & manpower

Q^x_T = manpower requirement

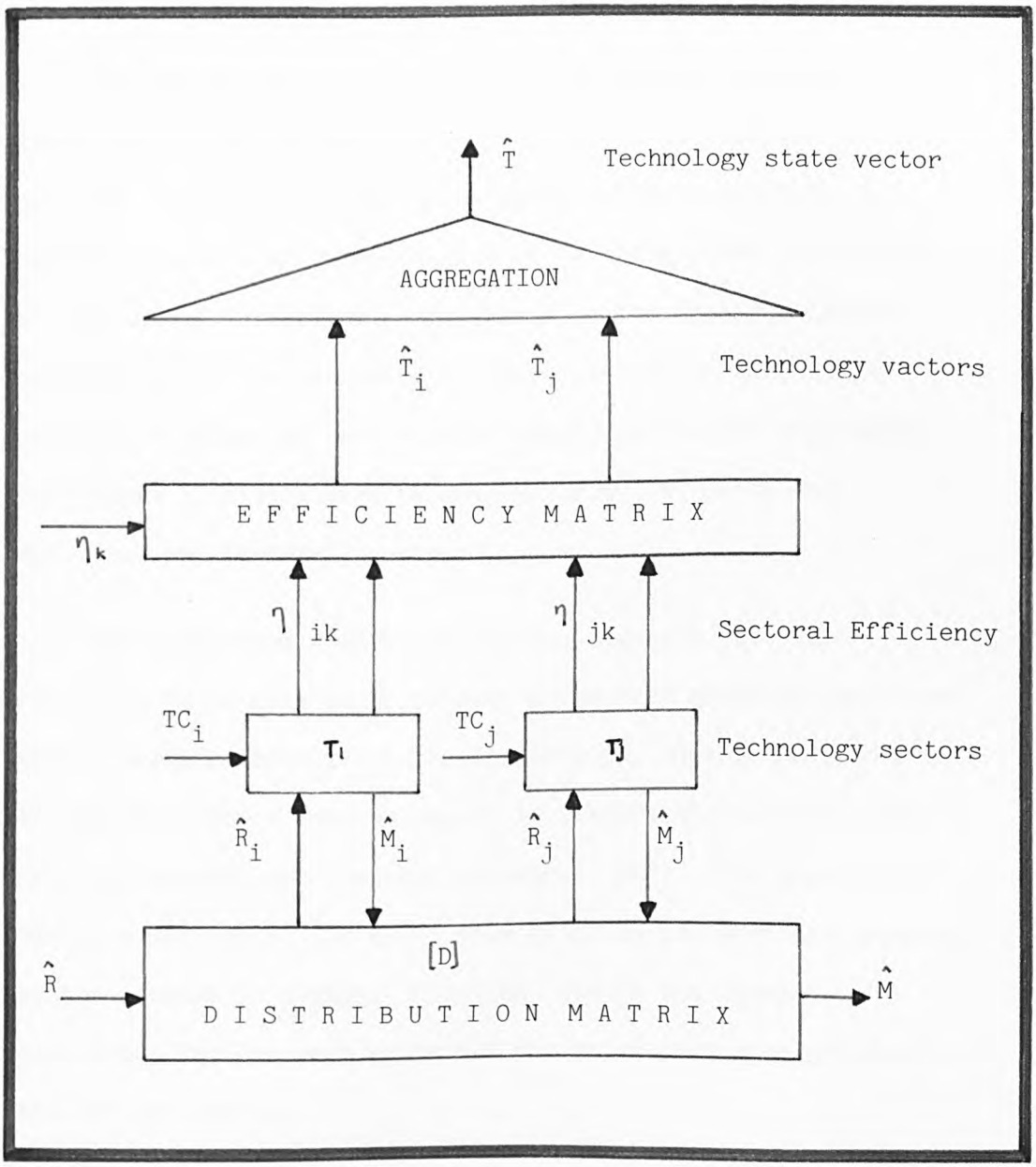
$Q_{T,R}$ = manpower supply to technology & research

H = environment hazard level

source: M'Pherson (164)

figure 1.17

Technology Model



source: M'Pherson (164)

1.5.2. The Engine Model of a Nation

A simplification of the idea in IMTC suggests that a nation can be considered as a resource converter. This is represented as figure (1.13), page (64).

The population increases at a given growth rate and a large part of the population (Labour force) is employed in the national engine. This national engine is represented by the capital stock to which new machinery is being added as the result of the annual investment. The result of the labour-machinery combination is the net output. There is also an allocation process of output by the decision makers within the population. The output is distributed between enjoyment of goods and services, and further investment.

The production system, of course, requires material resources to operate on to produce outputs of goods and services. These, whether imported or locally derived, have to be paid for. If imported, there must be export to balance the account, thus only net exports are credited to output (GNP). The quantity of GNP is a measure of the total flow of goods and services produced by the economy in a year. Dividing this by the average population for the year we obtain the rough indicator of benefit, the GNP per capita.

Human skill is the source of technological improvement, as well as efficiency improvement that lies behind economist's technical progress. This skill is evidenced through everyday experience, e.g. new technical capability, design, improvement in

machinery efficiency (of all sorts), and improvement in efficiency of energy use. The detailed development of the efficiency in labour, energy and material use is an important part of this thesis (chapter 3).

To test the concept of a nation as a resource converter, Prof. M'Pherson (164) tested the good correlation between primary energy use and GNP (section 1.4) and noticed that the time trajectory of each nation plotted against primary energy consumption and GNP coordinate altered in time is such that it seems to be logistic. This was interesting evidence that the national engine model might be valid, as the well documented logistic growth of technological capability and efficiency (Marchetti (159), Robert (190)) should also be applicable to a 'national engine model' (M'Pherson) (164).

1.5.3. The Gompertz Logistic Applied to Engine Model

The form of the logistic growth that correlates with the Energy-GNP growth of nation was examined in some detail by M'Pherson and Limantoro (167). Using a sample of 29 nations from United Nation data over a period of 1955-1977 extraordinarily high correlation high correlations were found with Gompertz logistic function (average correlation for the sample = 0.94), a much better result to M'Pherson correlation found earlier using Fisher-Pry logistic (164).

The Gompertz curve is slightly different form of logistic curve commonly known Pearl (182) or Fisher-Pry curve (78). (It is interesting to note that the ascription to Gompertz in technological literature is due to Martino (160), who first refers to the name Benjamin Gompertz (1779-1865) who was an English mathematician. According to the records available in the British Museum Library Gompertz did not invent the relationship nor use this logistic curve (Gompertz, (98))!). The so called 'Gompertz' equation can be described as:

$$y = a\, e^{-be^{-ct}} \qquad (1.58)$$

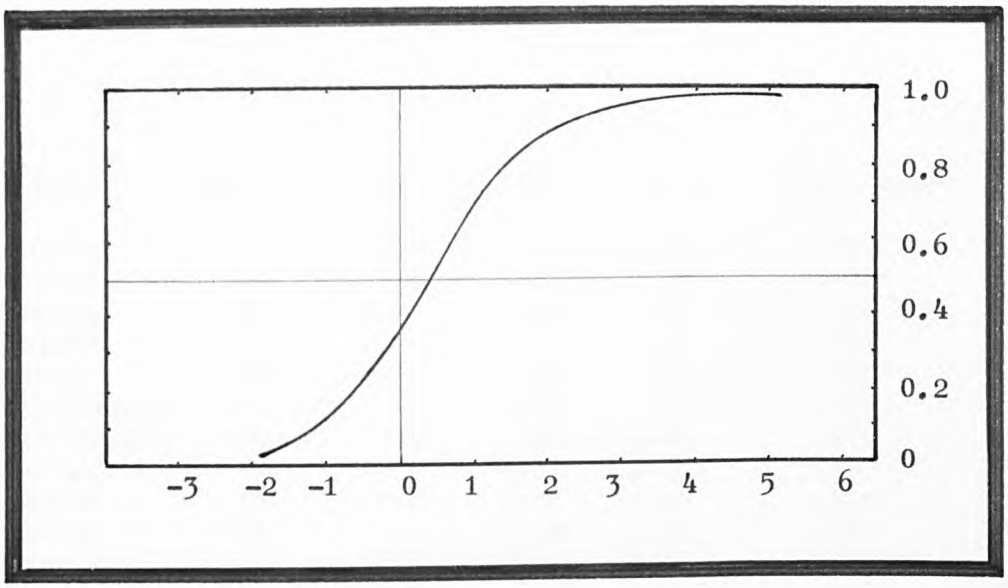
where a, b, c, = constants.

The typical Gompertz curve can be described as figure (1.18), page (83). The result of fitting the sample of 29 nations to the above equation is shown in table 1.4, (page 84).

The significance of the improved correlations using Gompertz was taken to be encouraging evidence that the "engine model" was a useful simplification of economic growth as it embodies technological change with it, in such a way that it may disaggregated as the components of technology vectors within IMTC.

figure 1.18

Gompertz curve



Characteristics:

$$y = a\, e^{-be^{-ct}}$$

where a = upper limit to the growth y

t = time

b, c = constants

(1). $y = 0$ at $t = -\infty$

$y = a$ at $t = +\infty$

(2). inflection point at $y = L / e$ or at $t = (\ln b) / k$

(3). curve is not symmetrical about its inflection point

table 1.6

Result of Gompertz Logistic Applied to Engine Model

model $y = a\, e^{b\, e^{c\,(v)}}$

country	a(min.)	a(max.)	b	c	corr. coeff.
Austria	150	200	.71	.17	.977
Belgium	144	164	.27	.75	.926
Denmark	260	-	-.40	.40	.940
Finland	120	180	.51	1.20	.981
France	170	240	-.03	.58	.969
East Germany	220	-	.50	.40	.971
West Germany	120	170	.63	1.00	.970
Greece	40	70	6.03	5.77	.950
Iceland	95	115	.81	1.00	.914
Ireland	250	-	-.48	.51	.933
Italy	52	100	3.36	4.03	.980
Netherlands	100	140	.84	1.18	.945
Norway	250	-	.20	.50	.980
Portugal	30	70	5.72	6.77	.957
Spain	42	50	4.56	3.73	.957
Sweden	290	1900	-.67	.24	.961
Switzerland	165	230	.09	.47	.960
United Kingdom	285	-	.20	.50	.680
United States	400	900	-.68	.27	.964
Australia	125	290	.19	.70	.980
Canada	175	184	.07	.67	.974
Japan	100	148	.78	1.11	.987
Bulgaria	167	485	.58	1.51	.986
Czechoslovakia	260	-	.20	.60	.964
Hungary	290	-	.05	.80	.920
Poland	100	200	.38	.75	.985
USSR	200	440	-.20	.60	.996
Romania	47	87	2.56	2.01	.952
Yugoslavia	30	96	3.98	2.89	.976
For the whole sample			-.387	-.902	.9408

source: M'Pherson and Limantoro (167)

1.6. General Format of this Research Programme

1.6.1. Introduction

The starting points of this programme were:

1. The problem of dimensional complexity if the dynamics of technological change within a socio-economic environment are to be studied in a non-trivial way (chapter 1.1).

2. The need to marry the macro-view of disembodied technical change as seen by the economists to the micro-view of embodied technological change as seen by the engineers (chapter 1.2.3).

The attack on (1) and (2) could be launched from:

3. The structure of an integrated model of Technological Change using a multi-dimensional vector space to carry the great dimensionality required (chapter 1.5.2).

4. The evidence that the IMTC model, in its reduced form as the national engine model, is a promising vehicle for the study of technological change in which human skill are taken as the gearing behind the rate of technological and economic growth (chapter 1.5.3).

1.6.2. Research Objectives

a. To establish a methodology for operationalizing the IMTC
   1. to establish the data base for technological, economic, and social factors.
   2. to obtain a satisfactory reduction method whereby this detailed database may be projected on to a finite number of axes defining "technological space".
   3. to provide a means of checking model validity.

b. To demonstrate the operational uses of the model of technological change resulting from (a).
   1. to operationalize the method of Factor Analysis as a means of reduction methodology.
   2. to interpret the results from b(1).

c. To demonstrate the effectiveness of this model as a forecasting aid for decision makers in science policy and research manpower.
   1. to relate the result of (b) to the engineer's process efficiency
   2. to relate the economist's technological change to the engineer's efficiency concept.
   3. to make a forecast model based on the process efficiency concept.
   4. to the forecast by the application of past historical data.

d. To conduct a research programme to achieve the degree of Ph.D.

1.6.3. Structure of the Thesis

The research boundary of this thesis can be described as figure 1.19 (page 88). Basically there are three major factors in the study of technological change, namely technology, socio-economic factor and its management and control. The technology factor itself can be described as a growth process of basic research and invention, diffusion and widespread implication of the technology. The effect of this technology on the socio-economic system can be monitored through the level of development, market forces, standard of living and pollution-to name a few.

The project starts by reviewing the concept of the 'engine model' and process efficiency model in chapter 1. The actual data are collected, organized, transformed and processed using the factor reduction method. The outcome of this reduction is a vector score in Euclidean space. The flowchart in figure 1.20 (page 89) shows the stages of this project. In chapter 3 the economist's rate of technical change and the engineer's rate of technological change are compared and examined. The overall relationship between process model conversion efficiency and socio-economic indicators is described in chapter 4 (figure 1.21, page 90). The analysis starts by comparing the economist's production function to the engineer's process efficiency concept. The socio-techno-economic indicators are related directly to the engineer's performance indicators. The direct outcome of this relationship is a time series model which can be used as a forecasting aid.

figure 1.19

AREA OF RESEARCH-INVESTIGATION

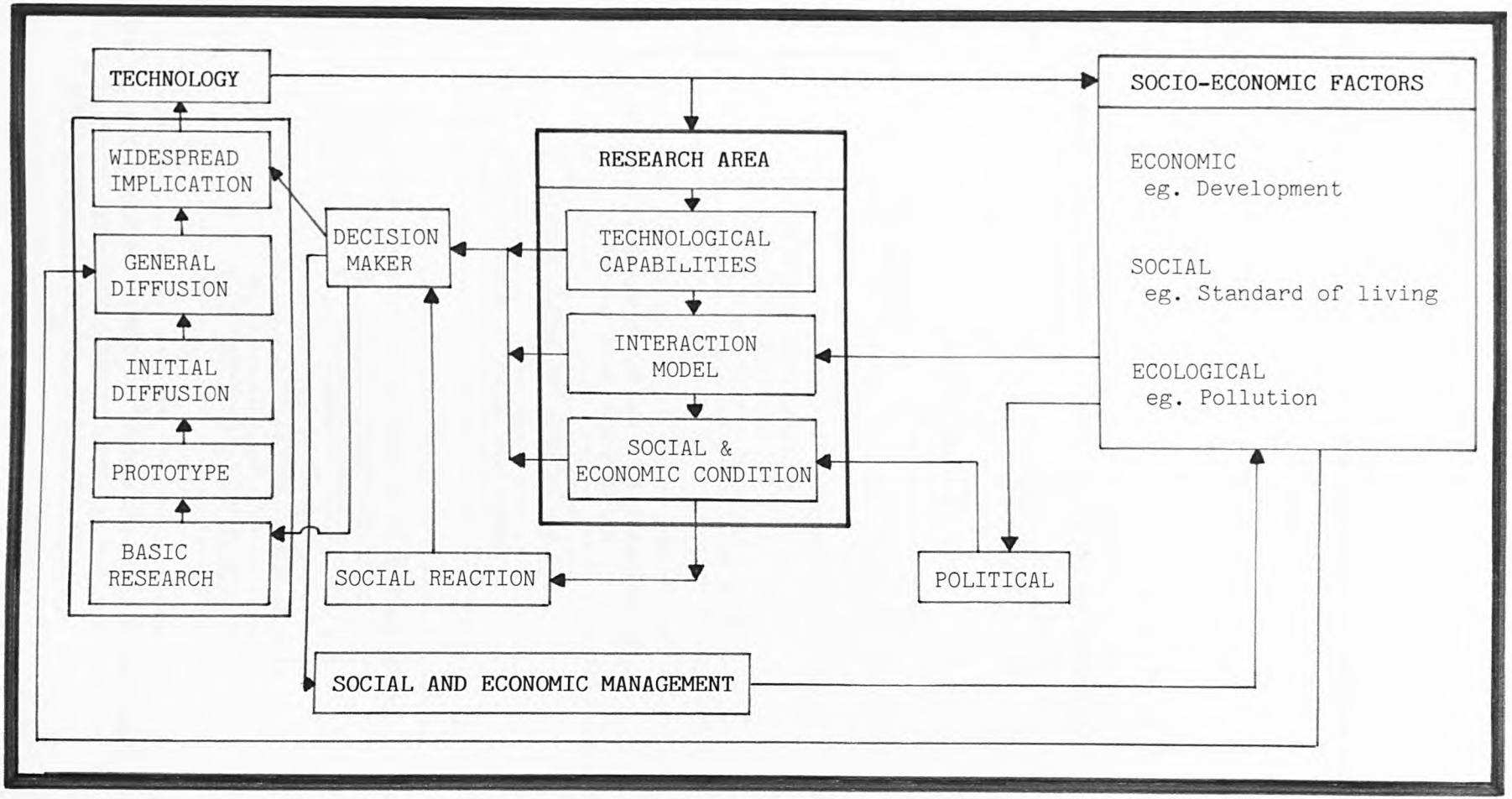


figure 1.20

PROJECT FLOWCHART

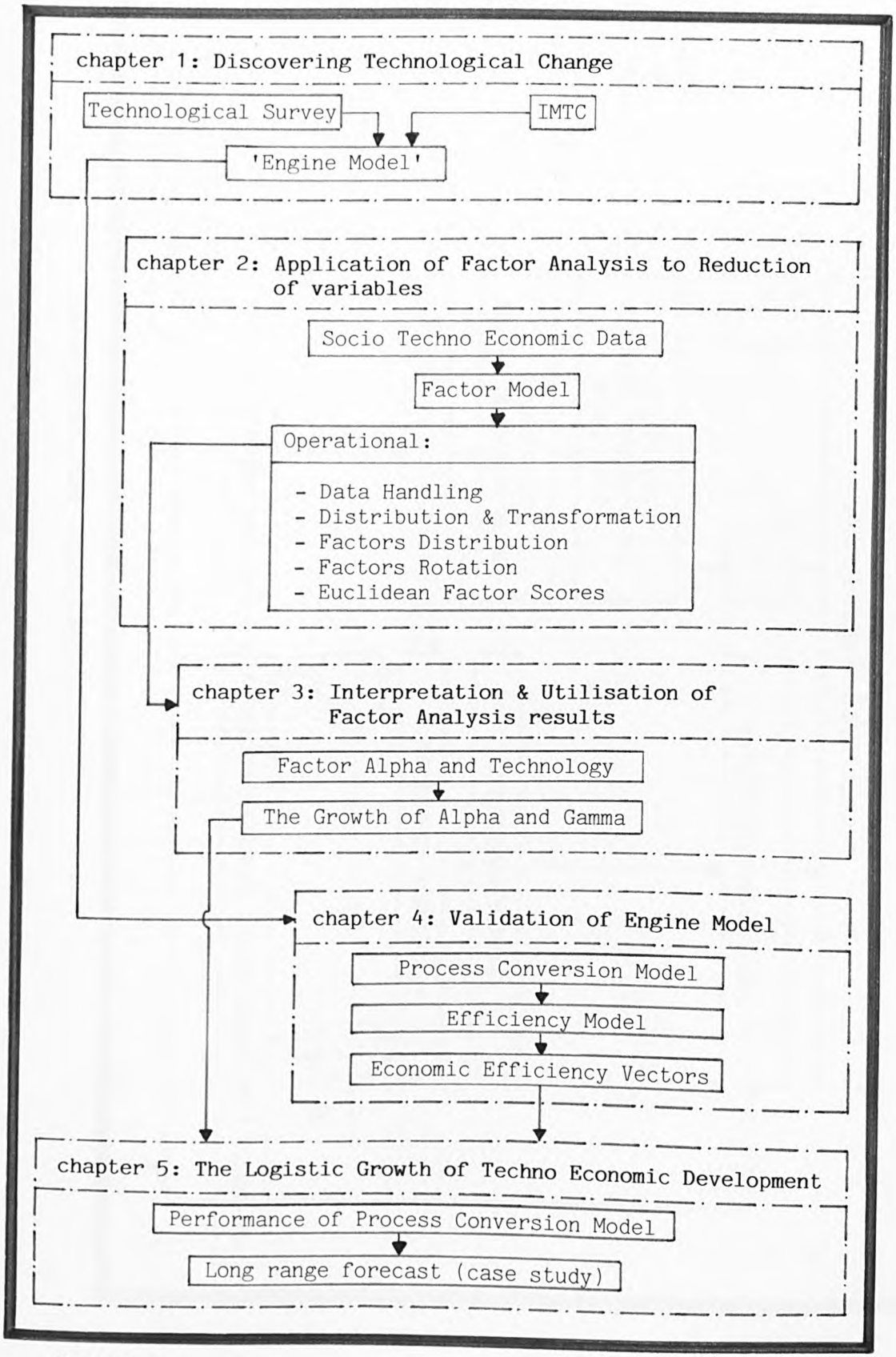
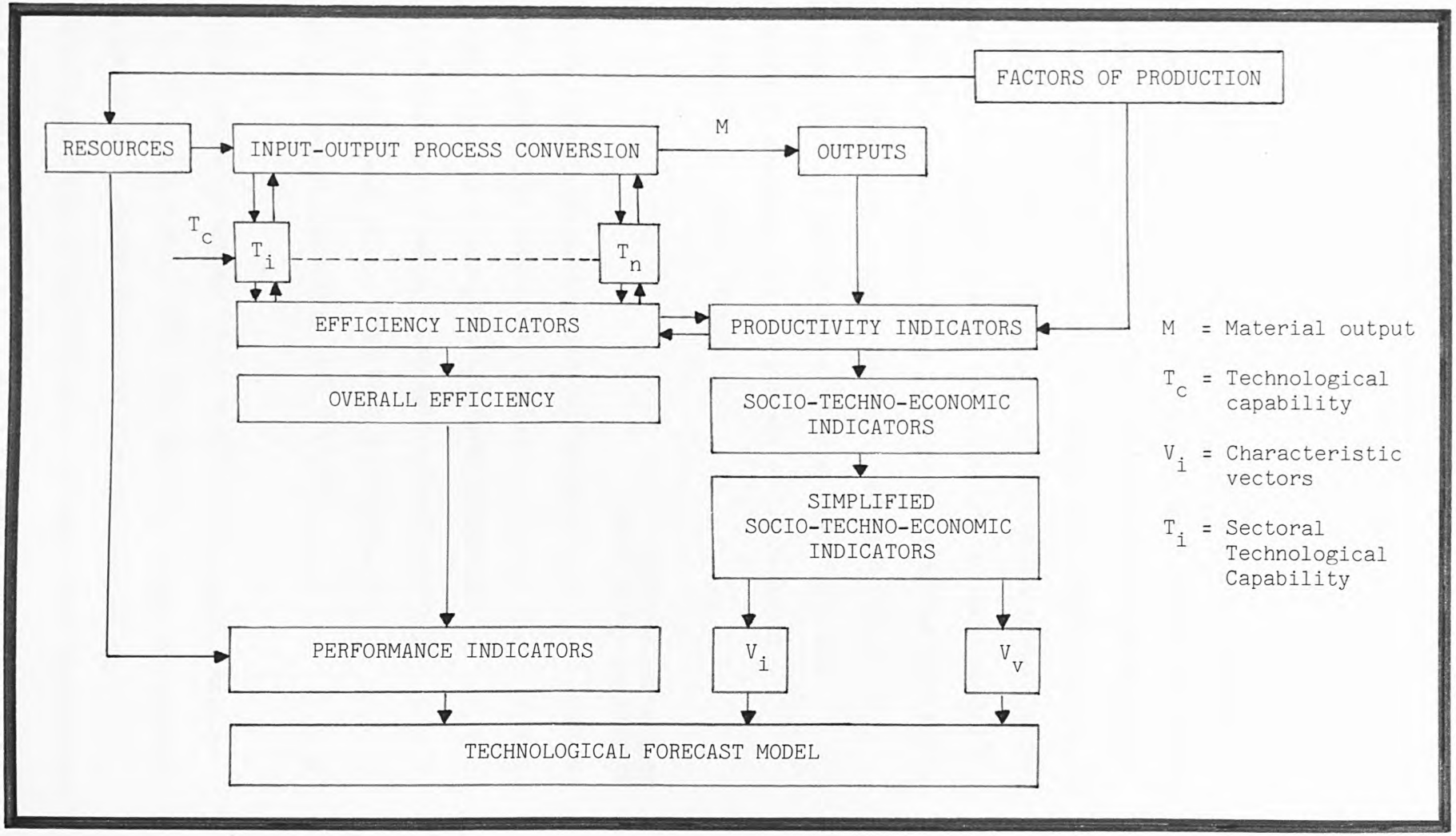


figure 1.21

TECHNOLOGICAL INDICATORS MODEL



1.7. Summary of Results and Claims for New Knowledge

1.7.1. Results

1. A comprehensive study of Technological Change at national level must use a very large number of variables and a vast amount of data. It is demonstrated that the method of Factor Analysis is a powerful analytical method to handle such large dimensionality. The second chapter of this thesis shows how the Factor Analysis method reduces the complexity of large variable indicators considerably: from a field of 59 variables selected to represent Technology, Social, Economic, and Demographic characteristics, 6 new variables (factor dimensions) are extracted to represent over 74 percent of the original characteristics. These factors are:

	minimum percentage each factor represents
1. Alpha (associated mainly with Technology).....	45.10 %
2. Beta (associated mainly with Scale).....	7.30 %
3. Gamma (associated mainly with Natural Resources)....	6.36 %
4. Delta (associated mainly with Agricultural activity)	4.01 %
5. Zeta (associated mainly with Foreign Dependency)....	2.97 %
6. Epsilon (associated mainly with Culture).....	2.27 %

2. This process of extraction is repeated for a period between 1950 to 1977. The results show that each new factor extracted at any time point is always associated with the same set of variables regardless of the difference in time. This demonstrates the consistency of Factor Analysis methodology which is essential

for scientific proof.

3. The location of each nation can be plotted along these new factors dimensions in Euclidean space to show its collective Technological, Economic, Demograpic, and Social state. In any dimension, (particularly in technology), we are now able to compare and measure the relative distance (technology gap being one of the most important) between any nations. It is also possible to study the behaviour of these factors over time. Therefore it is now possible to define the state of technology of any nation much more precisely.

4. In chapter 3, the idea of the Efficiency vector is developed through IMTC. It is shown that national efficiency is directly related to the Economist's Technological Change. The rate of change of Efficiency vectors for various countries between 1922-1977 are:

UK	1.09 percent per annum
USA	1.70 percent per annum
Sweden	2.00 percent per annum

these findings correspond and show remarkable similarity to many earlier findings by the economists (Solow (211), Denison (66)).

5. The factor Alpha (technology dimension) is shown to be very closely related to the level of national efficiency. Efficient countries produce high GNP per unit energy consumed.

6. In chapter 3, it is shown that there is an alternative simple method of the measurement of Technology which is based on the engineering concept. The findings also indicate that energy consumption is a major indicator for the state of technology. The number of scientists and engineers per-population also indicates the level of technology, although a very high proportion of scientist-engineer per-population ratio does not guarantee a proportionally superior technology level.

7. The performance of any country is shown to produce a high correlation (minimum 0.8755) to the linear combination of Alpha (Technology) and Gamma (Resources). Alpha (technology) and Gamma (Resources) can be studied and predicted independently. Together they can be used to make a forecast of other important variables such as GNP and Energy consumption. The forecast of Alpha, Gamma, Performance, GNP and Energy consumption per capita is included for the United Kingdom to the year 2000 (Chapter 4).

8. The credibility of this forecasting method is tested by "backcast" (using data at 1960-1977 to forecast United Kingdom GNP and Energy consumption at 1950). The results show very small percentage of difference between actual and predicted values as shown in this table:

	Predicted	Actual	% Difference
UK GNP percapita ($)	2 507	2 590	3.20
UK Energy consumption (tce)	4 657.22	4 358 (1950)	
		4 704 (1951)	
	average	4 531	2.78

1.7.2. New Knowledge

1. Statistical method of Factor Analysis is a stable, consistent and scientifically plausible method useful for analysing large amount of data.

2. Intergrated Model of Technological Change (IMTC) provides a useful methodoloy that can be operationalized.

3. Technology is not just an arbritrary collection of attributes, but it can now be quantified, measured, and studied as a total definable process rather than being represented by a few isolated cases (eg. speed of transport, the technology of computers, etc).

4. The technological gap between individual or groups of nations is therefore also quantifiable. Thus the difference in the state of technology between country A and country B along defined dimension can be measured. By knowing the rate of technological change of each nation we can therefore also compare the rates of technological improvement, divergence or convergence. It is of interest to developing countries to be able to forecast how long before the state of technology of country A will match to the state of technology of country B.

5. The study of Alpha (generalised technology process) over time indicates that Alpha follows an 'S' curve behaviour in the same way as many other technology research findings have shown (Fisher and Pry (78), Blackman (27,28), M'Pherson and Limantoro (162)).

6. The efficiency vector study shows that there is an alternative way (engineering approach) of calculating the economist's rate of

technical change. This method is simple to use and can be implemented easily using general national statistical data currently available.

7. The combination of Integrated Model of Technological Change and the new finding of Alpha (Technology factor) when applied to factors input such as energy consumption yields a further important new knowledge. The case study of United Kingdom indicates that it is quite possible for Technology to have increased sufficiently such that there is a **limit** on the percapita energy input requirement. Any incremental increase in energy demand would be met by the increase in efficiency conversion due to the technology itself.

8. The forecasting method based on the state of the IMTC, the technology vector, and the efficiency conversion process is capable of giving a stable long range forecast.

9. The forecast derived from IMTC are:

- realistic (based on massive data analysis rather than few arbitrary chosen variables).
- dependable (proven to give consistant results).
- useful (as policy instruments).
- accessible (defined in non complex terms).

CHAPTER 2

Application of Factor Analysis to the Reduction of Variables

2.1. Introduction..... 96

2.2. The use of Factor Analysis..... 96

2.3. The Adoption and Development of Factor Analysis for this Research..... 99

2.4. The Database and Variables..... 100

2.5. Organisation of Data..... 109

2.6. Missing Data Estimation..... 112

2.7. Data Screening

- 2.7.1. Introduction..... 115
- 2.7.2. Error in Definition of Data..... 115
- 2.7.3. Clerical Error..... 116
- 2.7.4. Errors Inherent in Data Collected..... 117
- 2.7.5. Computer Error..... 118
- 2.7.6. Missing Data..... 118
- 2.7.7. Random and Systematic Errors..... 119

2.8. Data Transformation..... 122

2.9. Results..... 135

- 2.9.1. Intercorrelation among Variables..... 135
- 2.9.2. Factoring Results..... 141
- 2.9.3. Consistency of Factors extracted..... 157
- 2.9.4. Factor Distances..... 164

CHAPTER 2

APPLICATION OF FACTOR ANALYSIS TO THE REDUCTION OF VARIABLES

2.1. Introduction

It was noted earlier that one of the main difficulties in an operational model for dealing adequately with the indices of technological change is that of handling the very large database necessary for such a study. Consequently the intermediate objective of this research project is to demonstrate the adequacy and stability of the methodology adopted for dimensional reduction. This chapter provides an account of the methodology adopted for organizing the large amount of international data used in the study.

2.2. The Use of Factor Analysis

The human brain is not capable of analysing in detail a very large amount of information at the same time. This leads to the need for modelling and simplification in our problems. If the real problem is very complex and it requires a large amount of variables as well as data points, the representative characteristics of the model depend on how adequately the selected variables represent the real problem.

In the past the study of Technological Change has been through the use of simple indicators such as Literacy rate, GNP per-capita (Millendorfer-Gaspari, 174), and a number of

technologically derived products (Fisher and Pry, 78) such as jet engine (Blackman, 26) and power boats (Sharif-Kabir, 211). These models are fine for these applications. When the model is to represent the problem of Technology as it affects our economic, social and general life, such models loose their adequacy. Their indicators are not sufficiently representative of the real problem. Indeed we are not sure what variables are necessary to represent Technology-as-a-whole. Consequently the first step needed to analyse this problem is to find that set of indicators which is sufficiently representative. Secondly the model will only be useful if it can be interpreted and used at a management level.

Factor Analysis is based on statistical theory. Its origins arose from the need to provide mathematical models for the explanation of psychological theories of human ability and behaviour (Adcock (7), Cattell (50), Fruchter (86), Spearman (220)). It starts with a set of observations obtained from a given sample by mean of a priori measures. The methodology is design to analyse such observations from their inter-relations to determine whether the variations represented can be accounted for adequately by a number of basic variables smaller than that with which the investigation started. By observing and analysing the pattern of inter-correlations of these variables the operation of one or more underlying traits or other sources of common variance is inferred. By establishing the basic sources of variance and determining the nature of each measure in term of basic categories we can determine (a) what types of variations the

variables are measuring, (b) the inter-relationship between these measures, (c) what the controllable and non controllable variables are and (d) what subsequently needs to be done to obtain complete control of the system.

In addition to the in psychological field the Factor Analysis method is sometimes used in political science to determine major empirical concepts and basic indicators for describing international relations and international conflict (Rummel (195)).

2.3. The Adoption and Development of Factor Analysis for this Research

Factor Analysis was chosen for this research project because, apart from its ability to handle and reduce large masses of data, its results can be mapped into Euclidean space. It therefore opens up further mathematical manipulation based on vector algebra as used by dynamicists to represent the trajectories of multidimensional system in state space. This is the avenue which provide the breakthrough for representing Technology - as - whole as a proper dynamic process.

Another unique aspect of this study is the adaptation of Factor Analysis to operate with data in the form of time series. No other work was found during the literature search in which Factor Analysis was used in such a mode. Therefore it is necessary to demonstrate that Factor Analysis is also suitable for data taken from different set of time series. Later in this chapter it is shown that Factor Analysis is indeed capable of providing a stable result over independent set of data and over different time periods. Consequently it is argued that Factor Analysis is a scientifically plausible methodology for use in this and similar applications.

The detailed theory of Factor Analysis is not repeated in the text of this thesis. It is a standard methodology and is assumed for the purpose of this research. Readers unfamiliar with Factor Analysis are referred to Adcock (7) and Harman (109). A brief description of Factor Analysis is also given in Appendix 1.

2.4. The Database and Variables

The field for the study of Technological Change is pitched at the national level. The reason for examining the macro level are as follows:-

- A stated objective of the research is to develop a model of Techno - Economic Development which avoids the disembodied technical change factor of production function models.

- Many micro models of specific technological change have already been explored satisfactorily.

- The research leads on from the previous work of M'Pherson and Limantoro which established a logistic pattern relating economic growth and energy use at national level.

- The research has another major objective in developing an operational form for the Integrated Model of Technological Change which is couched in terms suitable for national planning.

- Economic, Social and Industrial data are readily available at national level.

- If successful this research will provide an operational instrument of considerable value to national policy planners.

- The accent of this research is on the development of an operational methodology for the study of Technological Change as a whole process, rather than to give predictions on specific technologies.

The database for this research was formed from the more industrially developed nations over the period of 1950-1977. For practical reasons any countries with a population less than one million were not included; in any case these small countries usually do not have a sufficient set of data to satisfy requirements. The final number of cases used was therefore limited to one hundred. This is by no mean the 'universe', but it is sufficient because it represents over 99 percent of the world population.

The data base for each country (case) is comprised as follows:

* The field covers one hundred countries (see table 2.2, page (107).

* Five main groups covering Demographic, Social, Communication, Educational and Economics (table 2.1, page 103).

* Each group is further subdivided into subgroups, giving 58 variables in all (table 2.1, page 103).

* The data covers the period 1950-1977, but only four years (1960, 1965, 1970, 1977) were used as time points. Suffices 1, 2, 3, 4 are used to indicate the four benchmark years.

* The final matrix of variables and cases used therefore is 4 by 100 cases by 58 variables.

The table 2.1 (page 103) below lists the variables by group and code. The principal data sources were World Bank and United Nations statistics. A complete listing of data sources and definitions are given in Appendix 2. And table 2.2 (page 107) lists the 100 countries arranged in geographic-economic groups.

Table 2.1.

VARIABLES GROUPS AND CLASSIFICATIONS

Variables	Code	Var. No.
1. Demographic		
1.1 Midyear population	POPULA	2
1.2 Young population	YOUNPO	3
1.3 Adult population	ADULPO	4
1.4 Elder population	ELDEPO	5
1.5 Population density	POPDEN	6
1.6 Urban population	URBAPO	7
1.7 Birth rate	BIRTRT	8
1.8 Land area	AREA	58
2. Social		
2.1 Life expectancy	LIFEXP	10
2.2 Population per physician	PHYSIC	11
2.3 Population per nursing person	NURSES	12
2.4 Population per hospital bed	HOSPIT	13
2.5 Calory supply per capita	CALORY	14
2.6 Mortality rate	MORTAL	9
2.7 Infant mortality	INMORT	15
2.8 Lowest 20% income	LOINCO	48
2.9 Highest 5% income	HIINCO	49
2.10 Literacy rate	LITER	19

Table 2.1.
(continued)

VARIABLES GROUPS AND CLASSIFICATIONS

Variables	Code	Var. No.
3. Communication		
3.1 Radio per population	RADIO	24
3.2 Telephone per population	TELEPO	56
3.3 Newspaper consumption per population	NEWS	54
3.4 Passenger cars per population	CARS	25
4. Education		
4.1 Primary school enrolment	PRIMA	16
4.2 Secondary school enrolment	SECOND	17
4.3 Primary school pupil teacher ratio	PRIRAT	18
4.4 Secondary school pupil teacher ratio	SECTAT	46
4.5 Vocational school enrolment	VOCATE	47
4.6 Education expenditure	EDUEXP	57
4.7 Tertiary education	THIEDU	55
5. Economic		
5.1 Income sources		
5.1.1 Gross Domestic Product	GDPTOT	50
5.1.2 GDP from agriculture	GDPAGR	30
5.1.3 GDP from manufacturing	GDPMAN	31
5.1.4 GDP from other industry	GDPOTH	32
5.1.5 GDP from services	GDPSER	33
5.1.6 GNP per capita	GNPUS	51

Table 2.1.
(continued)

VARIABLES GROUPS AND CLASSIFICATIONS

Variables	Code	Var. No.
5.2 Consumption		
5.2.2 Government consumption as % GDP	GOVCON	27
5.3 Export		
5.3.1 Export as % GDP	EXPGDP	28
5.3.2 Export of food	EFOOD	34
5.3.3 Export of agriculture	XAGRI	35
5.3.4 Export of fuel	XFUEL	36
5.3.5 Export of machinery	XMACHI	37
5.3.6 Export of other manufactured goods	XOTHER	38
5.4 Import		
5.4.1 Import as % GDP	IMPGDP	29
5.4.2 Import of food	IFOOD	39
5.4.3 Import of agriculture	IAGRI	44
5.4.4 Import of fuel	IFUEL	42
5.4.5 Import of non-fuel goods	INFUEL	40
5.4.6 Import of machinery	IMACHI	41
5.4.7 Import of other manufactured goods	IOTHER	43
5.5 Monitory indicators		
5.5.1 Saving rate	SAVERT	45

Table 2.1.
(continued)

VARIABLES GROUPS AND CLASSIFICATIONS

Variables	Code	Var. No.
5.6 Employment		
5.6.1 Labour force	LABOUR	20
5.6.2 Agricultural labour force	PAGLAB	22
5.6.3 Industrial labour force	PINLAB	23
5.6.4 Women in labour force	PWOLAB	21
5.7 Agricultural mechanisation		
5.7.1 Tractors in use	TRACTR	53
5.8 Finance		
5.8.1 Investment as % GDP	INVGDP	26
5.9 Energy		
5.9.1 Energy consumed per capita	ENECAP	52

Table 2.2

Countries Geo - Economic development Grouping

1. Group 1: African Countries

1. Benin	2. Burundi
3. Central African Republic	4. Chad
5. Ethiopia	6. Ghana
7. Guinea	8. Ivory Coast
9. Kenya	10. Madagascar
11. Malawi	12. Mali
13. Mozambique	14. Niger
15. Nigeria	16. Rwanda
17. Senegal	18. Sierra Leone
19. Somalia	20. South Africa
21. Sudan	22. Tanzania
23. Uganda	24. Upper Volta
25. Zaire	26. Zambia

2. Group 2: Northern African and Middle East Countries

27. Algeria	28. Egypt
29. Iran	30. Iraq
31. Morocco	32. Syrian Arab Republic
33. Tunisia	34. Yemen Arab Republic

3. Group 3: South East Asia and the Pacific Countries

35. Hongkong	36. Indonesia
37. Korea	38. Malaysia
39. Papua New Guinea	40. Philippines
41. Singapore	42. Taiwan
43. Thailand	

4. Group 4: Southern Asian Countries

44. Afghanistan	45. Bangladesh
46. Burma	47. India
48. Nepal	49. Pakistan
50. Sri Lanka	

Table 2.2
(continued)

Countries Geo - Economic development Grouping

5. Group 5: Latin American Countries

51. Argentina
52. Bolivia
53. Brazil
54. Chile
55. Colombia
56. Dominican Republic
57. Ecuador
58. El Salvador
59. Guatemala
60. Haiti
61. Honduras
62. Mexico
63. Nicaragua
64. Paraguay
65. Peru
66. Uruguay
67. Venezuela

6. Group 6: Southern European Countries

68. Greece
69. Israel
70. Portugal
71. Spain
72. Turkey
73. Yugoslavia

7. Group 7: Major Oil Producing Countries

74. Kuwait
75. Saudi Arabia

8. Group 8: Western Industrialised Countries

76. Austria
77. Australia
78. Belgium
79. Canada
80. Denmark
81. Finland
82. France
83. West Germany
84. Ireland
85. Italy
86. Japan
87. Netherland
88. New Zealand
89. Norway
90. Sweden
91. Switzerland
92. U.K.
93. U.S.A.

9. Group 9: Socialist Countries

94. China
95. Chechoslovakia
96. East Germany
97. Hungary
98. Poland
99. Romania
100. USSR

2.5. Organisation of Data

The organization of the data input for Factor Analysis is described in figure 2.1 (page 111). The four main stages are:

1. Data collection: data are collected from primary and secondary sources (Appendix 5).
2. Missing data estimates (see 2.6 and 2.8)
3. Data screening (see 2.7)
4. Data transformation (see 2.8)

The experiment is divided into four different time points, 1960, 1965, 1970 and 1977. Data were gathered from 1950 onwards. However the quality of cross sectional (inter-country) data was not particularly good especially for developing and less-developed countries. As Factor Analysis works successfully only with a complete set of cases for any variable an excessive amount of missing data means a large number of missing data estimates which may not be acceptable. The primary purpose of the present exercise is to prove the consistency of the model and to avoid any undue complexity that may arise so that a proven operational methodology for IMTC is provided. Therefore only those variables with an acceptable amount of missing data are used.

Missing data are potential sources of error but their effect can be minimized. In order to keep the data errors to a minimum a step by step data error control procedure was followed:

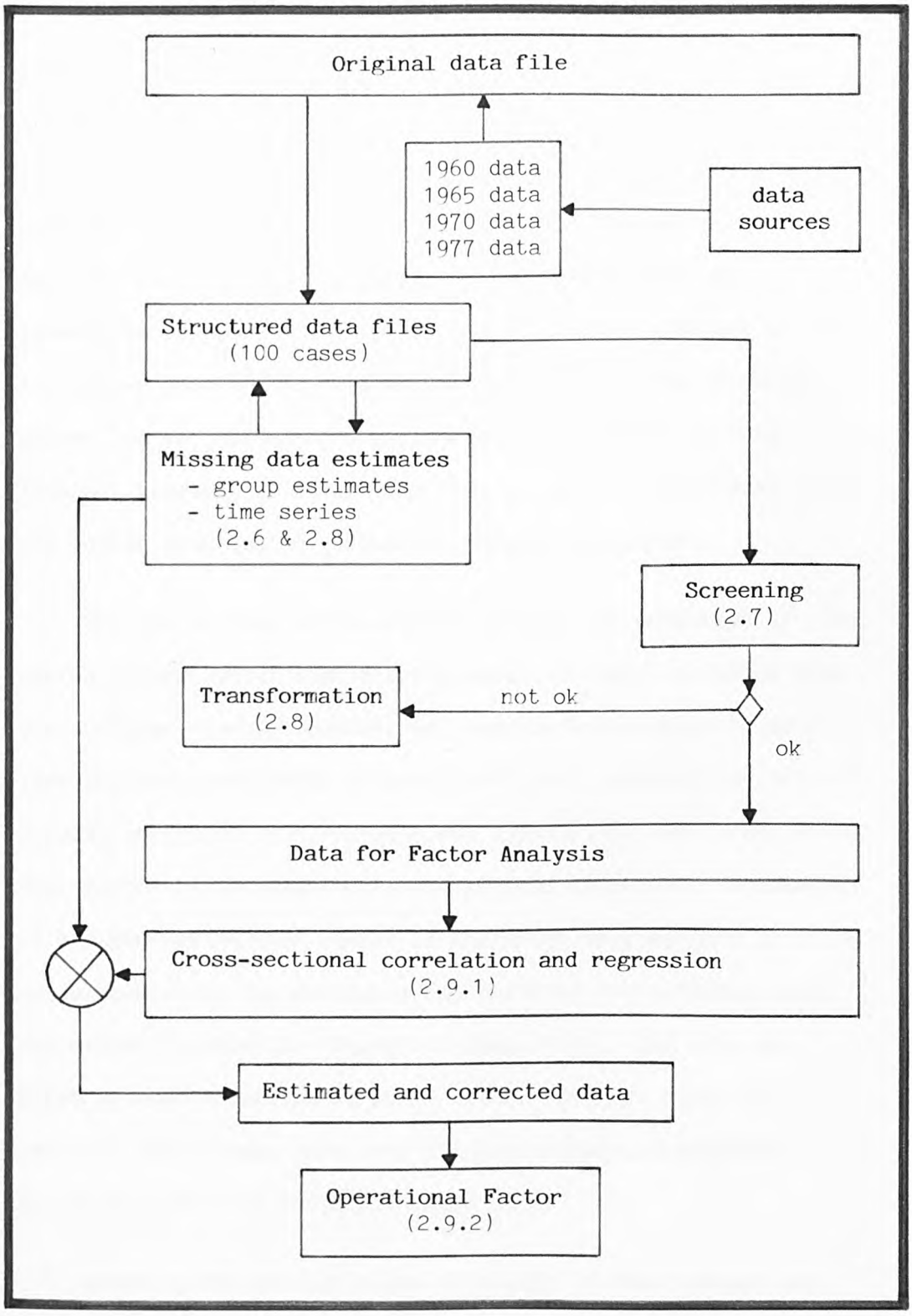
1. Variables used in the analysis are limited to those variables containing 70 percent of cases or more. On average over 90

percent of the variables used contained 80 percent or more of original data from the primary source. The secondary data source provided the missing data wherever possible.

2. To keep the interference level to a minimum all definitions and sources used for the variables are consistent from one time period to another. This guarantees the control of the quality of the data inputs used. But it has proved to be the major constraint in this experiment. Instead of over 100 variables collected and made available at any one time, only 57 variables (less than 60 percent) satisfy the imposed criteria. Consequently studies of this kind suffer from imperfection in the published data sources and present the analyst with a significant problem. But every country (especially the developing countries) needs this kind of information to monitor its progress. Unfortunately proper statistical sources with trained staff lacked up by computerised data processing system are expensive and are likely to be beyond the capacity of the less developing countries (LDC). The provision of such services would seem to be a very important form of aid for the LDCs. It is to be hoped that as the LDCs develop all national data will be a consistently high quality. Then the collection of information yielding full sets of consistent data will not be the problem that it is now.

figure 2.1

Flowchart of Data organisation



2.6. Missing Data Estimation

The first task in Factor Analysis is to estimate the missing data. As Factor Analysis is based on the correlation method it is argued that missing data should not be estimated just by simple correlation estimates. If correlation estimates on their own are used to estimate the missing data then the missing values are dependent entirely on the variables from which they are themselves estimated. This results in internal bias due to the interdependance of the missing data points with the variables chosen for the correlation estimation. The effect of this internal bias may be significant but it is best avoided as there are better alternative estimation methods available.

The use of time series methods brings the advantage of time-series estimation of some missing data. In most variables some trend changes are noticeable, eg. population is shown to grow steadily and predictably in most countries. However the rate of population growth is different from industrially developed North West Europe to the less developed African countries. Estimation of the average rate of change is therefore more uniform if it is calculated using the average group trend as the estimate basis. The method is shown in figure 2.2 (page 114). The data are first grouped according to their value. In most cases the national data breaks down into the geo-economic development groups as listed in table 2.2 (page 107).

Based on the average rates of change in these groups any individual missing value can be estimated by interpolation to

satisfy the rate of change of the associated data series at that time. If no other data is available for that time the group average is inserted. This value is then compared with secondary data sources (*). If data are available in the secondary sources, and they show some significant differences, an estimate is made using some other most highly correlated variable. Having selected the highest correlation, the square of the ratio of the regression coefficient to its standard error is tested for F distribution. Thus:

$$\left(\frac{r}{s}\right)^2 > 4$$

where r = regression coefficient.

s = standard deviation

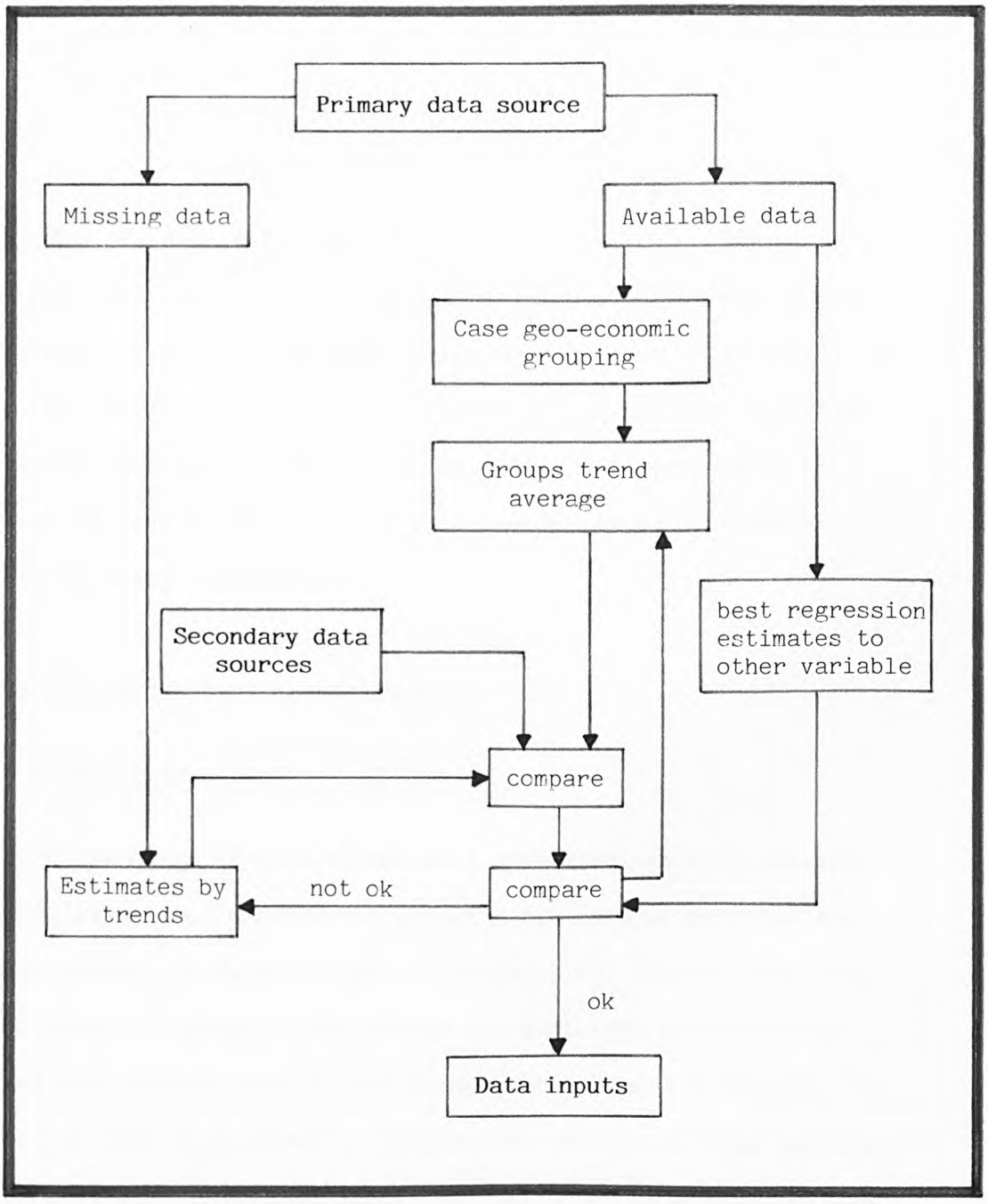
If the criteria above is not met, then the variable usually has a very low correlation with the other variable. In this case the missing data is replaced with the variable group average.

(*) Secondary Data Sources:

Asia Yearbook, Europa Handbook, European Historical Statistics, The Economists, ILO, OECD. See Statistical Sources Reference for more detail reference.

figure 2.2

Missing data estimation procedure



2.7. Data Screening

2.7.1. Introduction

The introduction of errors when dealing with this type of large scale analysis is almost unavoidable. There is a variety of errors to be found in the data itself, including the missing data and differences in variable definitions. The difference in variable definition between one country to another leads to non-comparable results in extreme cases. Any kind of data errors, if serious enough, can distort the result of the analysis and lead to wrong conclusions. There are many other different types of errors as well which also have to be minimised by systematic error handling procedures.

Data errors can be classified as:

2.7.2. Error in Definition of Data

Differences in definitions will affect statistical analysis. A good example of differences in definition and of data for the same variable is shown in table 2.3 (page 121) for the UK's 1975 production of energy. Such errors are minimized by using only those data sources that accord closely to definition adopted. In practice this is achieved by keeping the variety of data sources to a minimum. It is well known that different sources often show some discrepancies for the same variable and time period specified. To check the reliability of any one source, secondary data sources must be used. The main source of data used in this study was the World Bank compilation of data sources (reference

sources). The secondary sources came from the United Nation Yearbooks, the Europa Handbook, The Economist Yearbook, ILO Yearbook, IMF Yearbook and OECD (for OECD countries), and others as listed in the reference section. It must be stressed that variation in data definition are a critical factor in this analysis because a considerable amount of structural analysis depends on comparisons across national boundries. In the past this kind of difference had been known to occur even among the most developed nations where data reliability is not such a major problem any more. Even so table 2.3 (page 121) shows typical discrepancies between data sources for the UK's electricity production.

The problem of definition variety has to be treated carefully when dealing with the estimation of missing data. The missing data were estimated as outlined in section 2.6 and then compared to another source. This method of missing data estimation is preferable to direct substitution from other data sources because of the data definition problem as discussed above.

2.7.3. Clerical error

Clerical error includes errors in recording and entering data to the data base, and also some random error which occur during data transformations. It has already been pointed out that data for this kind of analysis can not be made available from one single source and therefore the units of measurement are

not uniform. A standardization procedure has to be adopted to get the unit of all cases uniform.

To minimise clerical errors, the data base file is first checked and double-checked. Variables were checked for their maximum, minimum, deviation from their mean values, distribution, and anomalousness by observation from the frequency distribution. All extreme values were double checked from the source to ensure its correctness. To make sure that data near the mean of distribution are also correct they are checked for reasonableness. This involved plotting and correlating two expectedly highly correlated variables together. For example Energy Consumption per capita and GNP per capita should usually give a high correlation. Therefore any country that consumes high energy percapita normally produces a high percapita GNP, and vice-versa. If a country has a large deviation from the expected value estimated from the best fitted regression line, the value is rechecked and compared to secondary sources.

2.7.4. Errors inherent in data collected

There is nothing much that can be done about these errors as they are imbedded in the statistical data itself. In this analysis, as the data are not actually collected in the field, we must assume that they are correct and statistically representative of the population. In many cases, especially for social variables, these data are only a small statistical sample of the whole population. They are therefore subject to sampling limitations. Also the methods of sample collection may vary from

country to country. For this reason data are mainly taken from internationally recognised sources, such as the International Monetary Fund, United Nations, World Bank, International Labour Office, etc., where supervision of the method of collecting data is known to be more uniform and reliable.

2.7.5. Computer error

Although computer error is relatively infrequent a computer does make errors such as in file reading and misprinting. One way of checking this kind of error is by creating a different format data file. If the reading errors occurred in one type of file then the chances of error is minimised in the second case. To ensure this, the result of two computer runs are compared and any discrepancy will show whether the error was due to the computer itself. The results are double-checked with a test of reasonableness at every stage of computation. After a large transformation and data manipulation the data precision can shift by a small margin. For example (0.6) may be printed as (0.599999) or (0.600001) after a very long computation. This error is considered insignificant. Otherwise all the computations use Fortran double precision. For the final results all figures are rounded up to 4 decimal figures.

2.7.6. Missing data

Data may be unobtainable for a variety of reasons, including unsettled political situations, the high cost of collecting data,

etc. In this study interest is focused on a country state or nation (set of national characteristics) as well as on its technological development. Consequently it is crucial that all sample cases have a complete set of attributes. Thus the justification for estimating these missing data lies in the structure necessary for the analysis. One of the primary objectives of this project is to be able to measure a country's technological 'lag' or 'lead' relative to the others. And this can only be achieved by knowing the complete set of original variables. The best that can be done is to interpolate the missing data. A methodology to estimate the missing data was developed in section 2.6.

2.7.7. Random and Systematic Errors

As the basic model depends extensively on correlation theory there are three other relevant sources of errors, namely:

1. Error in variable (1) is correlated with error in variable (2).
2. Error in variable (1) is correlated with the true value of variable (2).
3. The true value of variable (1) is correlated to the error in variable (2).

If any of these conditions holds the error effect on the correlation between variables (1) and (2) is bivariate and systematic (Rummel, 195); if none of these conditions hold, that is the error in one variable has no correlation with the error or true value of the other, then the error is bivariate and random.

Thus for a given correlation coefficient, the bivariate random error will reduce the correlation from the actual 'true' correlation coefficient. The case of bivariate systematic error is difficult to interpret. If it exists, the correlation coefficient may be increased or reduced from its 'true' value and the factor result may be biased in either direction. This is where human common sense becomes useful as a knowledge of the available sources of data enables the reliability of the results to be weighed.

table 2.3

Statistical Data Descrepencies from Various Sources

United Kingdom Production of Electricity (1975)

Sources	Quantity (M KWhr)	Variable description
1. United Nations	271 987	Production of electricity
2. UK Dept. of Energy	217 924	Sales of electricity
3. OECD	272 082	Electricity Production
4. Eurostat	253 880	Total Production of Electricity
5. European Historical	252 670	Output of Electrical Energy

Sources:

1. United Nations, World Energy Supplies 1973 - 1978, United Nations Statistical Papers series J, no. 22, 1979, table 24, pp. 286.

2. Department of Energy, UK, Energy Trends, A Statistical Bulletins, UK Department of Energy, HMSO, 1981, table 10.

3. OECD, Energy Statistics 1975 - 1979, International Energy Agency, OECD, Paris, 1981, pp. 283.

4. Eurostat, Energy Statistical Yearbook, 1973 -1977, 1979, pp. 142.

5. Michel, B R, European Historical Statistics, 1750 - 1975, MacMillan Press ltd, 2nd ed., 1980, pp. 503.

2.8. Data transformation

Factor Analysis is based on correlation and general regression theories. The basic requirement of correlation theory is the normal distribution of both the dependent and independent variables. This also means that both dependent and independent variables must not have extreme values (outliers). Usually data distribution belongs to one of the distribution families described in figure 2.3 (page 128). The existence of any extreme values in both dependent and independent variables has a significant effect on the correlation as they cause the best fitted regression line to depend too much on these values. Thus they introduce wrong interpretation of the data as is demonstrated in figure 2.4 (page 129) where a regression method fitted to the high outliers will produce a false representation of the data behaviour.

For a large cross sectional multivariable analysis extreme values are almost unavoidable. Take the population variable as an example; 85 percent of the 1977 national population in the sample used is less than 50 million. Together China and India have a total population of over one and half billion. Consequently if we take the figures in the raw all the cross correlations to other variables may be distorted by these two extreme values. An example of a distribution with extreme values, as given by population (POPULA4), is shown in figure 2.5 (page 130).

A method of data transformation was specially developed to

overcome the problem of extreme values. One may argue that transformation removes the natural characteristics of original data. This is not a critical factor in modelling because the transformed values can always be checked and worked backwards to obtain the value in the original unit. Interpretation can always be related to the transformed values by knowing the exact transformation. Figures 2.5 (page 130) and 2.6 (page 131) show the effect of data distribution as a result of transformation: by using log(x) as an operator on the data of figure 2.5 the transformed distribution of figure 2.6 results which will greatly reduce the effect of the extreme values.

Two types of transformations were considered and evaluated to overcome the problem of non-normal distribution and extreme values. An increasing dimensional transformation scales the original variables larger, while a reducing dimensional transformation reduces the magnitude of the variables and, therefore, the size of the errors. Figure 2.7 (page 132) shows that it is better to have a dimensional reducing transformation for the reason of error minimisation. A transformation such as the exponential (exp (x)) may enlarge the errors inherent to the data unnecessarily. For this reason the transformations used in this study are restricted to dimensional reducing.

Data transformation needs to be carefully handled. The criteria adopted for defining acceptable transformations are:

1. When removing extreme values:

The intermediate results are (a) a larger spread on a

univariate distribution, and (b) extreme values closer to the distribution mean.

2. For non-normal distributions:

The basis chosen to check the suitability of the transformation is the normality test. The normality of the distribution is checked by its skewness and kurtosis. The expected skewness, (s_k) is zero for a symmetric distribution. The standard error of expected skewness is equal to $(6 / n)^{1/2}$, where n is the number of cases. The skewness test for normality is defined as the ratio of the actual skewness to its standard error (Cramer, 7).

Similarly the kurtosis test of normality will also show zero for any normal distribution. It is positive for a distribution with heavier tails and negative for a distribution with lighter tail. The standard error for the expected kurtosis (s_r) is equal to $(24 / n)^{1/2}$ (Cramer, 7). The ratio of of the kurtosis to its standard errors is used to test the distribution normality.

Simplicity of interpretation is the first choice for transformation from the possible range of transformations. As opposed to a complex transformation a simple transformation (such as log (x) or square root (x)) can be interpreted as easily as the actual data itself. The effect of simple transformations on the variable distribution is shown in figure 2.8 (page 133).

To reduce the problem of data interpretation to a minimum, (log) and (square root) transformations were found to be

quite adequate. The addition of constants ensure that all transformed variables will have a normal distribution and minimal extreme values.

Sometimes the extreme values are not reducible; ie. they maintain their relative values regardless of the transformation used. In such case: the distribution must be an inherent property of that variable. There is nothing we can do about this, but as long as the normality criteria is satisfied, we can proceed while at the same time taking note of these extreme values (appendix 2).

The transformation described above may be considered rather unorthodox as a strict observer of the rule of data management would require that the primary data is not "bent" to make it more amenable to analysis. However experience with the primary data used in this study showed that very often the "good" correlation fits obtained were not appropriate to a rational interpretation For example figure 2.5 (page 130) will yield misleading results if standard analytical forms are used. Many runs were made to provide experimental satisfaction that the results from an analysis of transformed data were reasonable and liable to considerably less error of interpretation.

Appendix 2 lists the transformed and untransformed data, transformation variables, and other statistical measures to describe data normality. It can be seen that in almost every case the transformed data is considerably less skewed and is therefore more amenable to the methodology of Factor Analysis.

The same transformation was carried out for the whole of the data associated with a particular variable. But different variables had different transformations according to the nature of their data.

The question now arises as to the validity of interpretation of results on the transformed data. These transformations always produce a constant relative rank position for each data case. For example: the rank of the GNP percapita of United Kingdom in 1977 will always be lower than the United States's before or after the transformation. Suppose the transformed GNP percapita (variable B) is correlated to variable A, as shown in figure 2.9 (page 134), then the correlation result can always be interpreted relative to the original scale. The transformed B is represented as B^{*}.

The elimination of errors is not claimed. But it is argued that the risk of misinterpretation is considerably reduced through the use of reducing transformation. Anyway the reducing transformation reduces the overall effects of errors due to non-normal distribution and extreme values. The transformation method developed for this problem is commended as an effective way for overcoming the frequently encountered problem of non-normal data distribution. This transformation method is unorthodox by the standards of strict statistical analysis, but it is necessary if sensible results are to be obtained from cross sectional comparison of variables between system (ie. nations) which may be be eg. very unlike in their size but very similar in

their economic and industrial conditions. The effects of all the transformation on the correlation has been carefully examined and it is shown that the interpretive argument are not invalidated: the relative rank order of cases on any particular dimension is not affected. In the past Factor Analysis has often failed to produce results because of great unit difference between variables (ie. the lack of some kind of methodology to bring these variables to closer dimensional comparability to make basic regression assumptions valid). It is suggested that transformation is used to overcome this obstacle.

figure 2.3

Typical Data Distribution

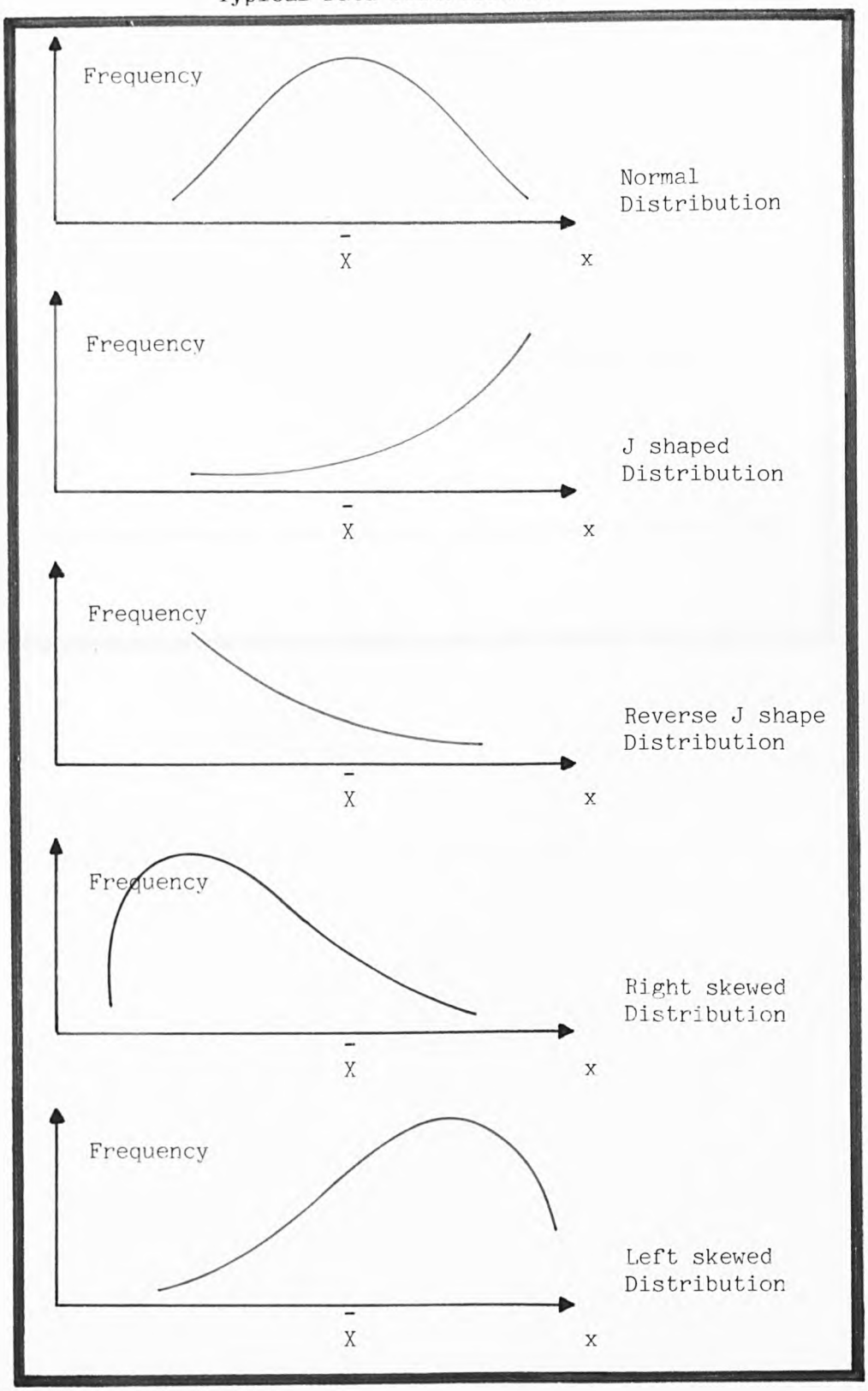


figure 2.4

False Regression Line due to Extreme Values

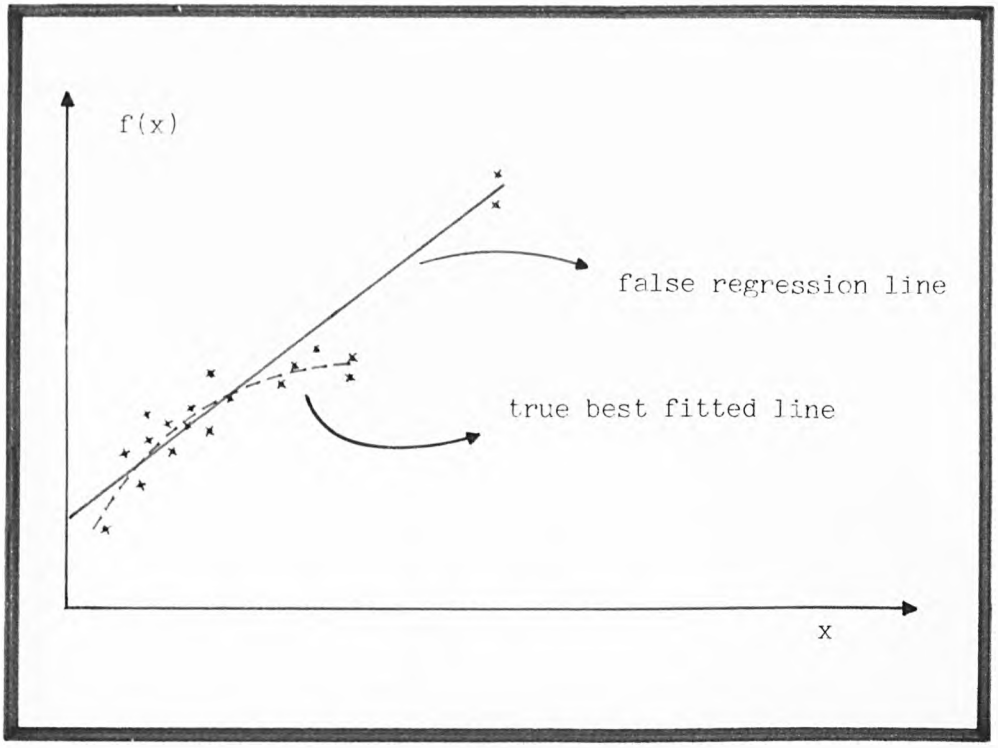


figure 2.5

Untransformed POPULA4 Distribution

(population distribution in 1977)

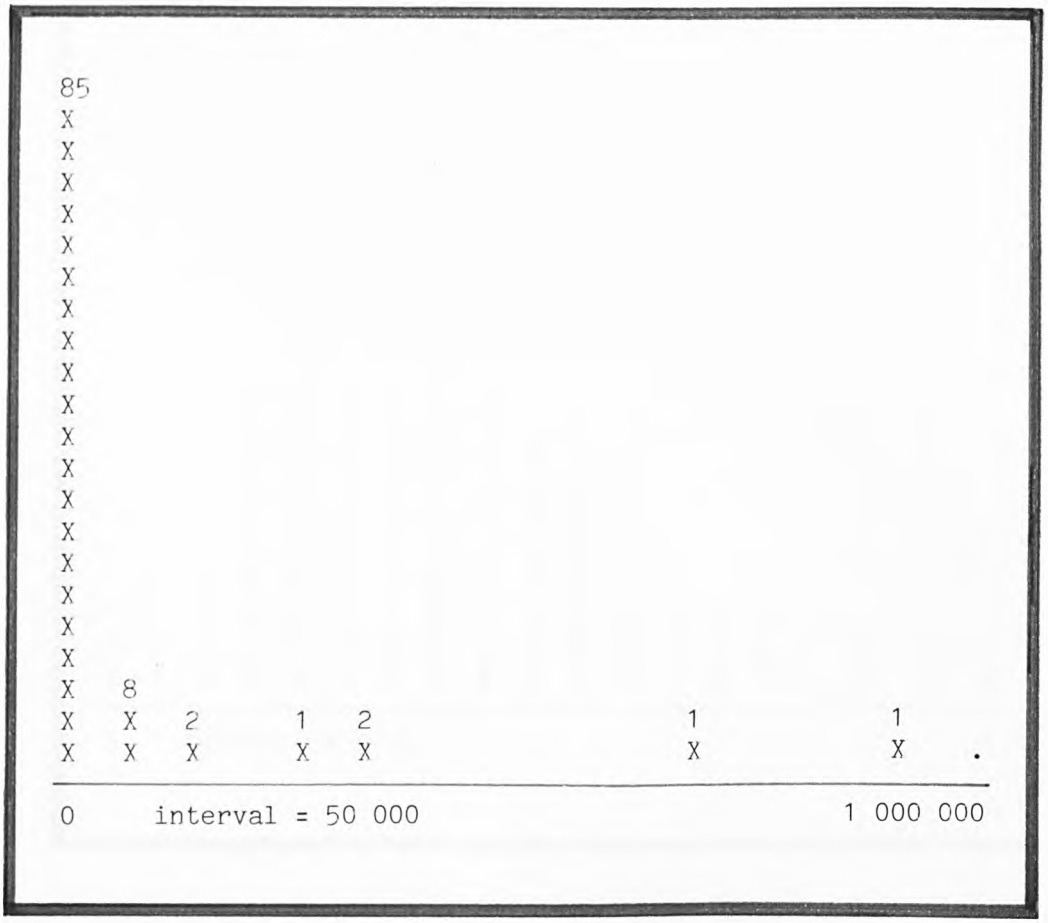


figure 2.6

Transformed POPULA4 distribution

(transformation = log(x))

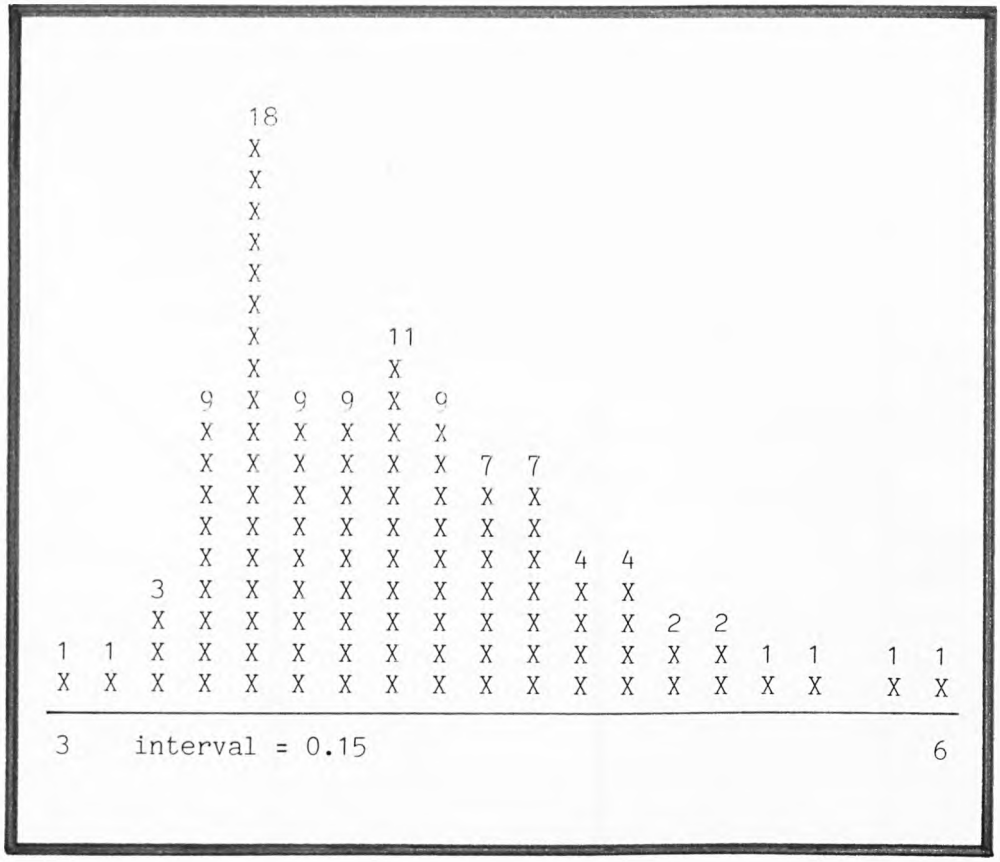


figure 2.7

Effects of transformation on data errors

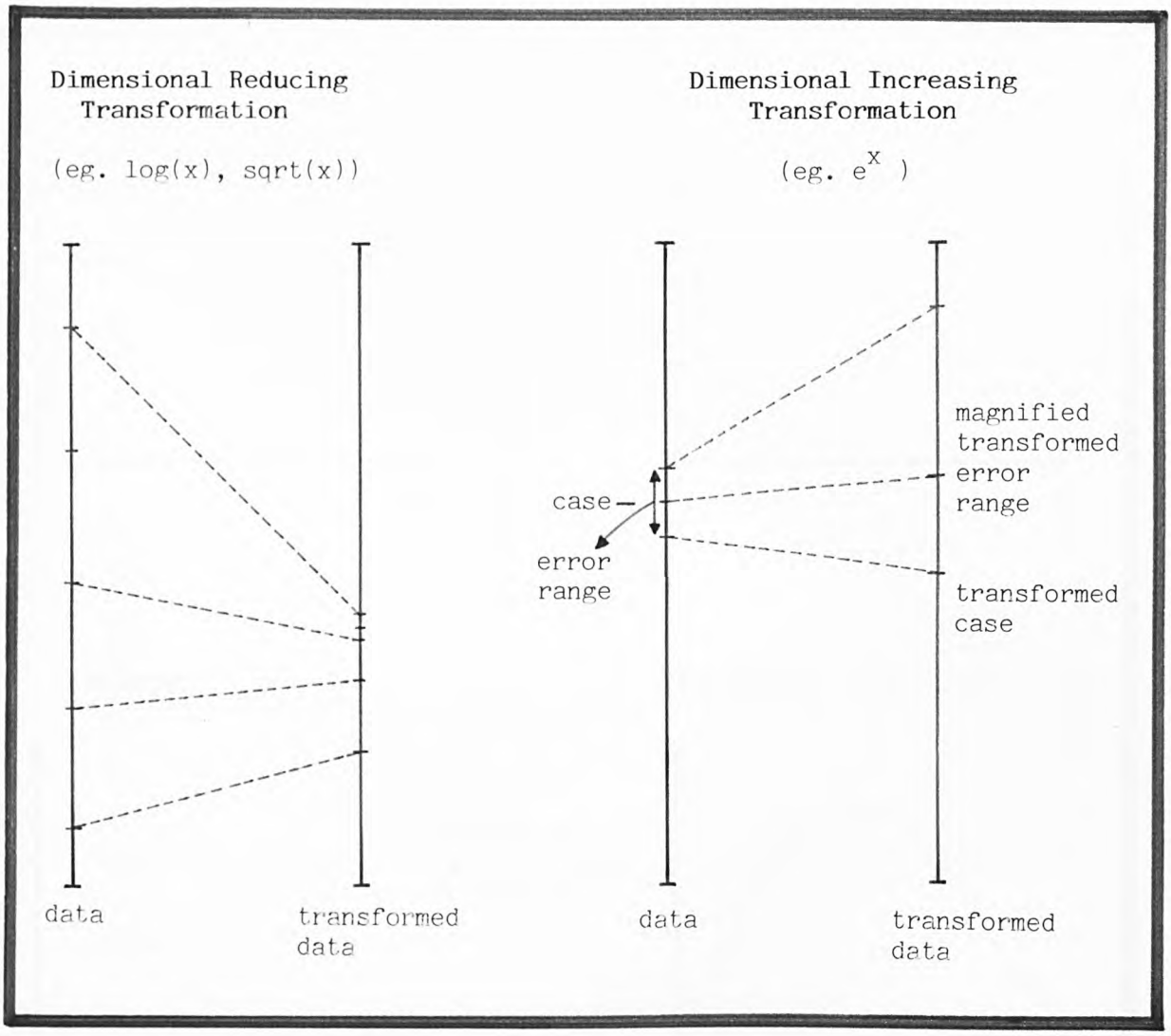


figure 2.8

Data Transformation Used

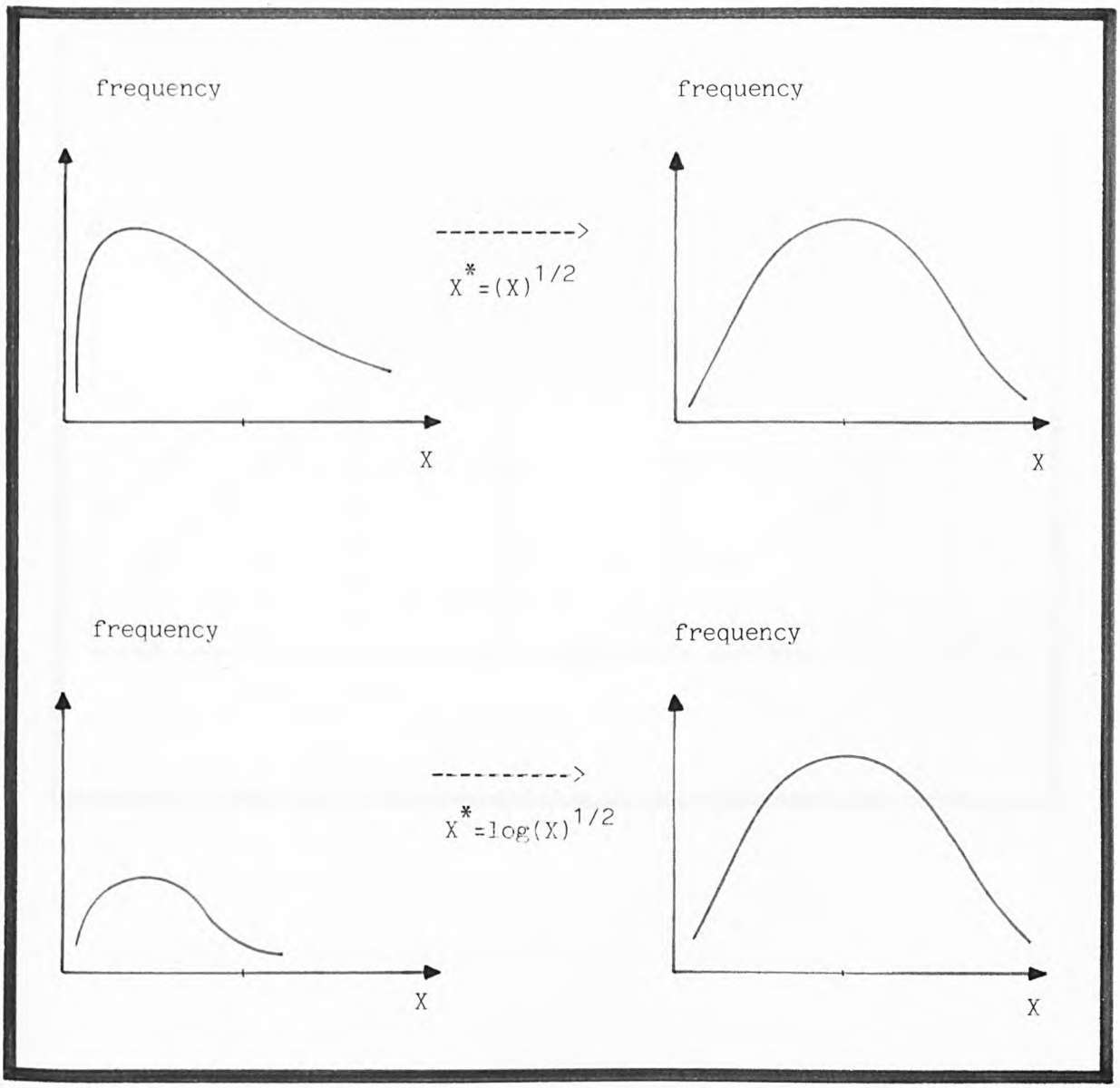
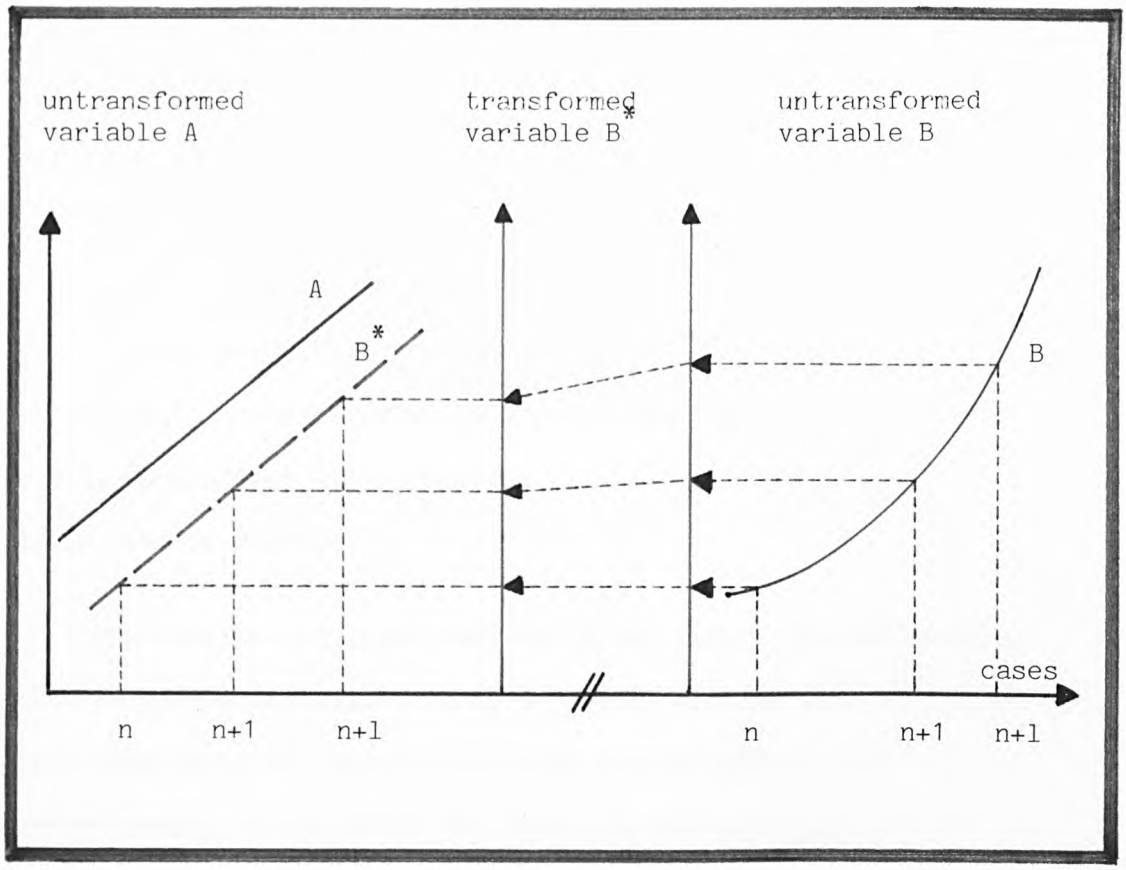


figure 2.9

Interpretation of Transformed Correlation
between 2 variables



2.9. Results

The stages for operationalizing the Factor Analysis process are:

2.9.1. Intercorrelation among variables (clusters)

2.9.2. Factoring results

i. Unrotated Factors

ii. Rotated Factors

iii. Factor scores classification

iv. Cross-correlation between new factors

2.9.3. Consistency of new factors

2.9.4. Factor distance

The results are summarized here, but their full explanation, interpretation and significance are dealt with in chapter 4. The interdependency of these results and the Integrated Model of Technological Change makes the combined interpretation in the later section more appropriate.

2.9.1. Intercorrelation among variables

The first stage of this analysis was an observation of the relationship between variables (correlation method). It was observed that many of the variables correlate highly one to another. A number of variables correlating highly one to another form clusters which may be best presented pictorially. Figures 2.10 to 2.13 (page 137 to 140) show the inter-correlation between variables (lower half of correlation matrix) for year 1960, 1965, 1970, 1977. The darker area on the top of these figures

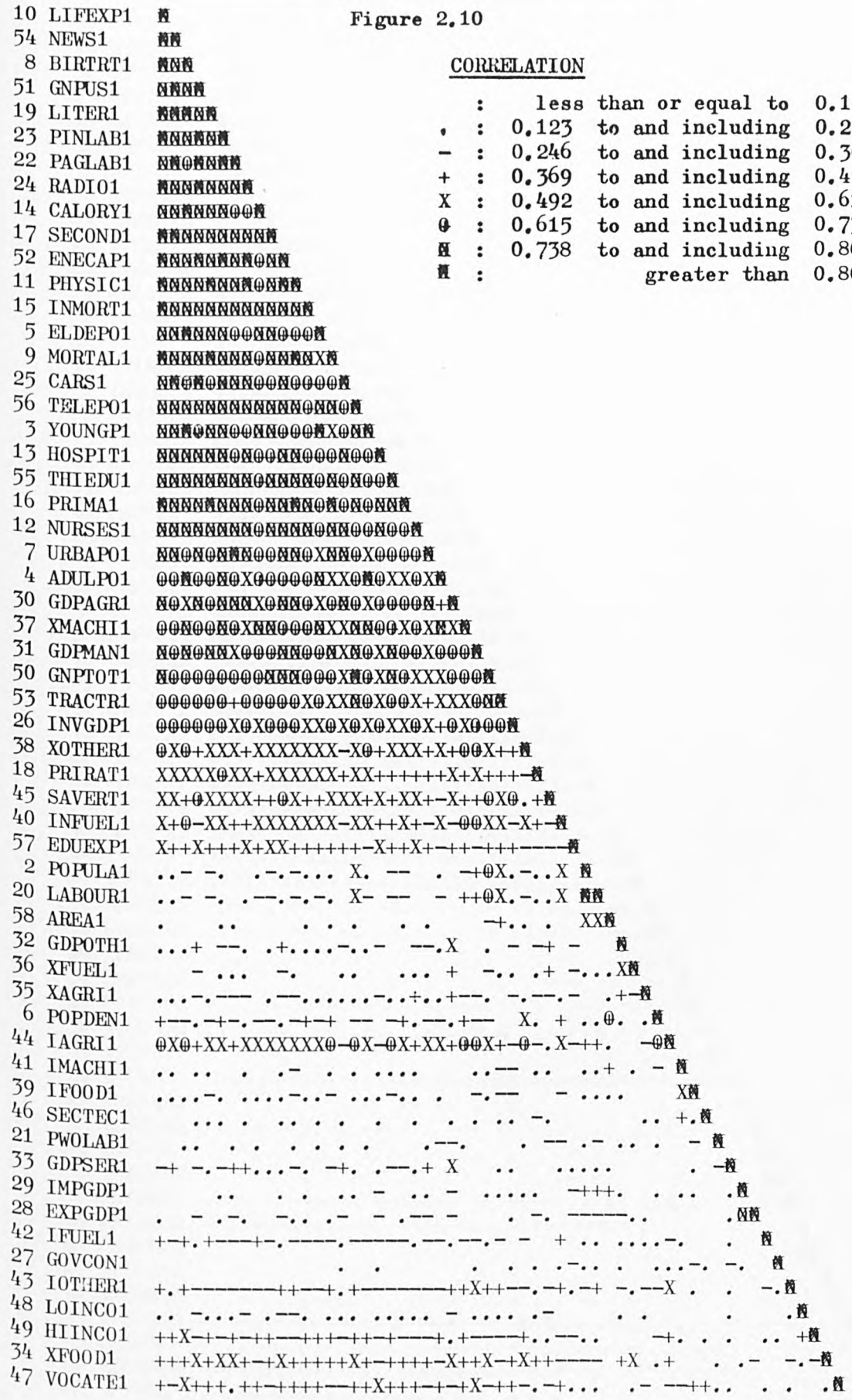
represent one large cluster which is composed of a collection of highly intercorrelated variables. There are a number of other smaller clusters as well, but they are not easily observable by naked eye.

The figures are actually square correlation matrices entered for the lower half below the diagonal. The 57 variables are listed against rows, and the same sequence of variables (variable no. 10 through to variable no. 47) label the columns from left to right along the bottom.

Identification of these clusters alone is not sufficient for the purpose of this study. Rather it is both important and essential to identify the composition of these clusters, and the relationship of each case (country) to these new clusters. This is provided by dimensionalisation of these clusters, the results of which are presented in the next sections.

LOWER HALF OF SQUARE CORRELATION MATRIX 1960

Figure 2.10

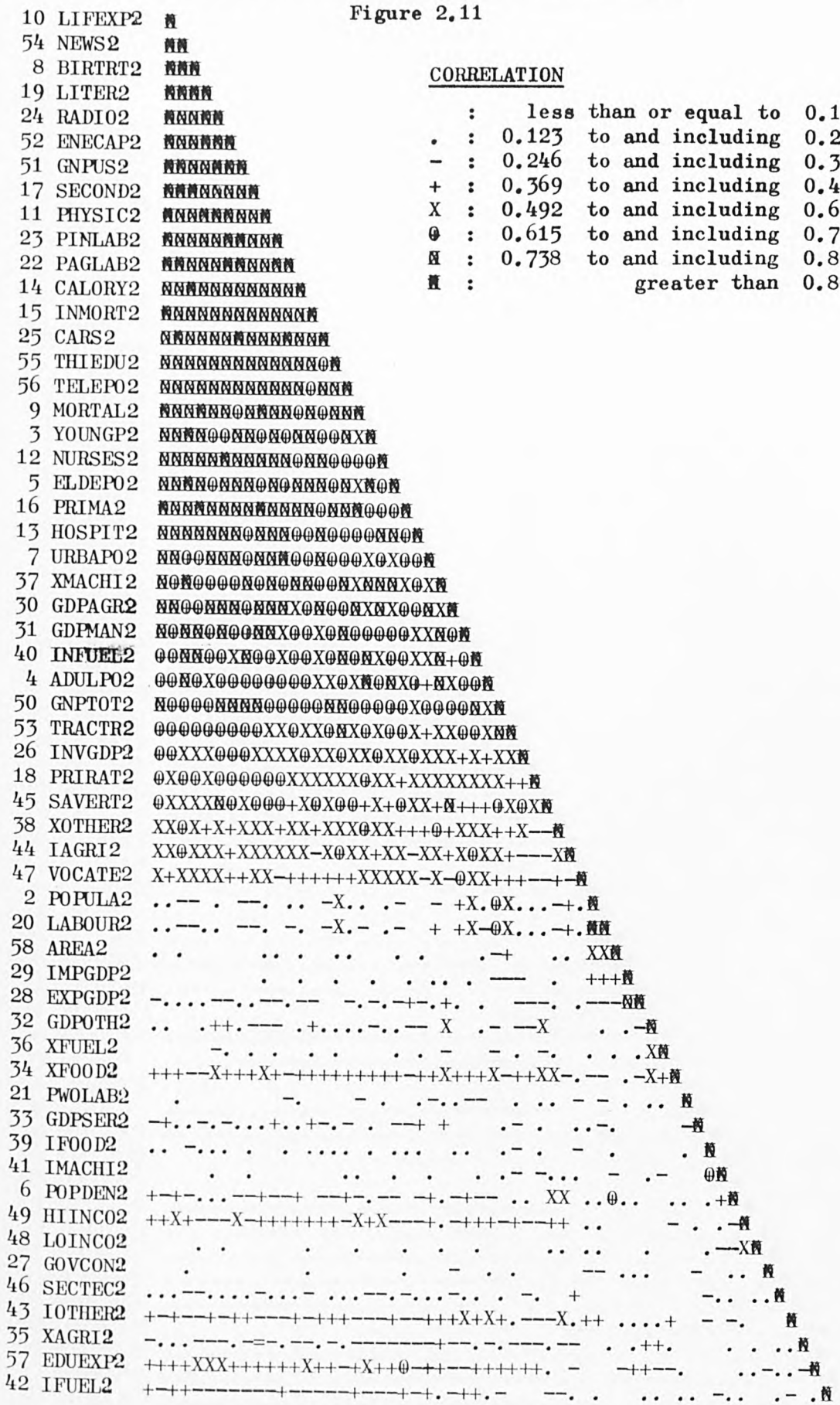


CORRELATION

	:	less than or equal to 0.123
.	:	0.123 to and including 0.246
-	:	0.246 to and including 0.369
+	:	0.369 to and including 0.492
X	:	0.492 to and including 0.615
0	:	0.615 to and including 0.738
8	:	0.738 to and including 0.861
8	:	greater than 0.861

LOWER HALF OF SQUARE CORRELATION MATRIX 1965

Figure 2.11

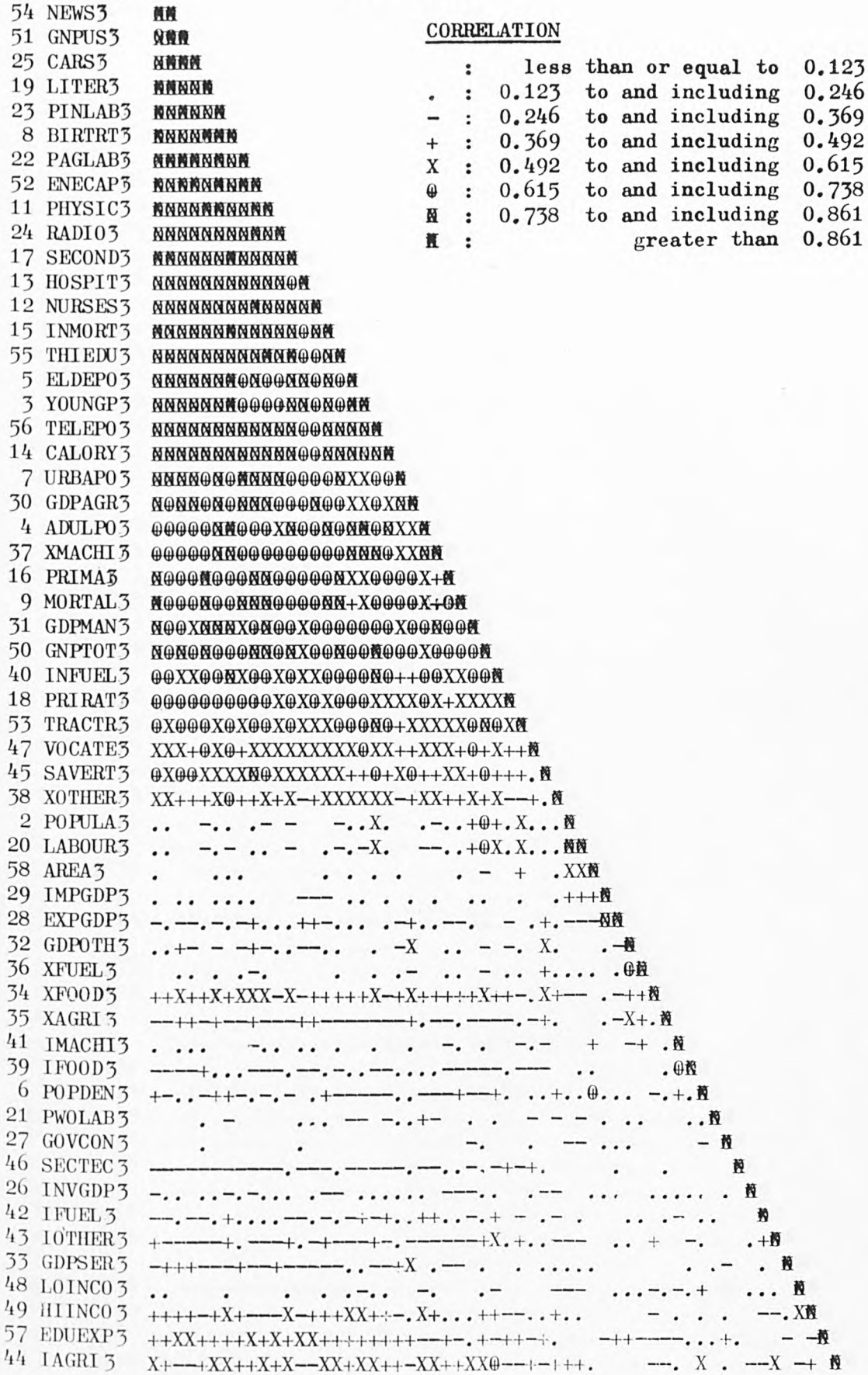


CORRELATION

	:	less than or equal to	0.123
.	:	0.123 to and including	0.246
-	:	0.246 to and including	0.369
+	:	0.369 to and including	0.492
X	:	0.492 to and including	0.615
0	:	0.615 to and including	0.738
M	:	0.738 to and including	0.861
M	:	greater than	0.861

LOWER HALF OF SQUARE CORRELATION MATRIX 1970

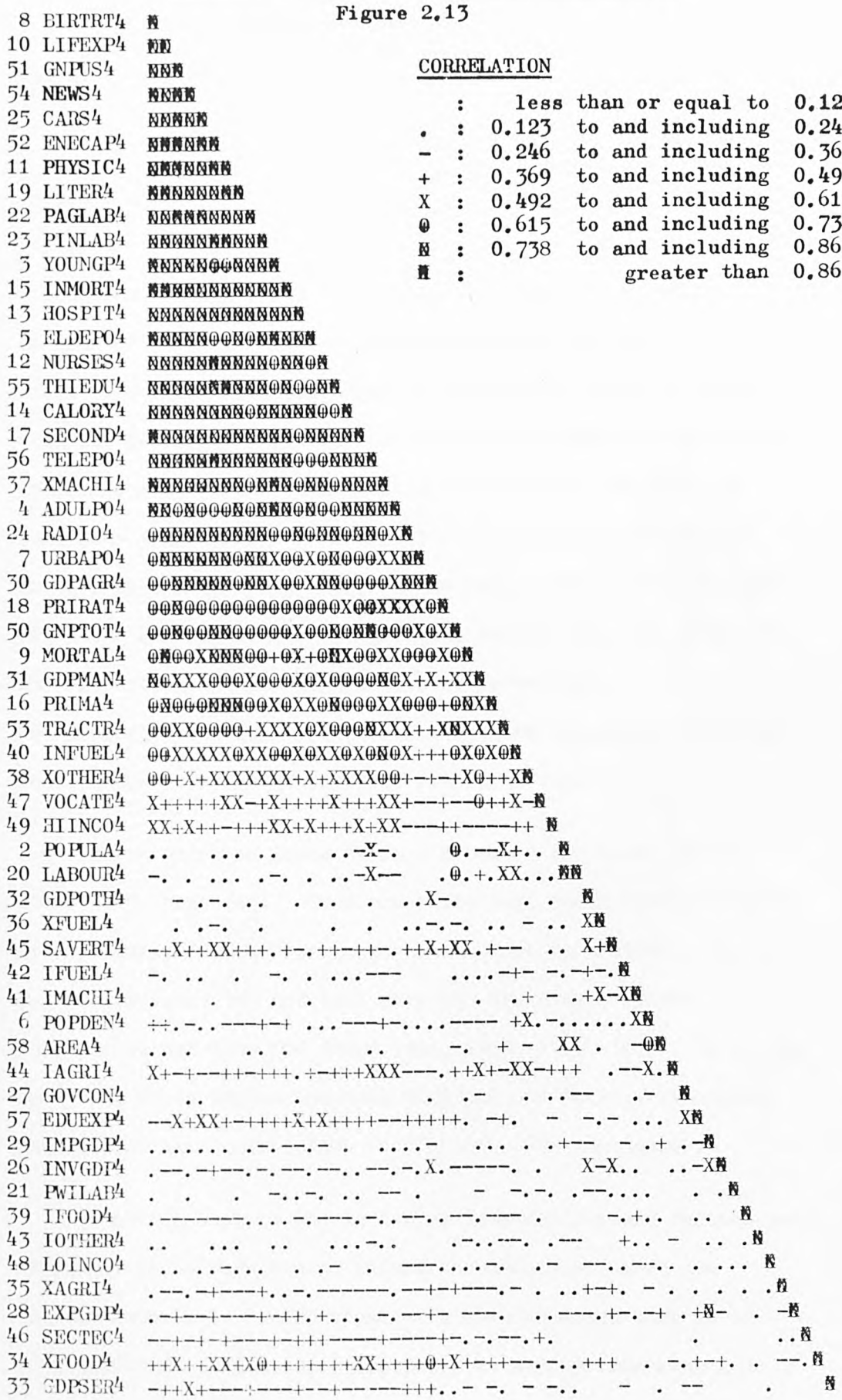
Figure 2.12



CORRELATION

:	less than or equal to	0.123
. :	0.123 to and including	0.246
- :	0.246 to and including	0.369
+ :	0.369 to and including	0.492
X :	0.492 to and including	0.615
0 :	0.615 to and including	0.738
M :	0.738 to and including	0.861
W :	greater than	0.861

Figure 2.13



CORRELATION

	:	less than or equal to 0.123
.	:	0.123 to and including 0.246
-	:	0.246 to and including 0.369
+	:	0.369 to and including 0.492
X	:	0.492 to and including 0.615
0	:	0.615 to and including 0.738
N	:	0.738 to and including 0.861
M	:	greater than 0.861

2.9.2. Factoring Results

It will be remembered that we are using Factor Analysis to reduce a massive data base to a finite number of significant variables in a Euclidean space on a basis of a few well defined dimensions. Factor Analysis enables the identification of clusters formed by inter-correlation between variables. These clusters suggest the dimensions in a Euclidean space in which case can be mapped. From these clusters a number of significant rotatable factors can be extracted to represent the basis of Euclidean space. In this analysis six relatively independent factors have been extracted from the data. They may be thought of as six different underlying causes on the data, ie. they can be regarded as the six empirically different data characteristics. The typical format of the unrotated factoring results are represented in table 2.4 (page 145).

The rotation on these factors produces the final result (table 2.5, page 146). To demonstrate that these rotated factors are virtually independent (uncorrelated one to another), tables 2.6 to 2.9 (page 147 and 148) show the lower half of the correlation matrices for years 1960, 1965, 1970, 1977. It can be seen that these tables indicate that the new factors extracted have almost zero correlation coefficient with each other.

Referring back to the variables from which these factors are composed, it is possible to relate the nature of these new factors from their associations. It must be noted that it is very difficult to pin-point precisely an appropriate name and

nature for these new factors. The composition of each factor is given fully in figure 2.14 to 2.17 (page 149 to 152). (The list of defined variables is given in appendix 2). Each new factor is given the code name of a Greek letter. Examining their composition suggests their likely nature. Appropriate labels for the association were chosen to represent the mixture of variables to which the factors are highly correlated. A list of each factor's association is given below.

Factor	Code name	Correlates highly to:	Association
1	Alpha	GNP percapita, Energy consumption, no. of telephones, etc.	Technology
2	Beta	Area, Population, size of labour force, etc.	Scale
3	Gamma	Export of fuel, GDP from other resources, etc.	Natural Resources
4	Delta	Population density, etc.	Population Activity
5	Epsilon	Import of machinery, Import of food, etc.	Foreign Dependency
6	Zeta	Percentage of women in labour force, etc.	Cultural

In this analysis these six factors are capable of explaining over 70 percent of the total data variance. Factor Alpha correlates highly with Technologically related variables such as Literacy rate, Calory and Energy consumption percapita, Number of cars, telephones, hospitals, physicians per population. Beta correlates highly on the size (or scale) of the population, land, labour force. Gamma is associated mainly on the resources such

as Export of fuel, Export per GDP. The contribution of these there factors are the most significant in the overall results (over 60 percents of total variance is explained by these 3 factors alone). The other three factors (Delta, Epsilon, Zeta) explains the remainining 10 percents.

The Eigenvalue row (no. 4 in table 2.4, page 145) represents the significance level of each new factor to the overall data. They measure the amount of variation accounted for by factor dimensions: the higher the Eigenvalues the higher are the contributions of the corresponding factors to the factors in question. In all four time point experiments, there are twenty factors with positive Eigenvalues, however only six factors have Eigenvalues higher than 1.5. The relationship between Eigenvalues, total variance and the number of factors extracted are represented in figures 2.18 to 2.21 (page 153 to 156). The decision on the number of factors depends on the marginal increase of factors' variance. Any Eigenvalue less than 1.5 is considered to be low. Those factors with very small Eigenvalues usually represent noise and random errors (correlations to other variables are less than 0.25). The variance represents the proportion of each factor involved in all data. In this experiment over 70 percent of the data are represented by these six factors.

Referring to table 2.4 (page 145), the figures along the column (no.2) represent loadings between the new factor and the original variable (see also table 2.10 page 157). For example GNP percapita (GNPUS1) and FACTOR1 has a loading of 0.898. This

measures the degree to which the variable is involved in each factor dimension. It can be interpreted as a correlation coefficient between that factor and the variable it intersects with. The degree of each new factor's association to the original variables is measured by how close the loading to unity. The sign indicates the direction to which the related variable is represented in the Euclidean space. The square of the loading represents the proportion of the variation of the variable in common with an unrotated dimension. They can be thought of as the variation of the data on a variable that can be produced (predicted) by knowing the values of the data case. Another perspective is that the percent figure is the reliability of prediction of a variable from the dimension.

The communality column (no. 3 in table 2.4, page 145) represents the proportion of variation of each variable involved in all factors. They are calculated by summing the squares of the variable's loadings.

Figure 2.14 to 2.17 (page 149 to 152) show the diagramatic representation of the result after the rotation for 1960, 1965, 1970 and 1977. The table of all numerical results is described in appendix 4.2.

table 2.4
Unrotated Factor Loadings (1960)
(selected unrotated example)

No.	Variable	Factor1 (1)	Factor2 (1)	Factor3 (1)	Factor4 (1)	Factor5 (1)	Factor6 (1)	Communality (3)
2	POPULA1	.311	.830	.152	.291	-.185	.038(2)	.996
3	YOUNGP1	-.836	-.110	.227	.094	-.213	-.263	.995
	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.
51	GNPUS1	.898	-.277	.150	-.051	-.052	.104	.991
52	ENECAP1	.932	-.131	.212	.052	.014	-.048	.979
53	TRACTR1	.751	.333	.311	-.120	-.081	.143	.962
54	NEWS1	.895	-.104	-.039	-.203	-.178	.098	.969
55	THIEDU1	.861	.109	.007	-.088	-.201	-.123	.942
56	TELEPO1	.906	.260	.133	.054	-.158	.123	.983
57	EDUEXP1	.543	-.194	.049	.167	.085	.226	.718
58	AREA1	-.061	.513	.693	-.079	-.089	.346	.983
Eigen values: (4)		26.000	4.704	3.517	2.342	2.100	1.675 (4)	
Percent of total variance		45.61 (5)	8.25	7.62	4.11	3.68	2.94 (5)	70.76 (6)

(1) Seperate dimensional relationship between all variables

(2) Degree and direction of relationship of the variables with this dimension (unrotated).

(3) Proportion of variation of each variable involved in this dimension.

(4) Sum of column of squared factor loadings: algabraic roots of a characteristic equation.

(5) Percent of variation among all the variables involved in the particular dimensions.

(6) Percent of total variation among all variables invclved in the dimensions.

table 2.5
Rotated Factor Loadings (1960)
(selected rotated example)

Variables	No.	(1) Factor 1	(1) Factor 2	(1) Factor 3	(1) Factor 4	(1) Factor 5	(1) Factor 6	(3) Communality
POPULA1	2		.921(7)					.996
YOUNPO1	3	-.840						.995
.		.	.	.	.	.	.	.
.		.	.	.	.	.	.	.
.		.	.	.	.	.	.	.
.		.	.	.	.	.	.	.
GNPUS1	51	.906		.302				.991
ENECAP1	52	.864		.327				.979
TRACTR1	53	.693	.488					.962
NEWS1	54	.941						.969
THIEDU1	55	.834						.942
TELEPO1	56	.842						.983
EDUEXP1	57	.506						.718
AREA1	58		.678		.527			.983
Rotated Eigen values		23.967	4.119	3.456	2.821	2.613	2.539 (8)	
Percent of of total variance		45.61 (5)	4.704	3.571	2.342	2.100	1.675 (5)	

(1) Seperate dimensional relationship between all variables.

(7) Degree and direction of relationship of the variables with this dimension (rotated factor)

(3) Proportion of variation of each variable involved in this dimension.

(5) Percent of variation among all the variables involved in the particular dimensions.

(8) Sum of squared of rotated factor loadings.

Note: Blank < 0.25

table 2.6

Correlation matrix between the new dimensions (1960)

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Factor1 (Alpha)	1.0					
Factor2 (Beta)	-0.009	1.0				
Factor3 (Gamma)	0.020	0.002	0.920			
Factor4 (Delta)	0.009	0.028	-0.028	0.969		
Factor5 (Epsilon)	-0.004	0.028	-0.012	-0.004	0.937	
Factor6 (Zeta)	0.019	-0.053	-0.031	0.008	-0.019	1.117

table 2.7

Correlation matrix between the new dimensions (1965)

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Factor1 (Alpha)	1.002					
Factor2 (Beta)	0	0.984				
Factor3 (Gamma)	0.011	0.010	0.946			
Factor4 (Delta)	-0.017	0.008	-0.033	1.121		
Factor5 (Epsilon)	0.004	-0.017	-0.006	0.017	0.921	
Factor6 (Zeta)	0.005	0.022	-0.008	0.052	-0.007	1.0

table 2.8

Correlation matrix between the new dimensions (1970)

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Factor1 (Alpha)	1.003					
Factor2 (Beta)	-0.002	0.996				
Factor3 (Gamma)	0.006	0.016	0.971			
Factor4 (Delta)	-0.012	0.007	0.035	0.925		
Factor5 (Epsilon)	-0.008	0.032	0.039	0.012	1.043	
Factor6 (Zeta)	0.002	-0.019	-0.051	-0.023	-0.100	1.164

table 2.9

Correlation matrix between the new dimensions (1977)

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Factor1 (Alpha)	1.0					
Factor2 (Beta)	0.003	1.006				
Factor3 (Gamma)	0.003	0.020	0.997			
Factor4 (Delta)	0.012	0.012	-0.010	0.996		
Factor5 (Epsilon)	-0.004	-0.033	-0.024	0.015	1.10	
Factor6 (Zeta)	-0.006	-0.049	-0.015	-0.072	-0.072	1.070

figure 2.14

Rotated Factor Loadings (1960)

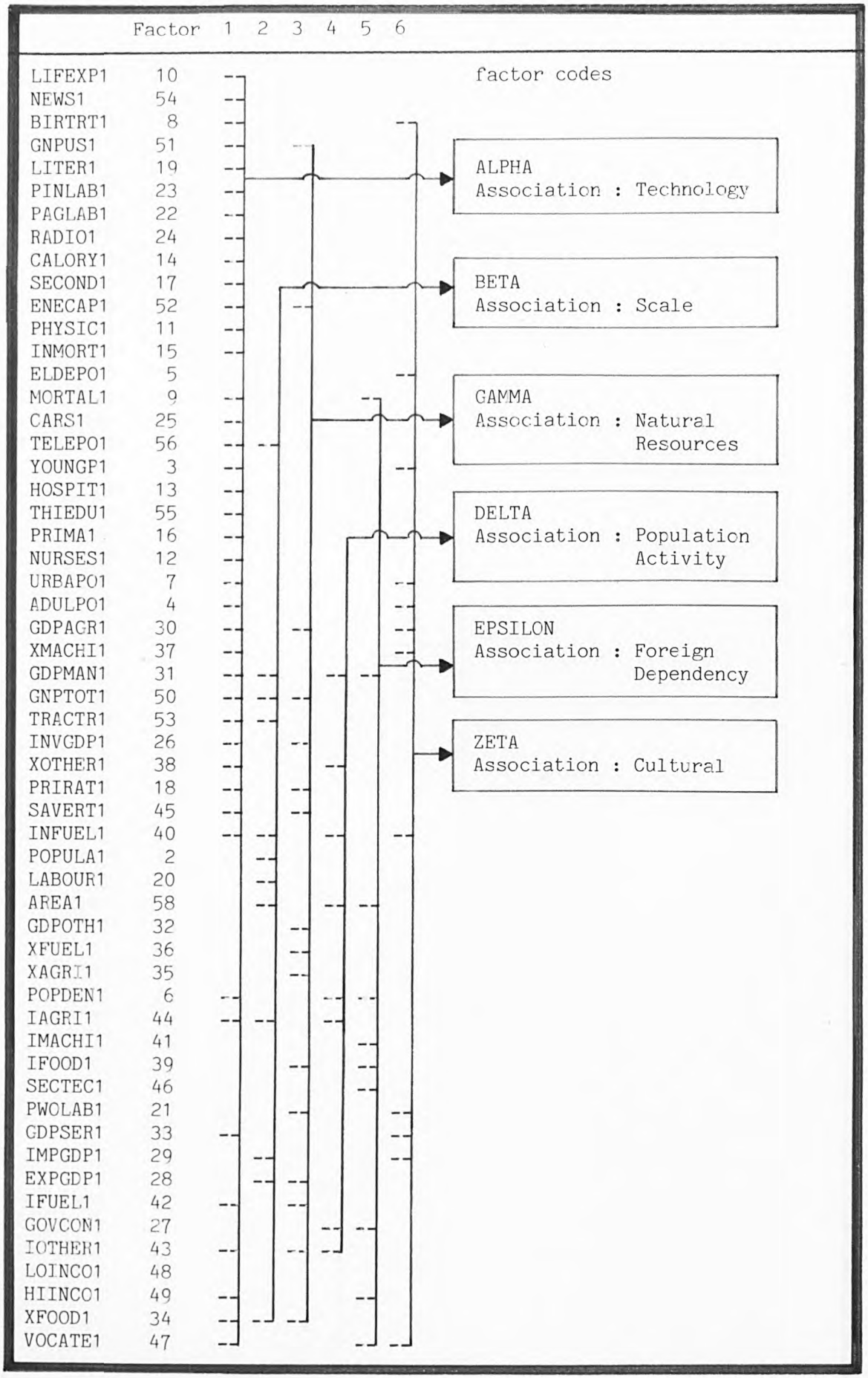


figure 2.15
Rotated factor loadings (1965)

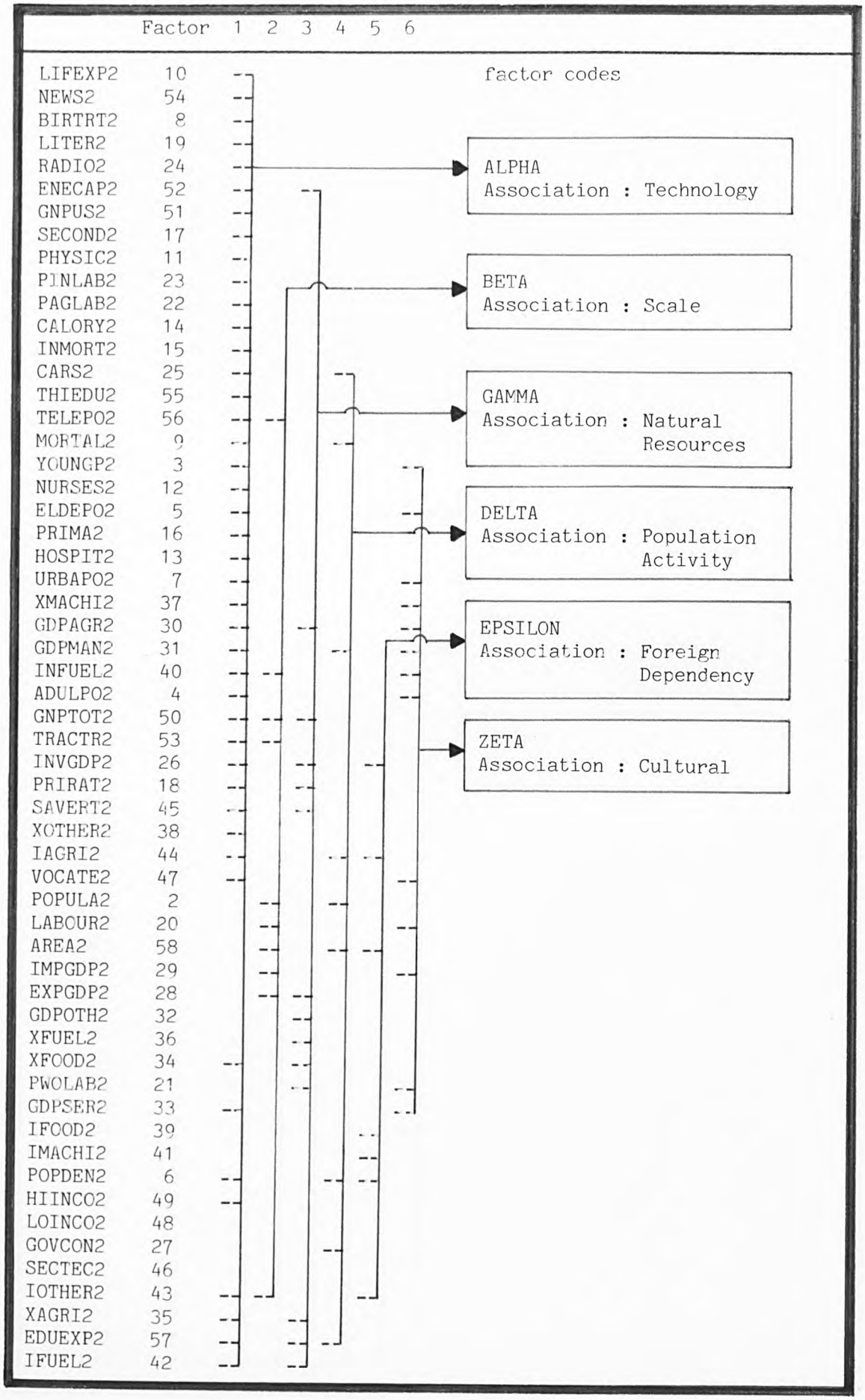


figure 2.16

Rotated Factor Loadings (1970)

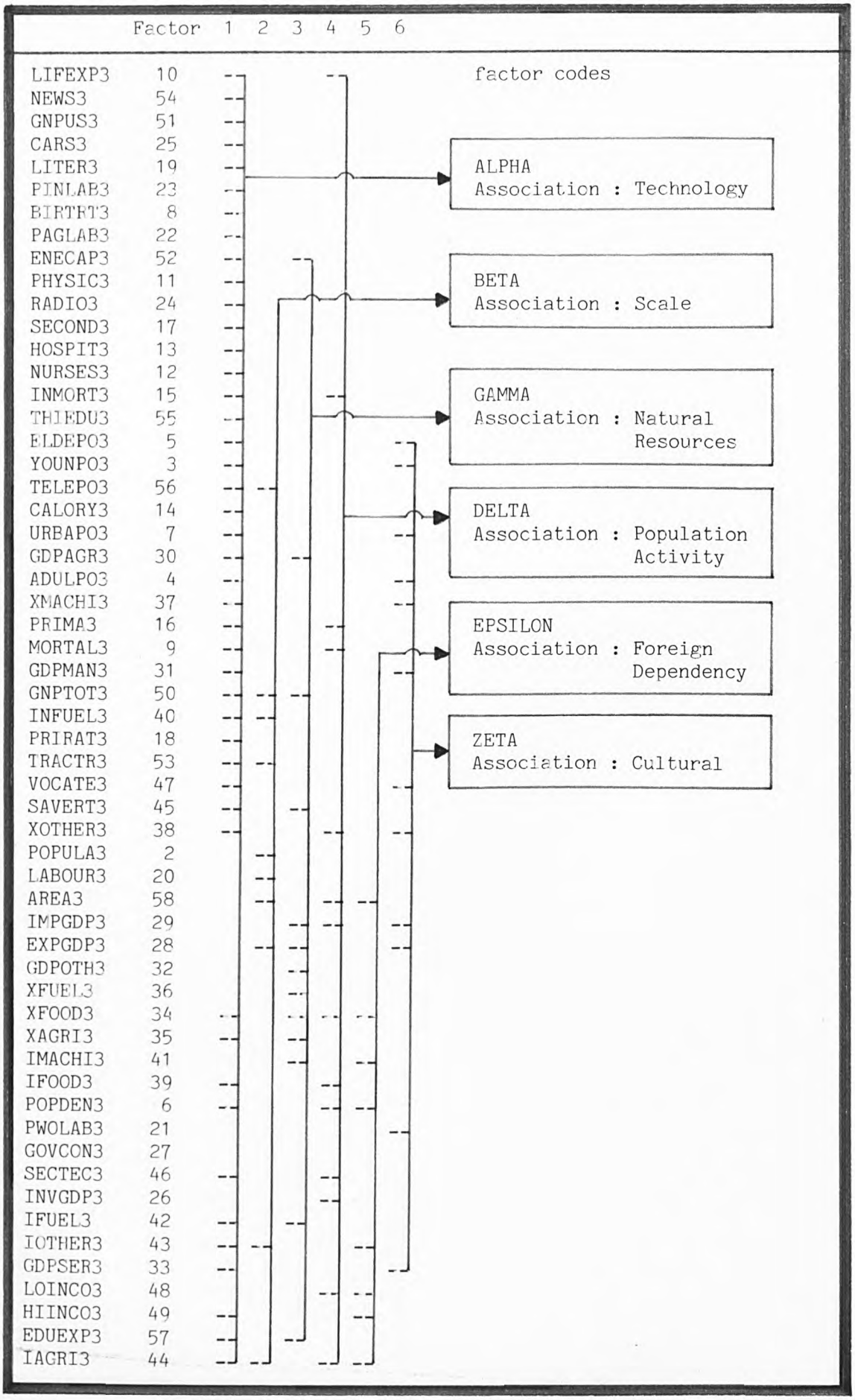
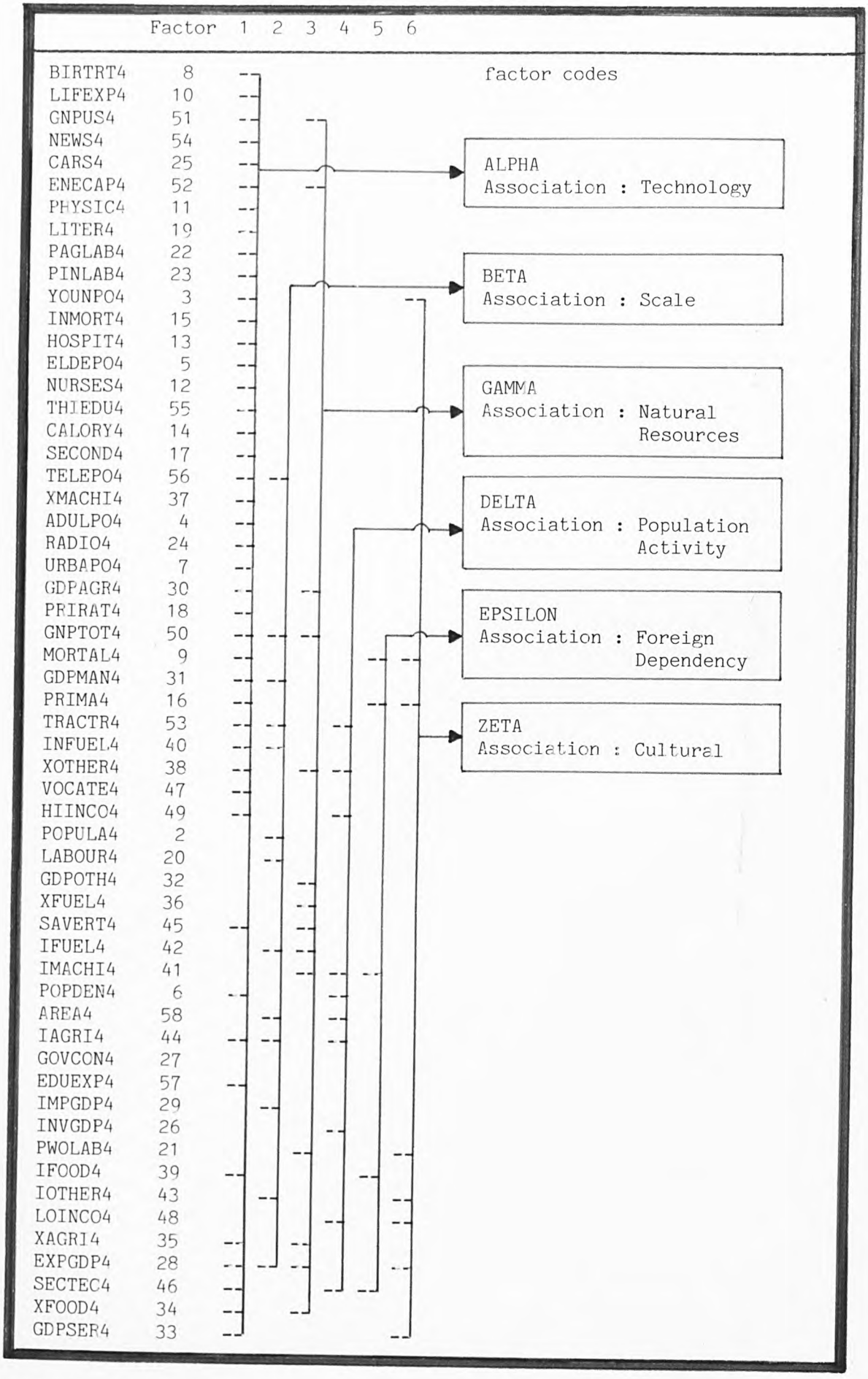
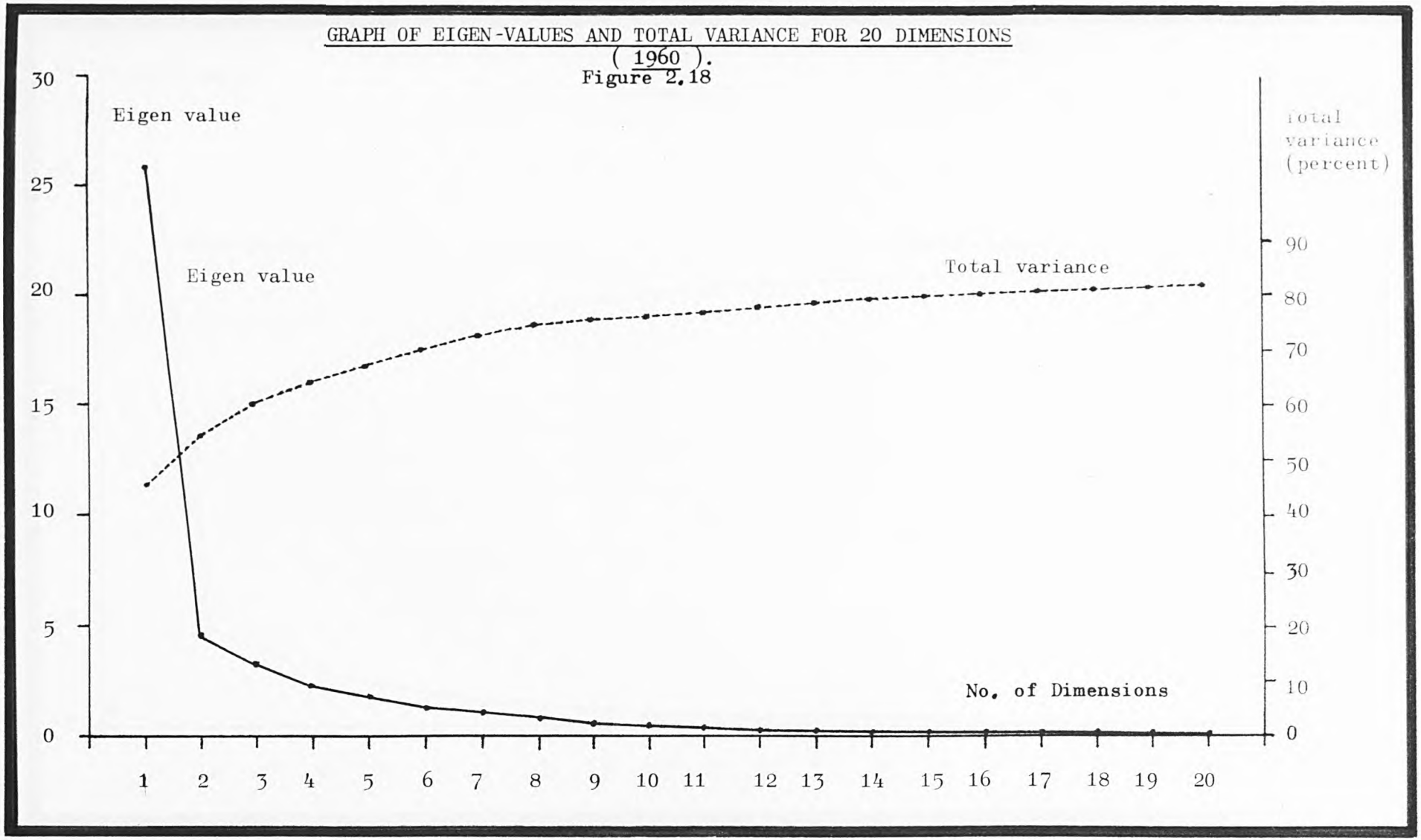


figure 2.17
Rotated Factor Loadings (1977)

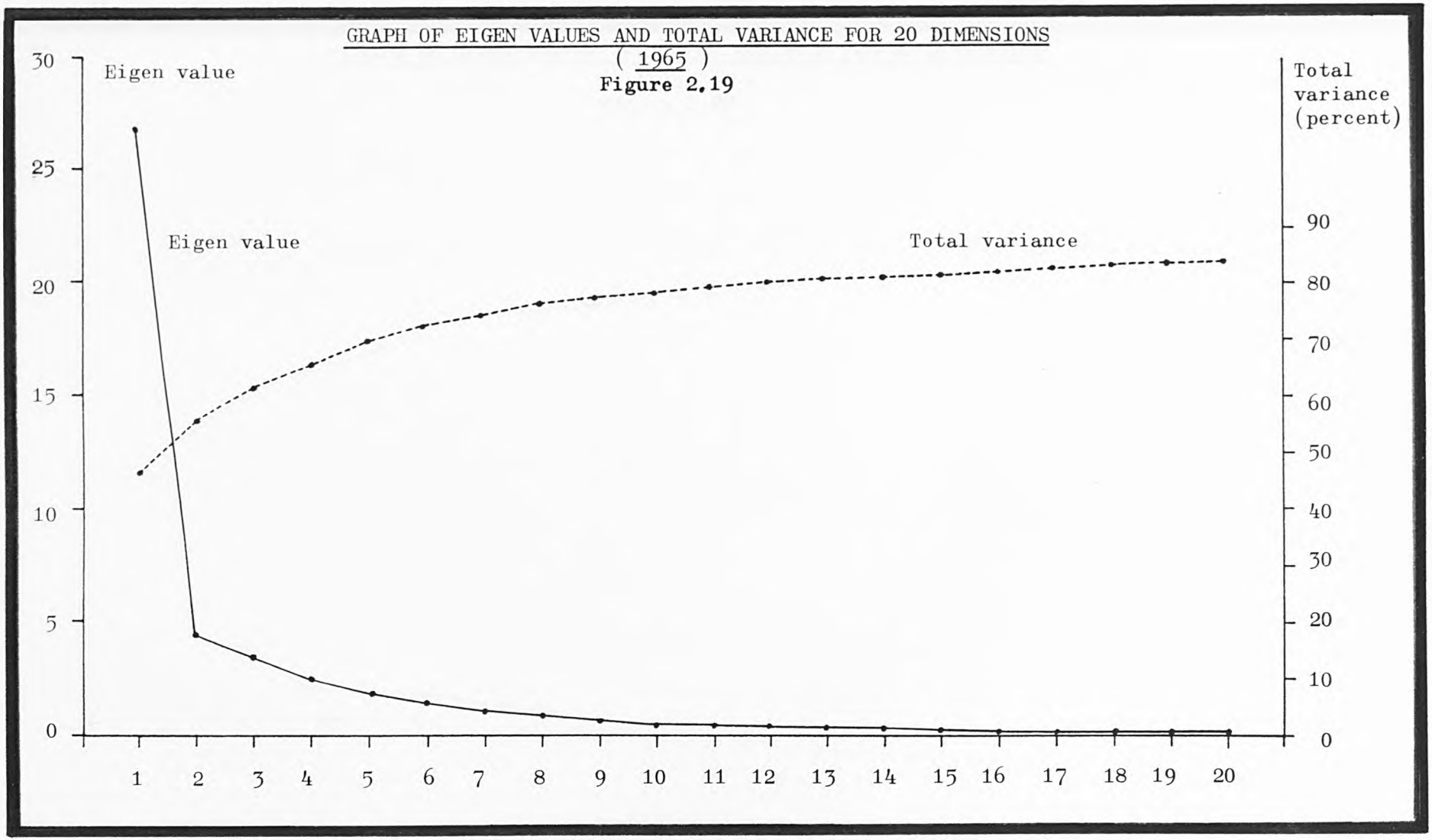


GRAPH OF EIGEN-VALUES AND TOTAL VARIANCE FOR 20 DIMENSIONS
(1960).
Figure 2.18



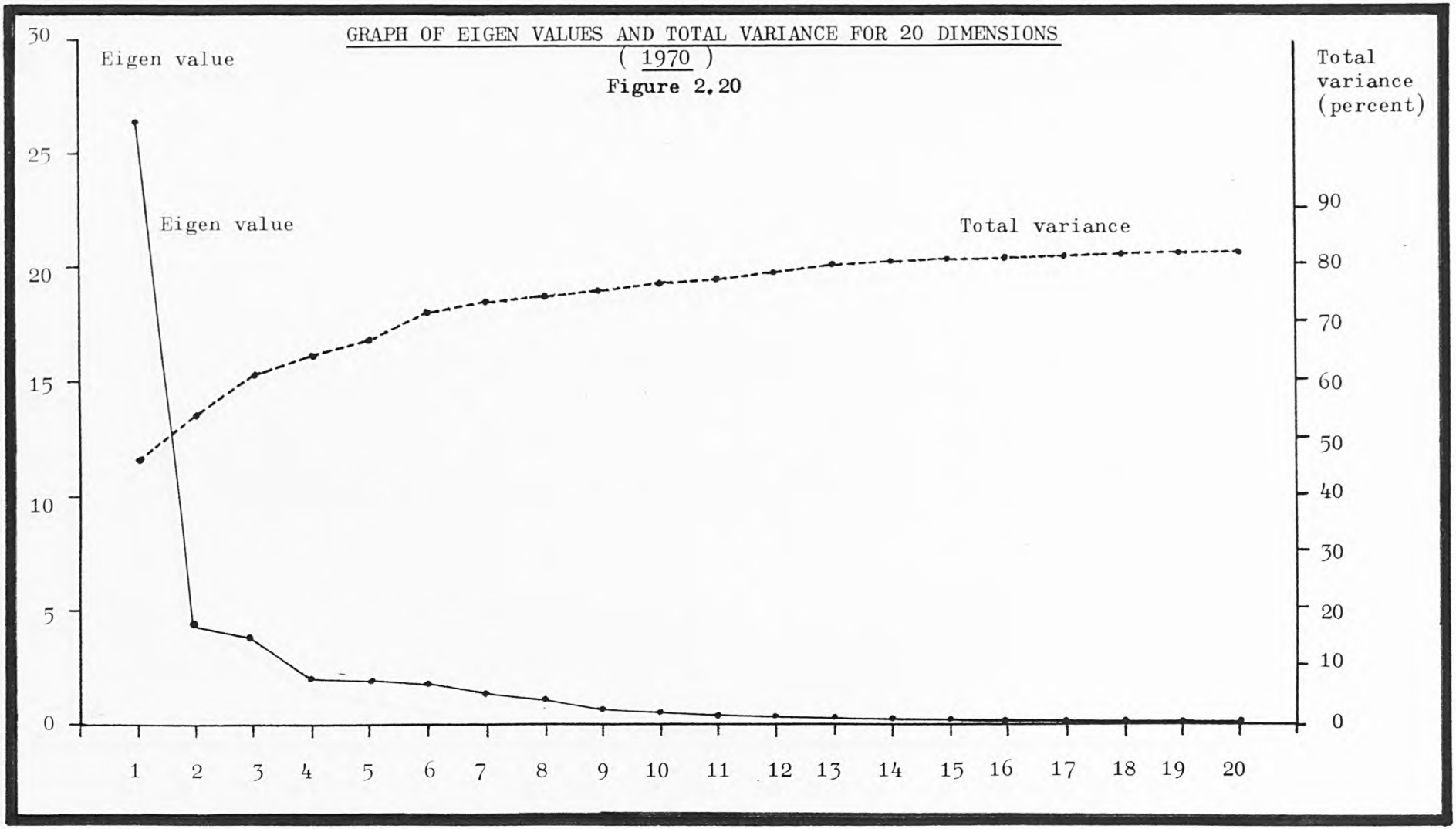
GRAPH OF EIGEN VALUES AND TOTAL VARIANCE FOR 20 DIMENSIONS
(1965)

Figure 2.19



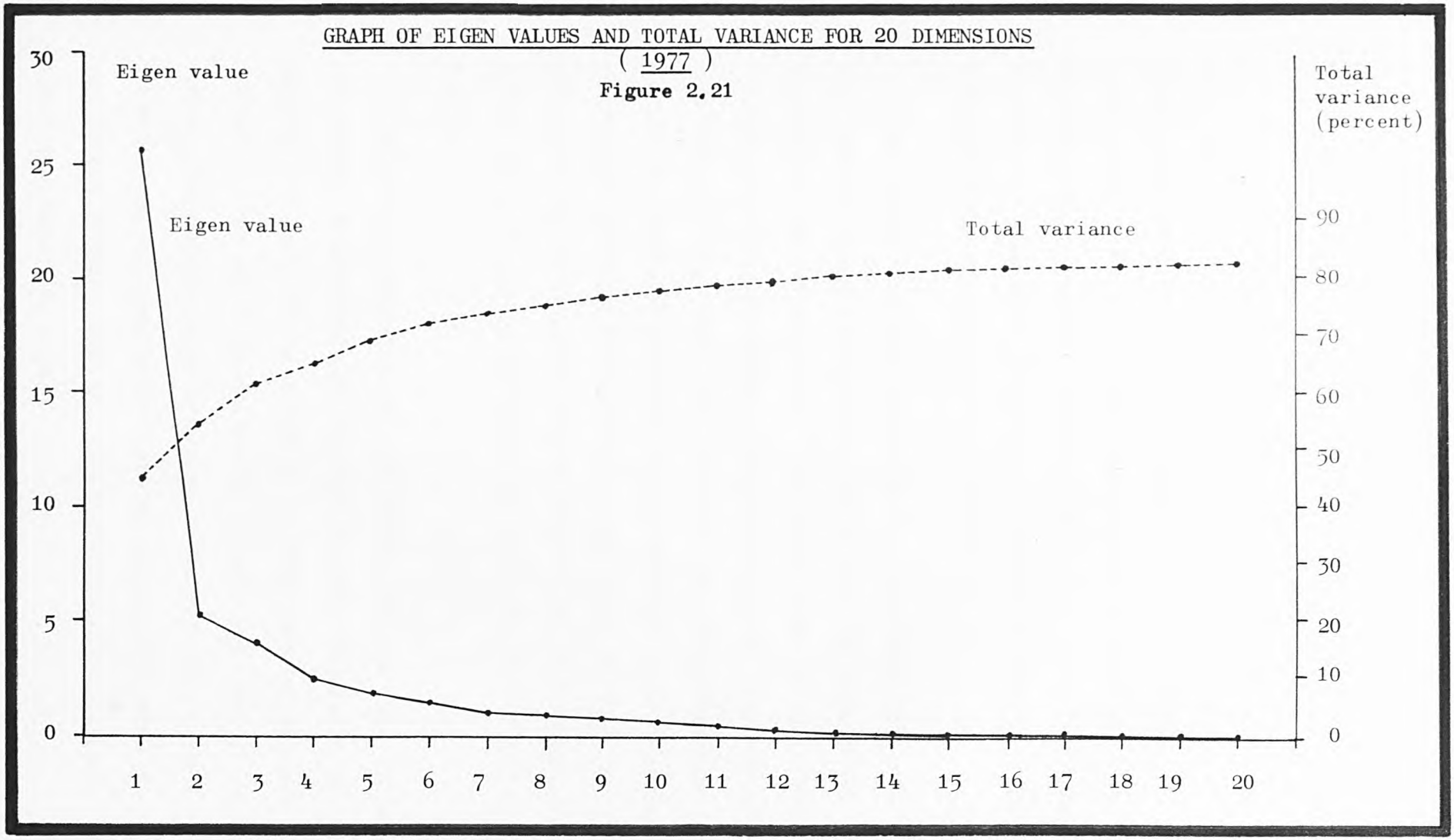
GRAPH OF EIGEN VALUES AND TOTAL VARIANCE FOR 20 DIMENSIONS
(1970)

Figure 2.20



GRAPH OF EIGEN VALUES AND TOTAL VARIANCE FOR 20 DIMENSIONS
(1977)

Figure 2.21



2.9.3. Consistency of Factors extracted

In this experiment four different time-bench were used to test the consistency of the new factor dimensions. If the dimensional reduction method of Factor Analysis is to be scientifically plausible, then theoretically it must be proven to reproduce similar results over different time. Independent data of different time bench are chosen to provide a mean for testing the consistency of this reduction method.

The factor components extracted from different time bench are compared in table 2.10 (page 158) to show the experiment consistency and repeatability. This table shows the correlations (significant loadings) between the new factors and the original variables for 1960, 1965, 1970 and 1977. It can be observed that each factor dimension with significant loadings (larger than 0.5) is composed mostly of the same variables. When the same factor components can be extracted from different data of different time bench, the consistency, and stability power of Factor Analysis is proven.

In the past experiment of this nature has never been carried out before. This experiment was made possible because of the availability data and the existance of large computer database system. In the way it proves the consistency and power of Factor Analysis Methodology which is very significant. This study is claimed to be the first to use time-series method to show the application of Factor Analysis as a scientifically plausible dimensional reduction method.

table 2.10

Rotated Factor Loadings at different time bench

Component of Factor 1 (Alpha)

No.	Variables	1960	1965	1970	1977
3	YOUNGP	-.840	-.852	-.847	-.885
4	ADULPO	.760	.744	.779	.836
5	ELDEPO	.855	.851	.852	.868
6	POPDEN	.296	.330	.268	.253
7	URBAPO	.796	.809	.817	.801
8	BIRTRT	-.917	-.937	-.910	-.923
9	MORTAL	-.848	-.852	-.753	-.718
10	LIFEXP	.952	.967	.936	.922
11	PHYSIC	-.862	-.901	-.898	-.902
12	NURSES	-.823	-.851	-.858	-.868
13	HOSPIT	-.834	-.848	-.861	-.871
14	CALORY	.872	.890	.843	.852
15	INMORT	-.862	-.887	-.856	-.882
16	PRIMA	.829	.848	.755	.706
17	SECOND	.865	.902	.873	.850
18	PRIRAT	-.521	-.639	-.689	-.737
19	LITER	.904	.929	.917	.898
22	PAGLAB	-.877	-.891	-.909	-.894
23	PINLAB	.900	.894	.916	.887
24	RADIO	.872	.911	.892	.828
25	CARS	.847	.872	.919	.918
26	INVGDP	.651	.650		
28	EXPGDP				.299
30	GDPAGR	-.754	-.785	-.783	-.772
31	GDPMAN	.723	.755	.753	.707
33	GDPSER	.366	.322	.401	.426
34	XFOOD	-.411	-.402	-.406	-.467
35	XAGRI		-.258	-.333	-.293
37	XMACHI	.751	.788	.765	.844
38	XOTHER	.599	.600	.523	.596
39	IFOOD			-.300	-.284
40	INFUEL	.507	.749	.695	.637
42	IFUEL	.401	.411	.325	
43	IOTHER	-.294	-.369	-.311	
44	IAGRI	.548	.578	.458	.388
45	SAVERT	.510	.615	.568	.383
46	SECTEC			-.373	-.440
47	VOCATE	.411	.533	.618	.521
49	HIINCO	-.493	-.470	-.412	-.507
50	GNPTOT	.708	.733	.718	.726
51	GNPUS	.906	.904	.921	.922
52	ENECAP	.864	.906	.902	.907
53	TRACTR	.693	.694	.678	.663
54	NEWS	.941	.942	.924	.940
55	THIEDU	.834	.865	.856	.867
56	TELEPO	.842	.862	.846	.849
57	EDUEXP	.506	.470	.461	.446

table 2.10 (continued)

Components of Factor 2 (Beta)

No.	Variables	1960	1965	1970	1977
2	POPULA	.921	.853	.907	.948
20	LABOUR	.882	.815	.882	.936
28	EXPGDP	-.264	-.620	-.583	-.431
29	IMPGDP	-.359	-.744	-.669	-.439
31	GDPMAN	.270			.252
34	XFOOD	-.278			
40	INFUEL	.336	.361	.374	.421
42	IFUEL				.287
43	IOTHER		-.353	-.375	-.367
44	IAGRI	.254		.292	.384
50	GNPTOT	.594	.534	.559	.576
53	TRACTR	.488	.534	.556	.579
56	TELEPO	.477	.433	.444	.457
58	AREA	.678	.764	.711	.632

table 2.10 (continued)

Components of Factor 3 (Gamma)

No.	Variables	1960	1965	1970	1977
18	PRIRAT	-.274	-.256		
21	PWOLAB	-.284			-.346
26	INVGDP	.268	.281		.380
28	EXPGDP	.289	.477	.478	.436
29	IMPGDP		.281	.255	
30	GDPAGR	-.439	-.430	-.404	-.389
32	GDPOTH	.746	.789	.837	.809
34	XFOOD	-.459	-.583	-.521	-.480
35	XAGRI	-.538	-.428	-.507	-.429
36	XFUEL	.660	.727	.726	.702
38	XOTHER				-.255
39	IFOOD	.273			
41	IMACHI			.277	.531
42	IFUEL	-.265	-.298	-.297	-.569
43	IOTHER	-.369	-.254		
45	SAVERT	.486	.512	.494	.611
50	GNPTOT	.256	.318	.301	.317
51	GNPUS	.302			.303
52	ENECAP	.327	.339	.337	.315
57	EDUEXP		.353	.349	

table 2.10 (continued)

Components of Factor 4 (Delta)

No.	Variables	1960	1965	1970	1977
2	POPULA		.266		
6	POPDEN	.787	.655	.591	.872
9	MORTAL	-.290	-.290	-.429	
15	INMORT			-.274	
16	PRIMA			.381	
25	CARS		-.268		
26	INVGDP			.494	
27	GOVCON	-.401	-.495		
29	IMPGDP			.265	
31	GDPMAN	.368	.333		
34	XFOOD			-.259	
38	XOTHER	.357		.380	.335
40	INFUEL	.350			-.476
43	IOTHER	-.439			
44	IAGRI	.564	.349	.389	.502
46	SECTEC			.263	.266
48	LOINCO			.367	.417
49	HIINCO				-.310
53	TRACTR				-.253
57	EDUEXP		-.353		
58	AREA	-.527	-.390	-.352	-.644

table 2.10 (continued)

Components of Factor 5 (Epsilon)

No.	Variables	1960	1965	1970	1977
6	POPDEN	-.338	.340	-.484	
8	BIRTRT				.295
16	PRIMA				-.322
26	INVGDP		-.320		
27	GOVCON	-.281			
31	GDPMAN	.253			
34	XFOOD			.273	
39	IFOOD	-.604	.742	-.683	.673
41	IMACHI	.732	-.699	.764	-.438
43	IOTHER		-.350	.304	
44	IAGRI		.261	-.356	
46	SECTEC	-.533			-.349
47	VOCATE	.454			
48	LOINCO			-.484	
49	HIINCO	.403		.370	
58	AREA	.255	-.307	.375	

table 2.10 (continued)

Components of Factor 6 (Zeta)

No.	Variables	1960	1965	1970	1977
3	YOUNGP	-.439	-.366	-.396	-.258
4	ADULPO	.459	.353	.409	
5	ELDEPO	.326	.275	.300	
7	URBAPO	-.268	-.277	-.261	
8	BIRTRT	-.312			
9	MORTAL				.347
16	PRIMA				-.251
20	LABOUR		.305		
21	PWOLAB	.630	.668	.683	.577
28	EXPGDP			.284	.281
29	IMPGDP		.260	.345	
30	GDPAGR	.281	.255		
31	GDPMAN		.274	.256	
33	GDPSER	-.595	-.593	-.452	-.382
37	XMACHI	.408	.387	.349	
38	XOTHER			.251	
40	INFUEL	.381	.312		
43	IOTHER				.340
47	VOCATE	.399	.446	.376	
48	LOINCO				.327

2.9.4. Factor Distances

The projections of individual case' scores on these new dimensions are given by factor distances. These are projections of the standard scores of the case (country) on the new factors. Appendix 1.4 describes this process graphically. The collection of these new variables forms a simplified version of characteristics which are based on most significant factors extracted from the data. In this experiment the most significant factors were found to be six. We shall call the collection of these new variables as the National Characteristics. A typical format of these characteristic is given as in United Kingdom' 1977 result in figure 2.22 (page 166).

The distribution of factor scores can be represented as figure 2.23 (page 167). Thus any country which has positive scores is higher compared to the overall average (which is equal to 0). However it must be noted that the absolute scores changes with time. Although it has been shown that this reduction method is scientifically plausible and consistent, one drawback of Factor Analysis method is that it is basically a non-dynamic method. For this reason the factor scores of different time bench are not directly comparable. A method however is developed to overcome this limitation. It is described later in chapter 3.

The National characteristics represented by new factors (figure 2.22 (page 166) can be represented by vector distance in the Euclidean-space. Since each new factor is independent one to another, these vectors are supposed to be right angle one to

another (in n dimension Euclidean-space). The multidimensional representation of these vector space in two dimension can only be best represented by arrows from hypothetical origin as shown in figure 2.22 (page 166). The unit of this factor distance is standard deviation relative to the overall mean. Thus 0 represents a distance equal to the one of sample average. The complete set of results for all cases for 1960 to 1977 are listed in appendix 5.1 (National Characteristic Graphs).

The format of comparative factor distance for the whole sample is given in figure 2.24 (page 168). This graph enables us to compare and measure the factor distance (gap) between any country (case). Thus how far behind any country relative to another can now be compared in quantitive manner. The complete comparative results for the whole sample between 1960 to 1977 are also presented in appendix 5.2.

figure 2.22

Format of Individual Case Results

United Kingdom (1977)

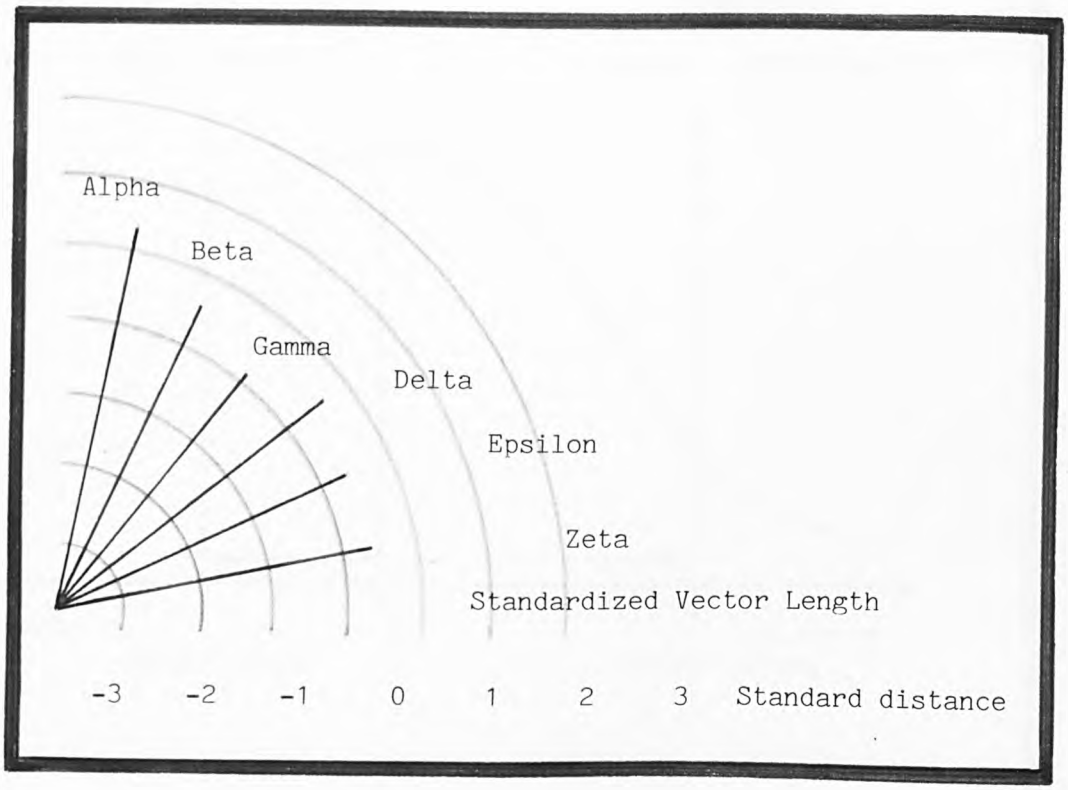


figure 2.23

Distribution of Factor Scores

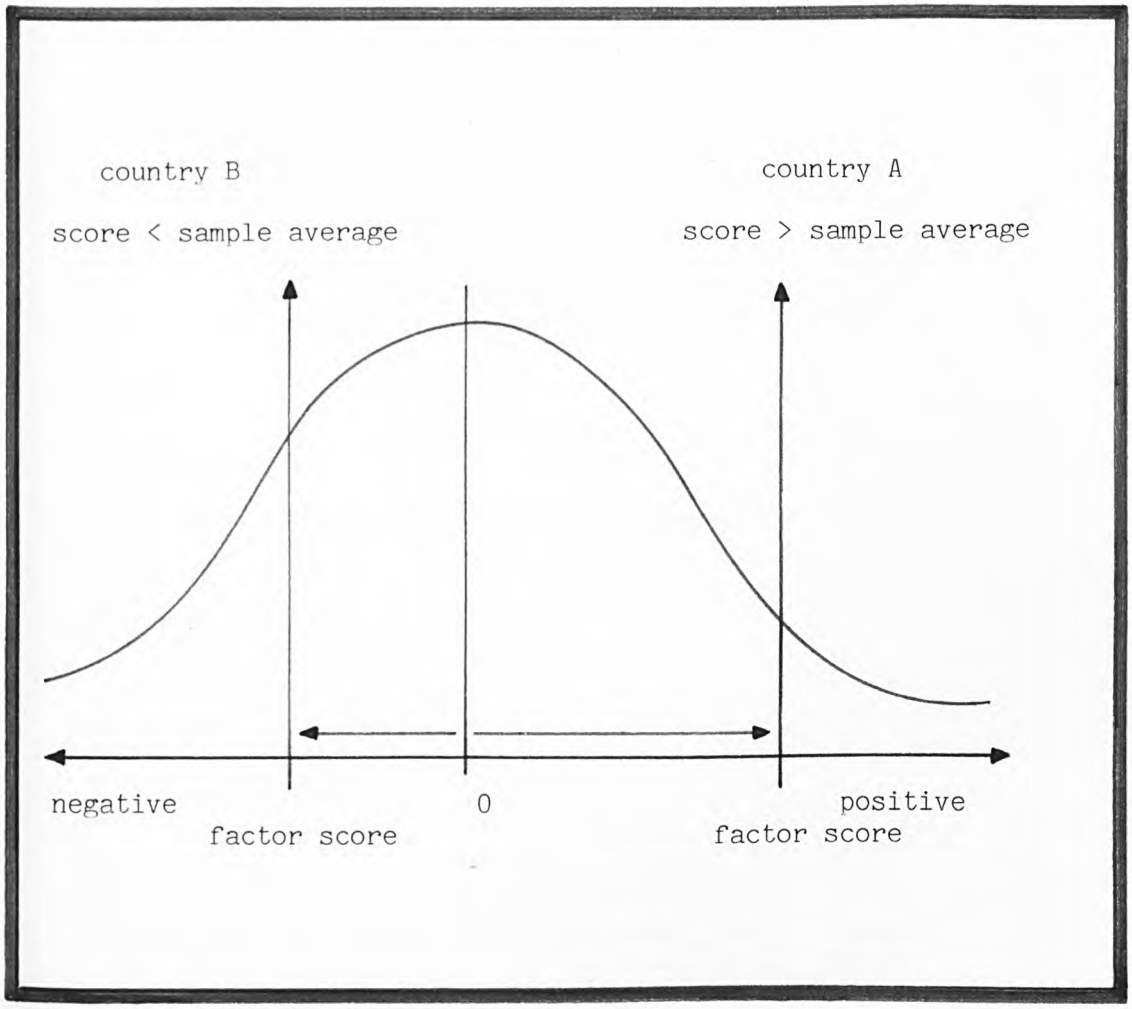
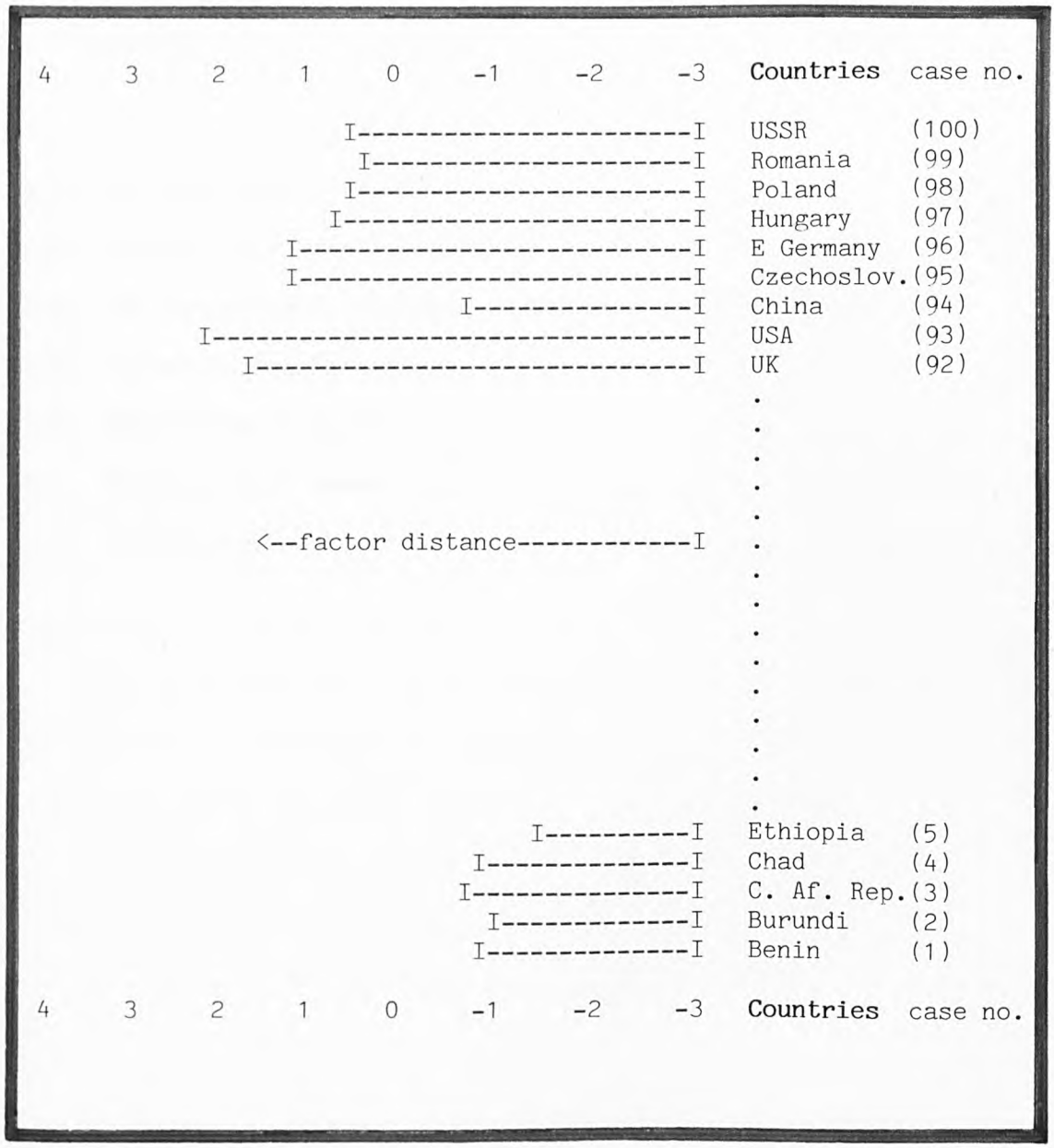


figure 2.24

Format of Comparative Factor Distance for the whole Sample

Factor Alpha 1960



CHAPTER 3

INTERPRETATION AND UTILISATION OF FACTOR ANALYSIS RESULTS

3.1. Introduction..... 169

3.2. Results of Factor Analysis..... 170

3.3. The Relationship of Alpha to Stock of Scientists..... 179

3.4. Technological Dimensions..... 182

3.5. The Growth of Alpha..... 185

3.6. The Growth of Gamma..... 188

3.7. Discussion..... 189

CHAPTER 3

INTERPRETATION AND UTILISATION OF FACTOR ANALYSIS RESULTS

3.1. Introduction

This chapter describes the results of dimensional reduction method as outlined in chapter 2. The results are classified according to geo-economic groups. This classification highlights the basic characteristic differences between countries belonging to these geo-economic groups.

To observe and analyse the behaviour of Technological Change at national level we need to approach our problem in general manner rather than in few isolated cases. The method of variable reduction reduces the level of complexity which usually inherent to large scale problems. In this chapter the results of Factor Analysis are approximated and correlated with the statistical indicators which are widely available. These approximate associations describe a better picture of the nature of each new factor. Factor Alpha for example is associated to technology itself. As expected, Alpha has a very close correlation with the number of scientists stock.

The growth of Alpha and Gamma, two of the most important characteristic factors are analysed and validated. This relationship will be used in conjunction to Efficiency model (chapter 4) to make a Technology Forecast model (chapter 5).

3.2. Results of Factor Analysis

The classification of countries according to their geo-economic development highlights the differences in characteristics between of new factor dimensions. Earlier our 100 nations sample was divided into 9 geo-economic groups (table 2.2, page 107). These groups are:

1. African countries
2. Northern African and Middle East countries
3. South East Asia and Pacific countries
4. Southern Asia countries
5. Latin American countries
6. Southern European countries
7. Major Oil Producing countries
8. Western Industrialised countries
9. Socialist countries

Figure 3.1 (page 178) shows Alpha scores between these groups for different time bench. It can be seen the African countries (group 1) have the lowest relative Alpha scores, the highest being Western Industrialised countries. Alpha is very closely related to variables we normally associate as the indicator of Technology (eg. life expectancy, number of physicians per population, education, infant mortality rate, etc). Table 2.10 (page 158) contains a complete table of correlation coefficients (components) supporting this association.

Referring to figure 3.1 (page 178) the African countries has the lowest Alpha scores. It corresponds to the fact that these

countries generally have the lowest average standard of living and are technologically behind most other countries. The average scores for this group is -0.90, -0.96, -0.96, -0.98 for 1960, 1965, 1970, and 1977 respectively. As it has been mentioned earlier these scores represent the standard deviation of the factor in that time bench. Thus any countries with score equals to 0 rank exactly in the middle of our sample. Near to sample average for Alpha scores are countries in group 5 (Latin American) with scores of -0.10, -0.04, -0.13, and 0.07 in 1960, 1965, 1970 and 1977 respectively. The implication of these results are:

1. Alpha scores at different time bench for African countries seem to indicate that they always stay on the lowest level and are getting relatively lower with time. It implies that they are not improving as fast relative to all sample. Hence, the technology of these countries with time is getting relatively further behind all others. In term of the Technology gap between the underdeveloped and the average developing countries, this indicator positively shows **that these less developed countries (LDC's) are lagging further behind (1960-1977).** Therefore the Technology gap has been shown to increase.

2. Equally however, the relative Alpha scores for the Western Industrialised countries (North Western European and North American) seem to have decreased from 1.62 in 1960 to 1.52, 1.50, and 1.48 in 1965, 1970 and 1977 respectively. This result may be different to general belief that the

industrialised countries are advancing so fast that they leave other developing countries behind. The result in table 3.1 (page 178) clearly shows that **technology gap between the highly industrialised countries and the overall average is narrowing.** It also implies that the state of Technology in most average developing countries are increasing **sufficient to narrow the gap to the highly developed Western Industrialised countries.**

Group 2 countries (Northern African and Middle East - Non OPEC countries) are observed to have higher Alpha scores in comparison to those in group 1. However with time it is shown to decrease from -0.54 in 1960 to -0.61 in 1977. This result implies that these countries are worse off than average sample at 1977 compared to at 1960. In fact its rate of Alpha increase is almost as little as that of group 1.

The country groups which show the most significant Alpha growth are those belonging to group 3 (South East Asia and Pacific countries), group 5 (Latin American countries), group 6 (Southern European countries), group 7 (major Oil Producing Countries), and Socialist countries (group 9). Given that they attain the same level of Alpha growth relative to Western Industrialised countries, in the long run it is possible for them to achieve similar level of Technological as these countries. It will be shown later that the rate of change of Alpha is at peak when Alpha is approximately equal to the sample average (figure 3.19, page 197).

table 3.1

Rate of Growth of Alpha for various country groups

No.	countries	rate of growth of Alpha relative to overall sample average growth rate between 1960-1977
1.	African countries	- 0.08
2.	Northern African and M. East countries	- 0.07
3.	South East Asia and Pacific countries	0.06
4.	Southern Asia countries	- 0.22
5.	Latin American countries	0.17
6.	Southern European countries	0.10
7.	Major Oil Producing countries	0.29
8.	Western Industrialised countries	- 0.16
9.	Socialist countries	0.34

The result in table 3.1 seems to indicate that Socialist countries achieve the highest growth. However on closer observation it reveals that their Alpha score for 1960 is relatively if not unrealistically low. This may due to the poor statistical data quality available at that time. If we look at the Alpha scores from 1965 onwards, the rate of growth is small (around 0.03 between 1965-1970 and 0.06 between 1970-1977). Otherwise as expected, the highest rate of increase of Alpha is found in OPEC countries. After a remarkable relative retardation between 1960 to 1965, these countries show a very steep Alpha increase especially after 1970.

One drawback of the existing dimensional reduction method is that it is not a time series methodology. Thus if we need to compare the absolute rate of change of any factor characteristic over time directly, there is no direct way of doing so. In this thesis a new conversion method to change static dimensional reduction results to a time series one is developed. This is described more fully in chapter 3.4.

The second factor (Beta), basically relates to the scale (size) dimension. It can be observed that it has some very high loadings (correlations) to variables such as population, area, labour force, and others relating to size characteristics. Figures in Appendix 5.2 show relative Beta scores among all samples. China, USSR, India, and USA all have very high scores on this factor dimension.

The third most significant factor (Gamma) has a number of high loading on variable such as percentage of Export of Fuel to Total Export (XFUEL), GDP from services and others as percentage of total GDP (GDPOTH), Export per GDP (EXPGDP), and a number of other related national resources. These three factors are responsible for large proportion of the overall characteristics relative to all other additional dimensions. Figures in 2.18-2.21 (page 153-156) show that with further additional dimensions added, the contribution of the variance explained decreases significantly. For reference purpose, we shall associate Gamma as a factor related very closely to National Resources.

Factor Delta and the other remaining dimensions (Epsilon and Zeta) are presented for a complete overall characteristics. Factor Delta (Factor dimension 4) correlates to Population Density (POPDEN), Import of agriculture (IAGRI), and to Area (AREA). To some extend this factor seems to be related to the nature of agricultural activity. However since its relationship to any particular variable which we commonly use is not very strong (as shown by factor loadings), it is very difficult to associate this factor dimension precisely with a particular variable name.

Similarly the fifth factor dimension (Epsilon) contains factor loadings of Import of foods (IFOOD) and Import of machinery (IMACHI). Referring to the table 2.10 (page 158), we noticed that for the year 1965 and 1977, the sign of the loadings changed in 1960 and 1977. This merely means that the direction of the resultant vector is opposite relative to the origin. The

relative positions of the other countries' scores as well as the variables which have high loadings remain unchanged. Through out the four different periods considered, these factor dimensions are in fact correlated highly to the same variables. Therefore they are identical. This new factor dimension is thought to some extend to be related to the inter-dependency of any nation to others (foreign dependency factor).

The factor Zeta has the lowest Eigenvalue among all factor dimensions selected (representing variance less than 2 percent through out the four time series). It is also found to be the most inconsistence in its representation of the variables. It contains around 60 percent loadings to Percentage of Woman in Labour Force (PWOLAB) and less than 50 percent to GDP from service. Perhaps this is the cultural or / and social characteristics which is inherent to the nature of national development.

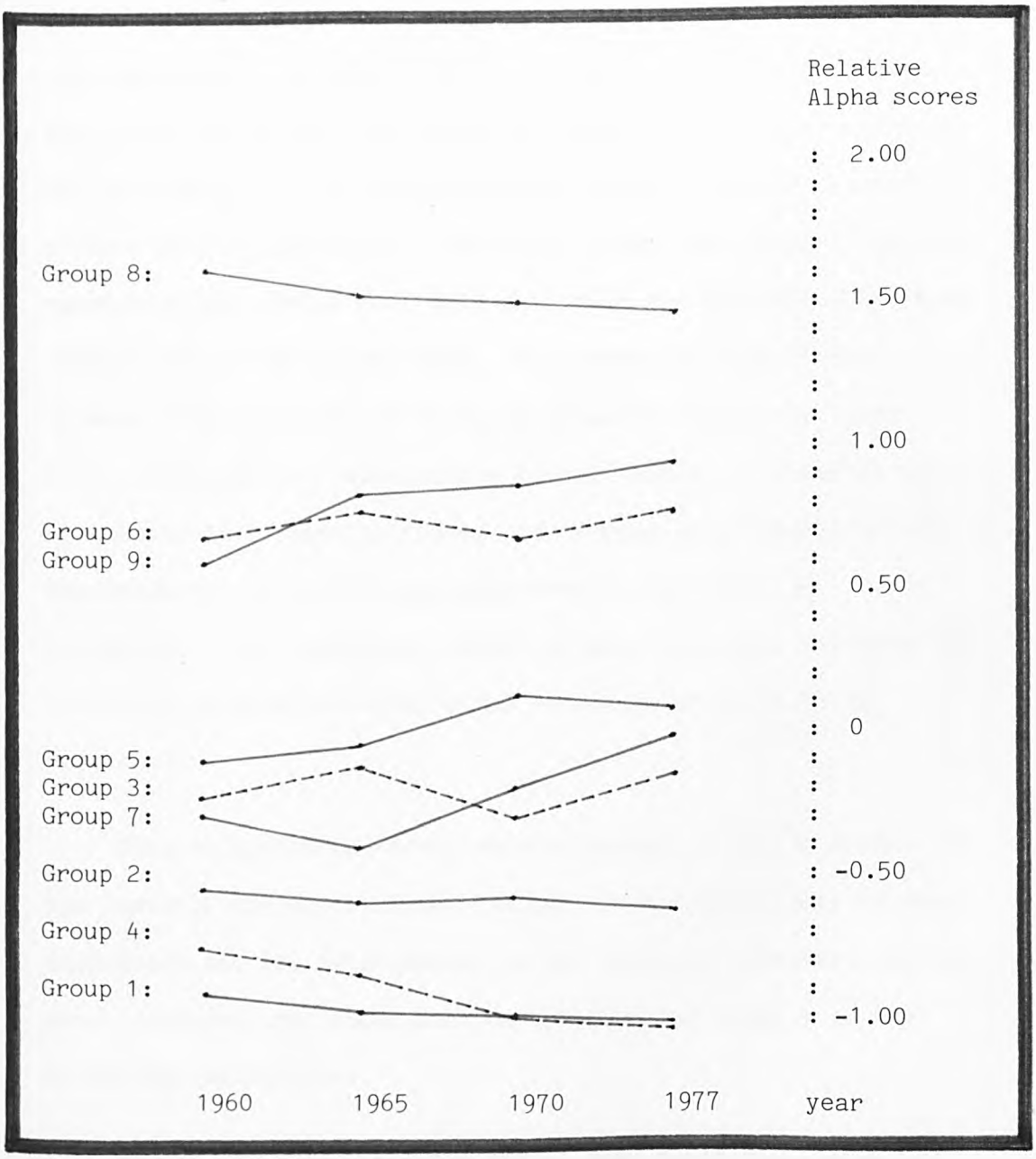
To summarise the six basic national characteristics extracted, we list all factors and their associations:

Factor:	Association (characteristics):
1. Alpha	Technology utilisation
2. Beta	Scale (size)
3. Gamma	Resources
4. Delta	Agriculture
5. Epsilon	Foreign dependency
6. Zeta	Cultural

As it has been mentioned earlier only the first three factors are the most significant (as it accounts over 70 percents of the total variance) to our purpose of studying to the dynamic of technological change. For this reason we will explore and concentrate on these three factor dimensions.

figure 3.1

Relative Alpha scores for 1960, 1965, 1970, 1977



Group 1: African countries
Group 2: Northern African and Middle East countries
Group 3: South East Asia and Pacific countries
Group 4: Southern Asia countries
Group 5: Latin American countries
Group 6: Southern European countries
Group 7: Major Oil Producing countries
Group 8: Western Industrialised countries
Group 9: Socialist countries

3.3. The relationship of Alpha to the stock of Scientists

It is often suggested that the level of technology must have some relationship to the number of 'brain' (stock of scientists and engineers). Although there is only incomplete set of data available (valid and comprehensive global data of this nature is not available), it is convincing that Alpha is indeed related closely to this indicator. Table 3.2 (page 180) shows a typical example of the statistical data available for any particular year nearest to our data time bench. The graphical relationship between this indicator to Alpha is shown in figure 3.2 (page 181). Although the relationship is not linear, it confirms the hypothesis that there is indeed some strong relationship between the number of scientists and engineers to the level of technology. The inadequate amount of data available prevents the inclusion of this variable to the reduction method used in chapter 2.

This relationship reconfirms the nature of factor Alpha. On the basis of the association of Alpha to technologically related indicators and its relationship to the stock of Scientist, we are more convinced that Alpha must be related very closely to the technology utilisation.

Figure 3.2 also indicates that a **very large proportion of Scientist and Engineers per population does not guarantee high Alpha scores (Technological State).** However it is essential for Technologically developed nations to have sufficiently large Scientist and Engineers stock.

table 3.2

Stock of Scientists and Engineers around 1965

No	Countries	Population (000) (1)	Scientists & Engineers (2)	(2)/(1)	Alpha (1965)
9	Kenya	9471	2536	0.26	-.792
11	Malawi	3910	1235	0.31	-1.199
15	Nigeria	58448	3970	0.06	-1.197
16	Rwanda	3128	207	0.06	-1.265
21	Sudan	12533	1668	0.13	-1.015
22	Tanzania	11595	1346	0.11	-.904
24	Upper Volta	4511	160	0.03	-1.476
37	Korea Rep	28089	88300	3.14	-.246
38	Malaysia	9281	9885	1.06	-.179
42	Taiwan	12978	60550	4.66	.335
43	Thailand	30641	25577	0.83	-.377
48	Nepal	10260	713	0.06	-1.103
49	Pakistan	52414	27207	0.51	-.827
55	Columbia	18448	26697	1.44	-.044
58	El Salvador	2886	2784	0.96	-.158
60	Haiti	3911	1357	0.42	-.832
62	Mexico	42872	3623	0.08	.284
65	Peru	11721	3600	0.30	-.302
66	Uruguay	2693	11930	5.70	1.122
67	Venezuela	9112	14050	1.54	.196
76	Australia	11378	99511	8.74	1.342
77	Austria	7255	49294	6.79	1.348
78	Belgium	9646	69965	7.39	1.430
81	Finland	4564	34002	7.45	1.377
85	Italy	51994	195200	3.75	1.163
89	Norway	3723	41500	11.14	1.498
90	Sweden	7735	65924	8.52	1.704
92	UK	54520	211231	3.87	1.709
93	USA	194345	1272000	6.54	1.935

Sources:

(1). World Tables, The John Hopkins University Press, Baltimore and London, Washington, USA, second edition, 1980.

(2). Total number of scientists, engineeers and technicians and number engaged in research and experimental development by field of specialization or training, Table 3.1, UNESCO Year book 1969, pp.458-466, UNESCO, 1969.

RELATIONSHIP BETWEEN ALPHA AND NUMBER OF SCIENTISTS

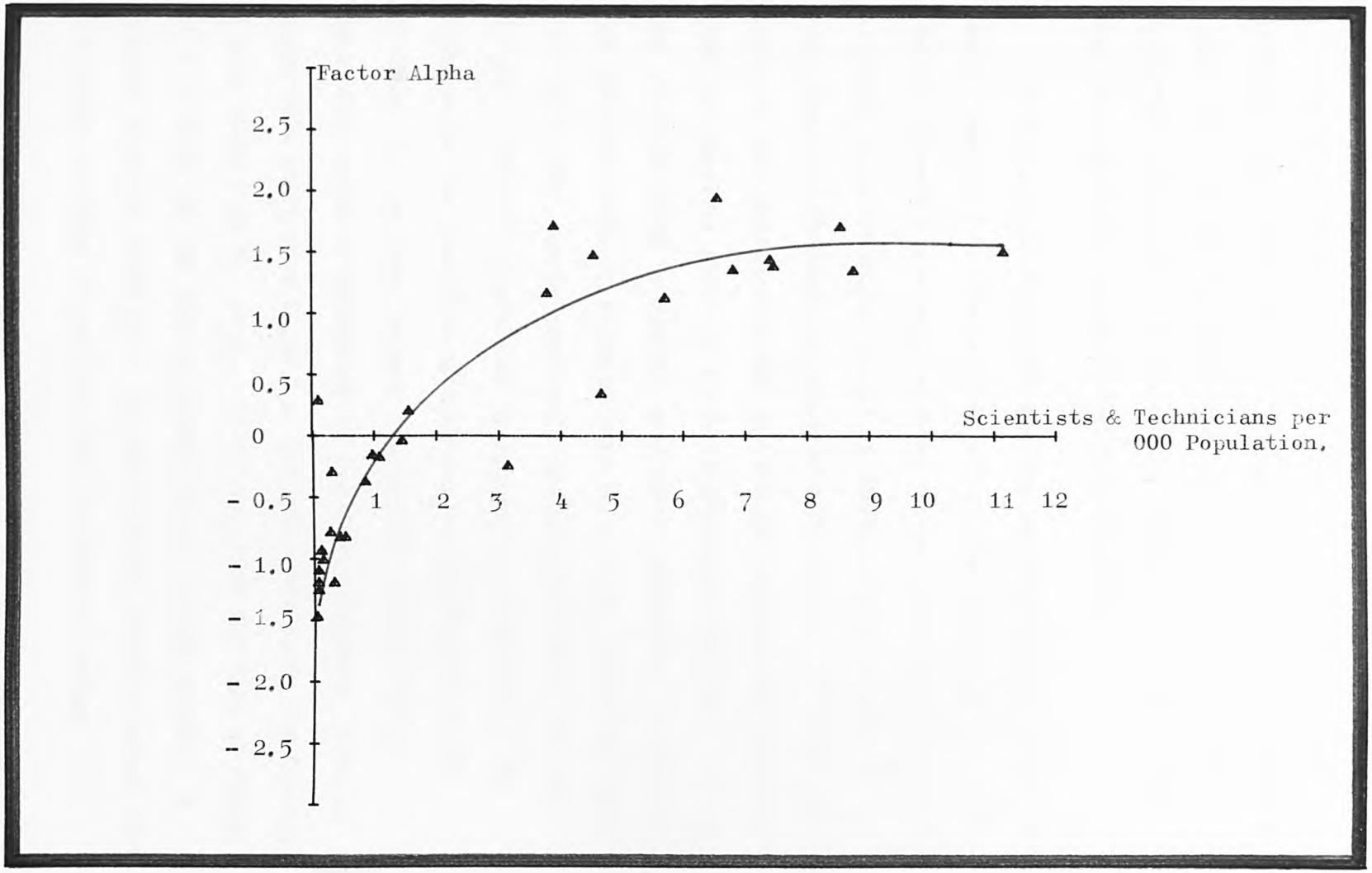


Figure 3.2

3.4. Technological dimensions

The distribution of factor Alpha among all samples at different time bench can be described approximately as figure 3.3 (page 190). d_1 and d_2 represents relative Alpha scores for different time bench. As Technology changes with time, there must be a shift in the absolute value of Alpha.

As it has been mentioned earlier the dimensional reduction method described in chapter 2 is not a time series method. The results therefore are only relevant to one particular time bench. Although cross sectional result is useful, factor score for one time bench is not directly comparable to others. A smaller Alpha score in 1965 relative to one in 1960 for example does not mean that its absolute level of Alpha (Technology) decreases. It is the relative score to overall mean which decreases. To measure the absolute level of Alpha we need to do some conversion which will make these scores comparable and more meaningful for our purpose. This is illustrated by figure 3.3 (page 190). The Alpha score for country A at time t=1 is represented as the distance d_1. As time changes, the overall average (cross sectional) level of technology is expected increases. This is shown as a shift from X_1 to X_2. The new Alpha score for country A also moves from d_1 to d_2. If $d_1 = d_2$ then the rate of change of A is equal to the rate of change of the average sample. A smaller relative Alpha score for any country therefore means that the change of Alpha is smaller than the overall average.

At this stage we need to define factors which contribute to

the overall economic performance, which also defined as the overall national characteristics. It can be described by;

$$P_t = f (A, B, G) \qquad (3.1)$$

where P_t = total economic performance (measurable as Total GNP)

A = Alpha

B = Beta

G = Gamma

From table 2.10 (page 158), we can observed that the factor Beta itself is very closely related to the size of the overall population. The factor loadings are:

Variable	Year	Factor loadings on Beta
POPULA1	1960	0.921
POPULA2	1965	0.853
POPULA3	1970	0.907
POPULA4	1977	0.948

For practical purposes it is reasonable and sufficient to take factor Beta as directly proportional to the size of population. Therefore the equation (3.1) can be reduced into:

$$P_c = f (A, G) \qquad (3.2)$$

where P_c = Economic Performance per capita (measurable in term of GNP per capita).

The simplest model arising from the function above is the linear model in the form of:

$$P_c = a + b A + c G \qquad (3.3)$$

where P_c = Economic Performance per capita
(measurable in term of log(GNP percapita))

a, b, c = constants

The application of model (3.3) to the overall data yields the following results:

table 3.3

Economic Performance model fitted on actual data

year	model $P_c = a + b A + c G$			
	a	b	c	corr. coefficient
1960	2.2769	1.1214	0.3953	0.9094
1965	2.4202	1.1795	0.3271	0.8755
1970	2.5887	1.2672	0.3485	0.9110
1977	2.7956	1.3582	0.4481	0.9471

These results show remarkable high correlations between the economic performance and the two most significance national characteristics. This relationship exists because the productive system in the economy depends to a very large extend to the level of technology and the resources utilised. Figures 3.4 - 3.7 (page 191-194) confirm the relationship between these factors and Economic Performance. They also show the actual and expected values resulting from the models above.

The implications of this result are very interesting. First

they show that there is a very close relationship between the economic performance and factors Alpha and Gamma (Technology and Resources). With high Alpha and Gamma scores, a country is expected to perform very well. However it also means that a country with low Alpha (technology level) can still manage a relatively high overall economic performance if it has high Gamma score. The oil producing countries are typical countries with high Gamma and low Alpha scores. Similarly countries with low Gamma and high Alpha is also possible to attain high performance (for example Japan).

The coefficients in table 3.3 are also important. It is observed that there is an increasing trend on Alpha coefficient (constant b) with time. In the absence of Gamma growth, this in itself represents an increasing trend in the technology itself (as figure 3.8, page 195).

3.5. The growth of Alpha

Assuming for this analytical reason that Gamma remains constant, we can plot two dimensional relationship between Performance and Alpha. The two dimensional form of multiple linear regression above can be represented as figure 3.8 (page 195). Using this relationship, the relative standardised Alpha scores as obtained by dimension reduction method in Chapter 2 can then be converted to a more meaningful time series values. The technological growth of each country can then be mapped into these lines. The relationship between standardised Alpha scores

and their converted indices is explained in figure 3.9 (page 196). These indices relate all the Alpha scores for all time benches. The factor distances as on the right hand side of the graph can be transformed to factor distance on the left hand side by substituting Alpha into equation 3.3. The converted Alpha scores referred is time comparable, which can therefore reflect its growth. The converted Alpha indices for all countries are represented in table 3.4 (page 198).

As expected, the growth pattern of factor Alpha itself confirms the typical 'S shaped' growth curve commonly found in the technical capability (Ayres, 33). This is demonstrated by the plot of rate of change of Alpha vs. Alpha as in figure 3.10 (page 197), which on integration, produces the well known 'S-shape' growth curve (figure 3.11, page 206). The 'S curve' produced here however is not a typical symmetrical curve such as Pearl or Fisher and Pry curves. The figure 3.11 (page 206) demonstrates the rate of major difference of Alpha curve as compared to Pearl's curve.

This result also implies that the **technology utilisation at national level behaves in the same manner as the the behaviour of technological capability** of through time. The remarkable similarity between the growth of technology utilisation and the efficiency changes over time must suggest that they are not only very closely related but are two of the same nature.

Further observation of figure 3.10 (page 210) reveals that there are basically three clusters along the Alpha growth line.

The first cluster is mainly the countries with low Alpha scores (group 1: African countries). The rate of growth of these countries are low. The second cluster with the highest rate of change of Alpha are the developing countries. The third cluster which has the highest Alpha scores are mainly the industrialised countries (North Western European and North American countries). The rate of change of Alpha for these countries are somehow lower than the one of second cluster but higher than the first's. The implication is interesting, the developing countries are advancing faster than the advanced industrialised countries. On the other hand the less developing countries with low Alpha scores are left further behind.

Within relatively short period considered and data available, we can approximate the growth of Alpha for each individual countries. This is illustrated as figure 3.12 (page 207). The growth is found to follow the growth equation estimated by:

$$A = a \exp (b\ t) \qquad (3.4)$$

where A = Alpha

t = year

a, b = constants

To show the validity of this model approximation, a correlation table is constructed. Table 3.5 (page 200) shows the correlation and line equation of each sample. The results show high correlations among all samples, which indicate that exponential model is indeed a valid approximation for the period considered.

3.6. The Growth of Gamma

Similarly in the absence of growth of Alpha (technological), we can estimate the growth of Gamma (Resources) from equation 3.3. The diagramatic representation of this process is similar to Alpha (as in figure 3.9 with Gamma instead of Alpha). Plotting Gamma against time it is found that Gamma increases in linear manner. We can therefore convert the standardised Gamma scores into indices which are comparable from one year to another (table 3.6, page 202). The equation for deriving Gamma indices can be described as:

$$G = a + b\,T \qquad (3.5)$$

where G = Gamma

T = year

a, b = constant

The correlation coefficients of the fitted line for the model above are given in table 3.7 (page 204). It is noted that a small number of countries do not produce high correlation. Generally it is observed that they are caused by the disruption in the flow of resources output (eg. Niger, Egypt, Burma). It is possible that these disruptions are due to political nature.

3.7. Discussion

We have identified that the rate of technological growth is different from one country to another. The difference in its rate of change seems to be governed by the absolute level of the technological capability possessed by the country. As observed, it is required that a state of technological 'take off' must be be reached before substantial technological growth occurs (as demonstrated by countries such as Japan, Hongkong, Singapore, etc.).

For a short term at least, the prospect of growth for less developing countries is very grim. These countries still have a long gap to close before they even reach the technology 'take off' stage. Meanwhile other more developed countries also grow at faster rate, which effectively opens the gap to the LDC's even wider. The dilemma is that the LDC's without high Gamma (Resources) available to buy technology, have no choice but to follow this growth path slowly.

In the long term however, high growth period (technological 'take off') will have to take place. This is then the only chance for the less developing nations to catch the technology, hence the standard of living of the more developed ones.

The practical application of this theory is an observation and learning the basic technological capability belonging to the more developed countries. Technology transfer would be one of the solution to shorten the time delay, but it is an investigation area beyond this thesis.

RELATIVE AND ACTUAL ALPHA SCORES FOR DIFFERENT TIME PERIODS

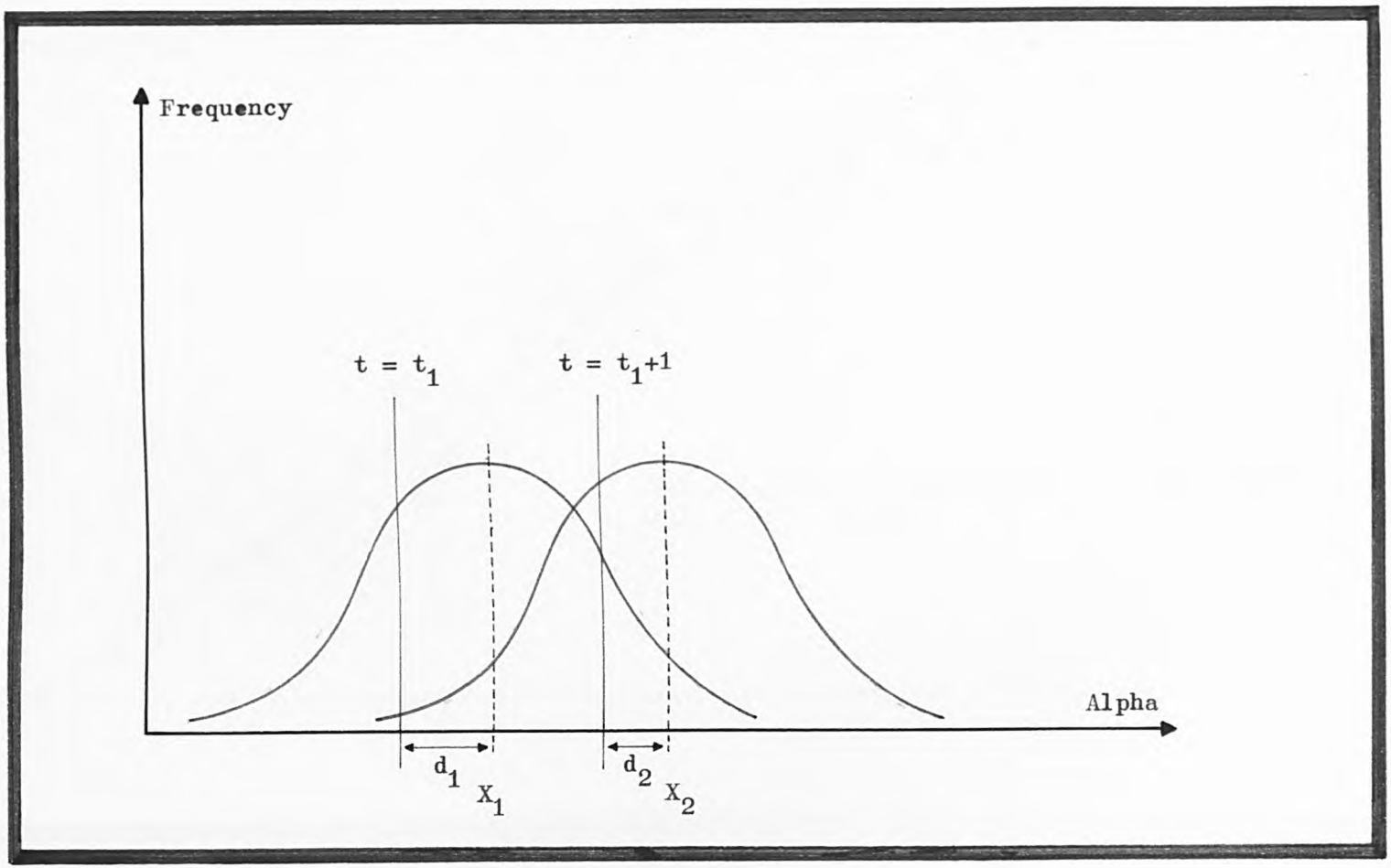


Figure 3.3

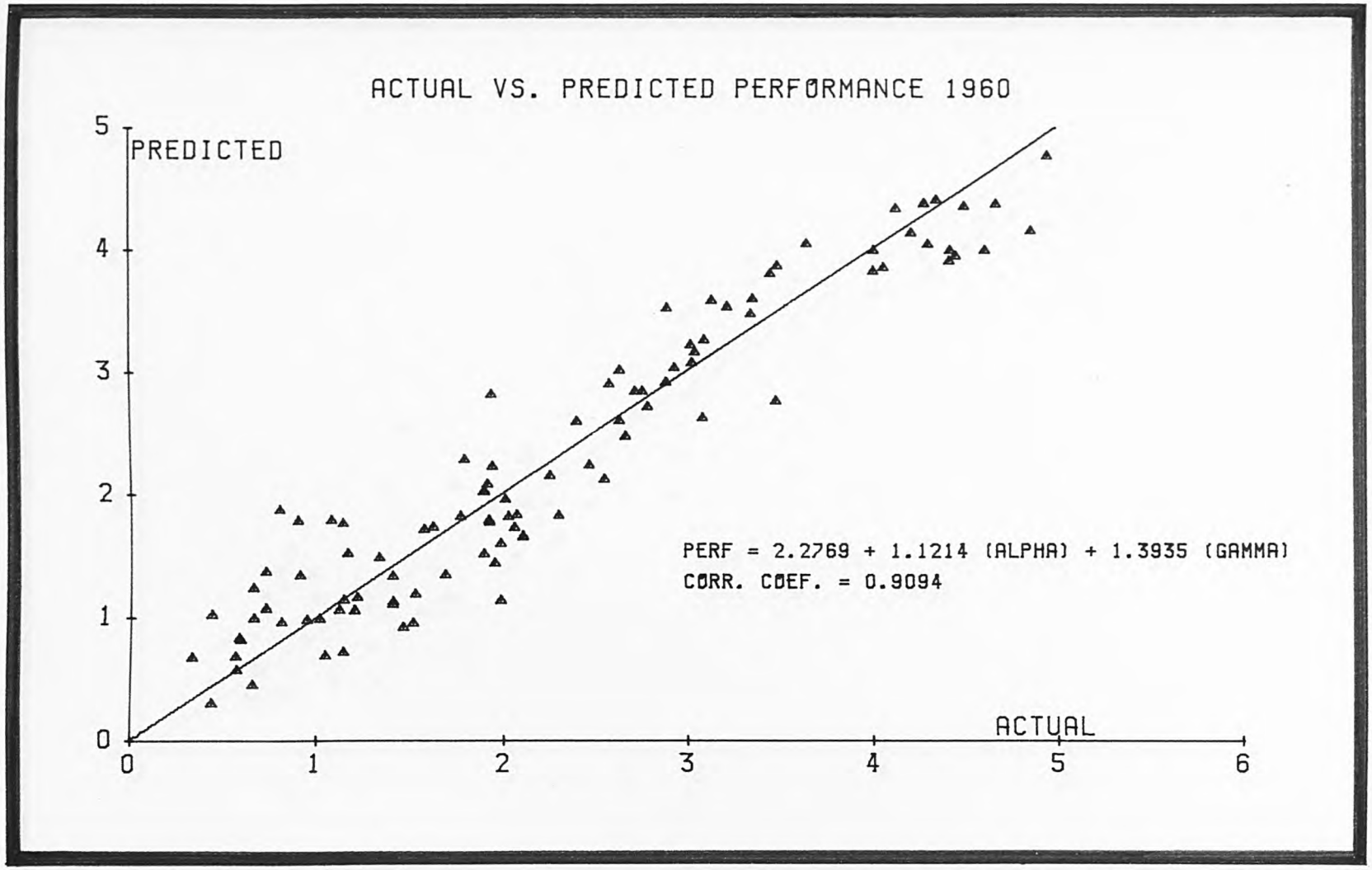

ACTUAL VS. PREDICTED PERFORMANCE 1960
PREDICTED
ACTUAL
0
1
2
3
4
5
6
PERF = 2.2769 + 1.1214 (ALPHA) + 1.3935 (GAMMA)
CORR. COEF. = 0.9094

Figure 3.4

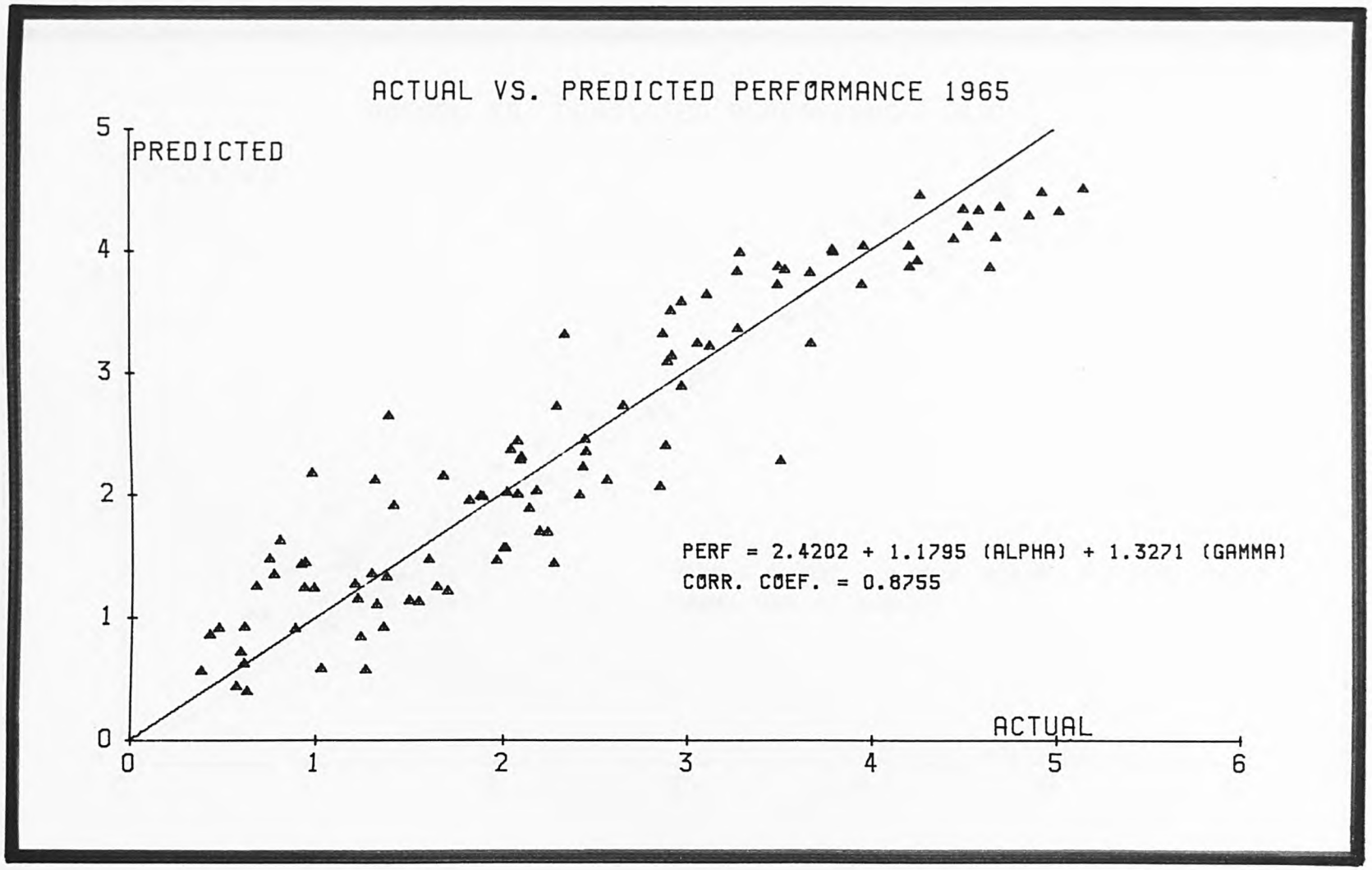

ACTUAL VS. PREDICTED PERFORMANCE 1965
PREDICTED
ACTUAL
PERF = 2.4202 + 1.1795 (ALPHA) + 1.3271 (GAMMA)
CORR. COEF. = 0.8755
0
1
2
3
4
5
6

Figure 3.5

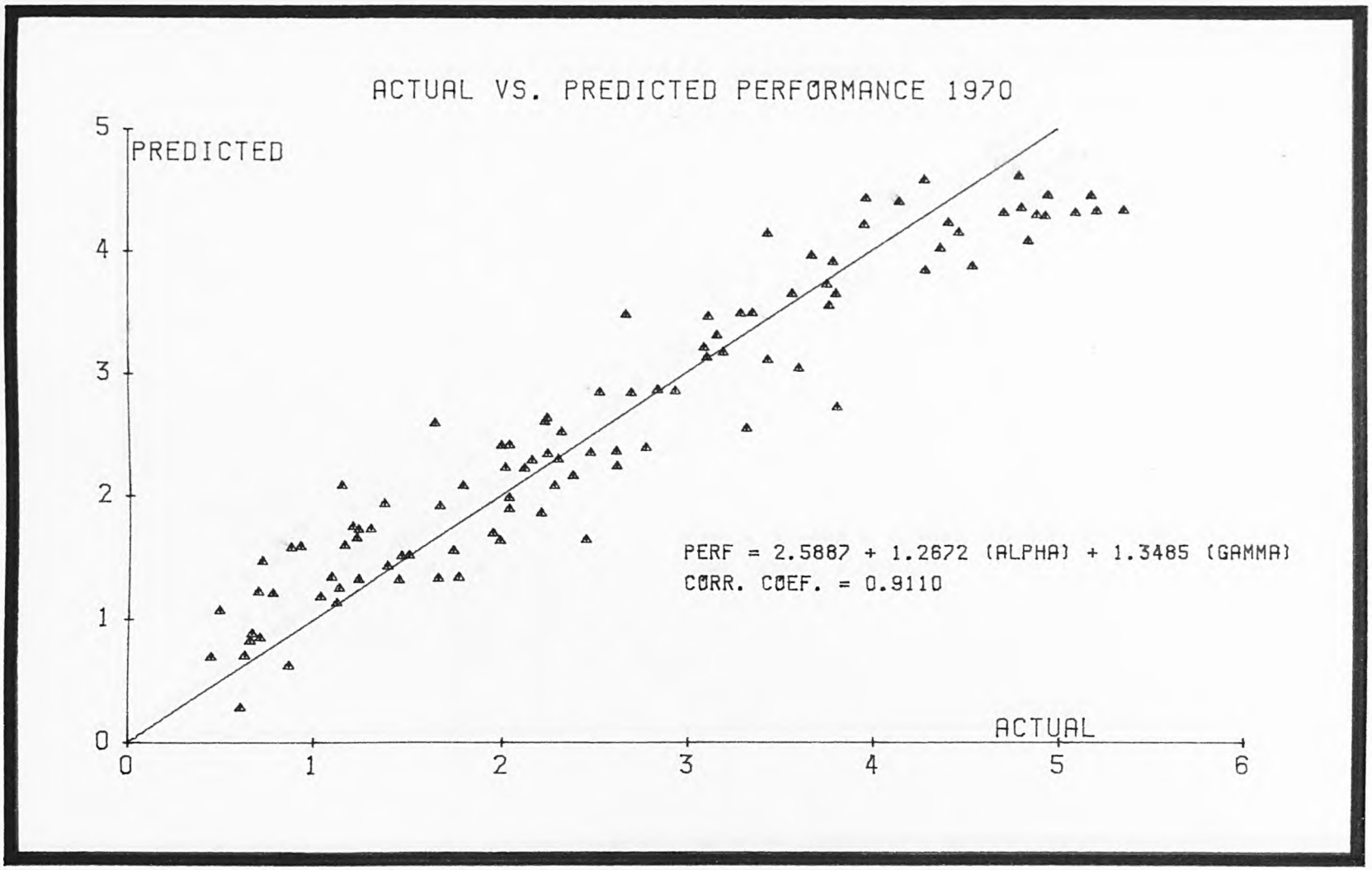

ACTUAL VS. PREDICTED PERFØRMANCE 1970
PREDICTED
ACTUAL
0
1
2
3
4
5
6
PERF = 2.5887 + 1.2672 (ALPHA) + 1.3485 (GAMMA)
CØRR. CØEF. = 0.9110

FIGURE 3.6

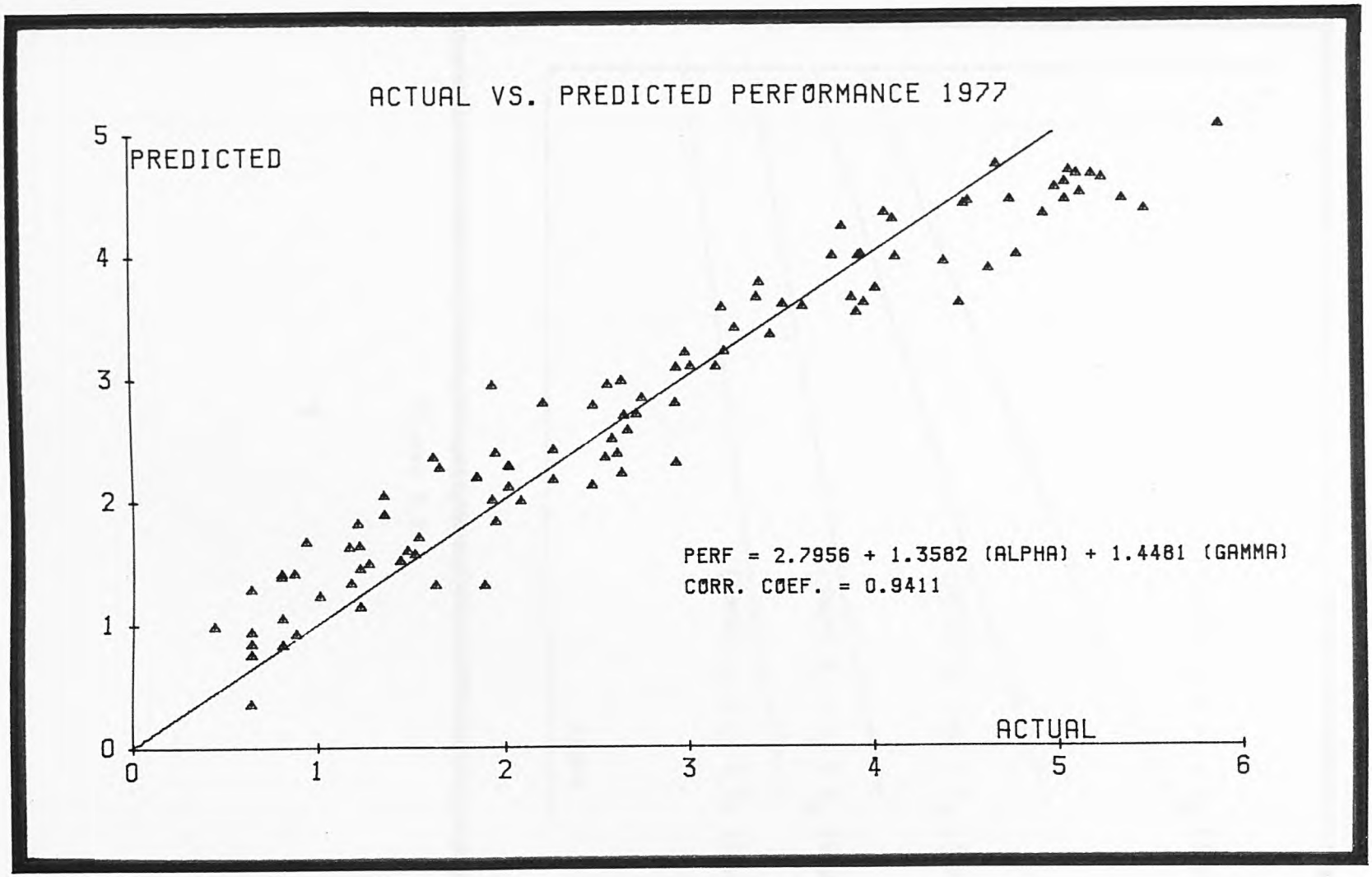

ACTUAL VS. PREDICTED PERFORMANCE 1977
PREDICTED
ACTUAL
0
1
2
3
4
5
6
PERF = 2.7956 + 1.3582 (ALPHA) + 1.4481 (GAMMA)
CORR. COEF. = 0.9411

Figure 3.7

PERFORMANCE (P_c) vs. ALPHA IN THE ABSENCE OF GAMMA

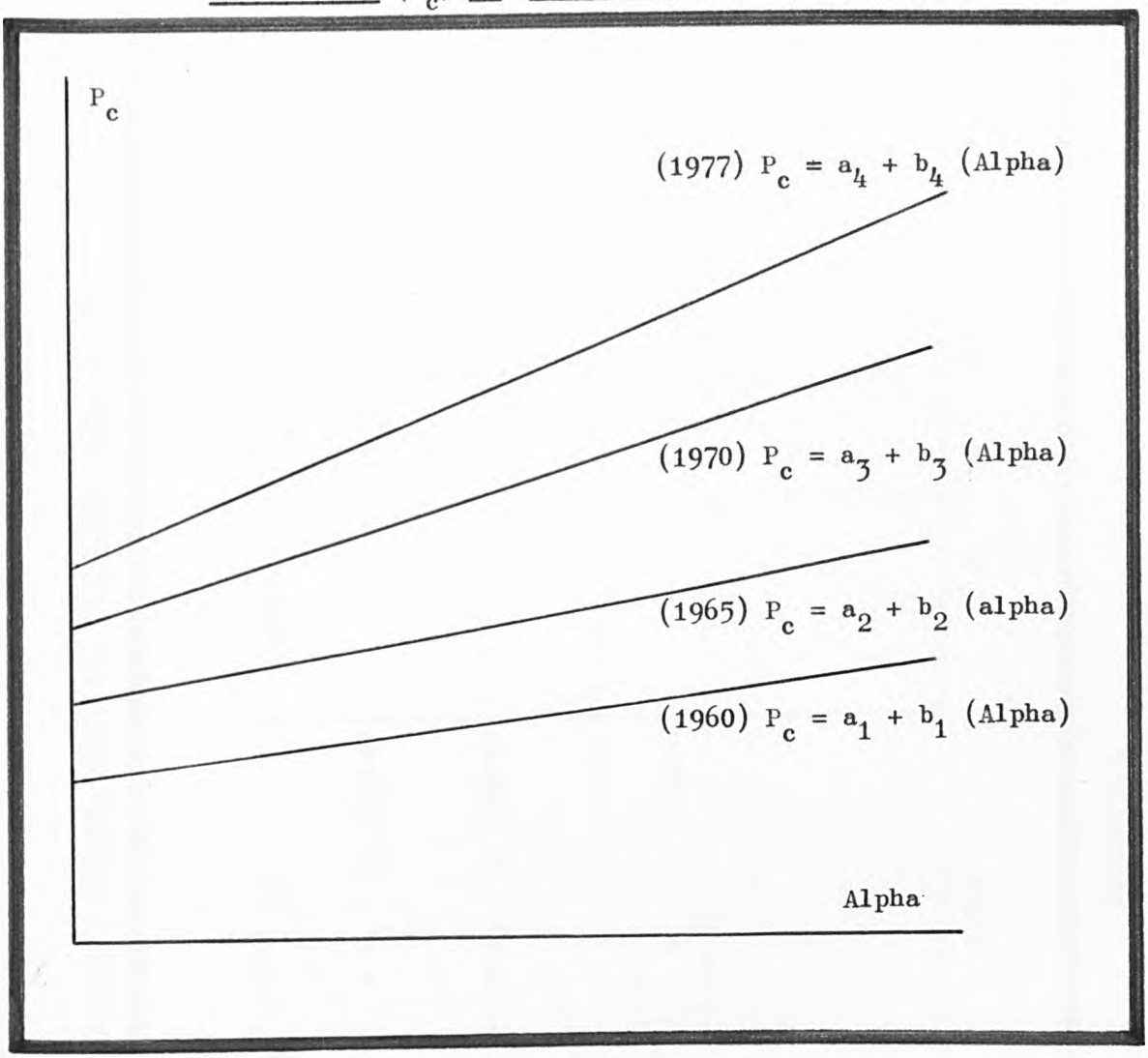


Figure 3.8

RELATIONSHIP BETWEEN ALPHA AND CONVERTED ALPHA SCORES

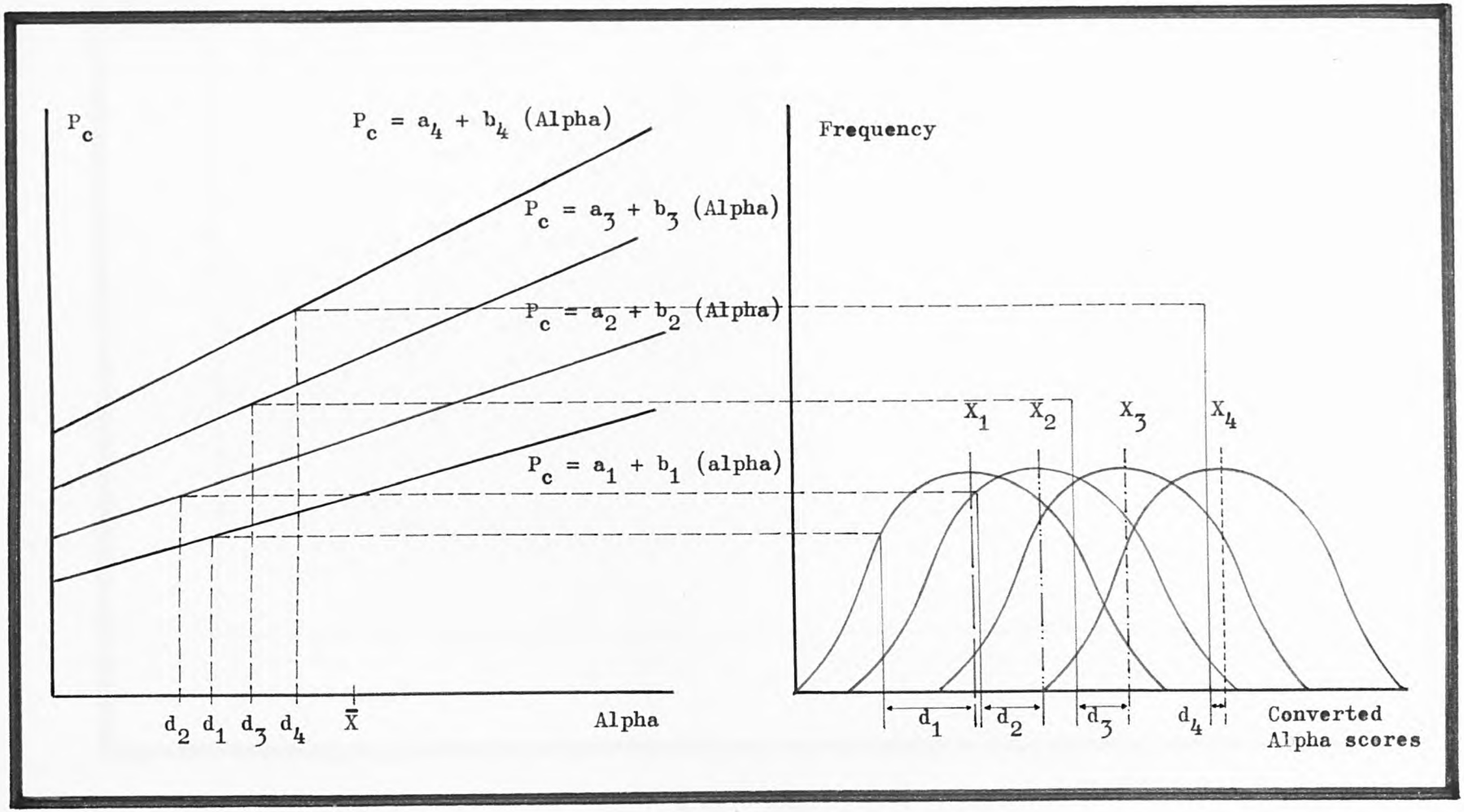


Figure 3.9

RATE OF CHANGE OF ALPHA vs. ALPHA SCORES

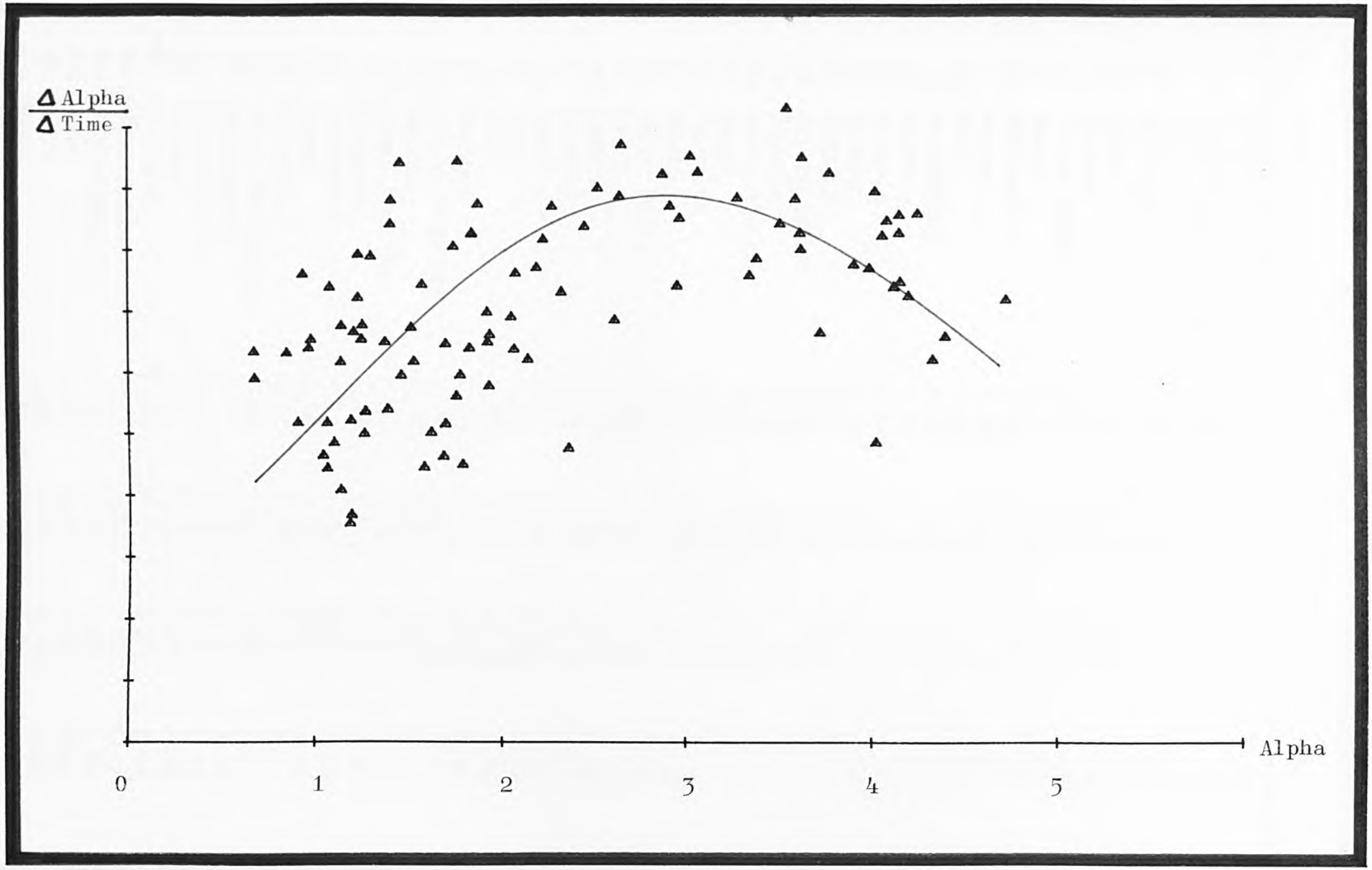


Figure 3.10

table 3.4: **Converted Alpha scores**

No.	Countries	1960	1965	1970	1977
1.	Benin	1.56	1.73	2.34	2.37
2.	Burundi	1.26	1.71	2.08	2.37
3.	Cent. African Rep	1.75	1.85	2.22	2.71
4.	Chad	1.56	1.66	1.75	2.37
5.	Ethiopia	0.96	1.18	1.41	1.91
6.	Ghana	1.99	1.93	2.45	3.08
7.	Guinea	1.25	1.52	2.05	2.33
8.	Ivory Coast	1.52	1.83	2.03	2.80
9.	Kenya	1.87	1.92	2.29	2.46
10.	Madagascar	2.07	2.10	2.54	2.64
11.	Malawi	1.38	1.44	1.66	2.07
12.	Mali	1.48	1.59	2.02	2.26
13.	Mozambique	1.91	1.97	2.25	2.64
14.	Niger	1.13	1.46	2.01	2.19
15.	Nigeria	1.33	1.44	1.58	1.96
16.	Rwanda	0.96	1.36	1.72	2.02
17.	Senegal	1.67	1.95	2.27	2.77
18.	Sierra Leone	1.22	1.45	1.97	2.59
19.	Somalia	1.96	1.70	2.05	2.60
20.	South Africa	2.90	3.27	3.63	4.09
21.	Sudan	1.55	1.66	1.86	2.27
22.	Tanzania	1.42	1.79	2.12	2.44
23.	Uganda	1.54	1.75	2.13	2.65
24.	Upper Volta	1.19	1.11	1.63	1.96
25.	Zaire	1.48	1.42	1.36	1.87
26.	Zambia	1.37	1.96	2.12	2.69
27.	Algeria	1.98	2.08	2.31	2.75
28.	Egypt	2.21	2.60	2.91	3.31
29.	Iran	1.70	1.91	2.64	3.37
30.	Iraq	1.80	2.10	2.58	2.96
31.	Morroco	2.04	2.18	2.48	2.92
32.	Syrian Arab Rep	2.22	2.57	2.74	3.14
33.	Tunisia	2.20	2.52	2.77	3.43
34.	Yemen Arab Rep	1.42	1.35	2.26	1.92
35.	Hongkong	3.16	3.76	4.24	4.95
36.	Indonesia	1.43	1.81	2.16	2.59
37.	Korea	2.35	2.56	2.51	3.42
38.	Malaysia	2.36	2.64	3.15	3.74
39.	Papua New Guinea	1.54	1.95	1.94	2.71
40.	Philippines	2.11	2.49	2.60	3.19
41.	Singapore	3.24	3.74	3.90	4.57
42.	Taiwan	2.50	3.25	2.95	4.02
43.	Thailand	2.06	2.41	2.60	3.02
44.	Afghanistan	1.35	1.22	1.83	2.12
45.	Bangladesh	1.46	1.44	1.58	1.82
46.	Burma	1.82	2.12	2.42	2.84
47.	India	1.49	1.79	2.16	2.63
48.	Nepal	1.35	1.55	1.38	1.93
49.	Pakistan	1.68	1.88	1.93	2.51
50.	Sri Lanka	2.65	3.02	3.00	3.31

table 3.4: Converted Alpha scores (continued)

No.	Countries	1960	1965	1970	1977
51.	Argentina	3.80	4.19	4.72	5.38
52.	Bolivia	1.69	2.08	2.61	3.28
53.	Brazil	2.74	2.99	3.70	4.31
54.	Chile	2.81	3.15	3.80	4.45
55.	Colombia	2.05	2.80	3.38	3.89
56.	Dominican Republic	2.15	2.46	3.20	3.82
57.	Ecuador	2.42	2.73	3.41	3.45
58.	El Salvador	2.33	2.67	3.37	3.53
59.	Guatemala	2.02	2.30	2.89	3.51
60.	Haiti	1.59	1.87	2.24	3.04
61.	Honduras	1.86	2.16	2.74	3.20
62.	Mexico	2.61	3.19	3.76	3.91
63.	Nicaragua	2.21	2.60	3.32	3.34
64.	Paraguay	2.47	2.74	3.43	3.88
65.	Peru	2.21	2.50	3.29	3.66
66.	Uruguay	4.01	4.18	4.85	5.15
67.	Venezuela	2.55	3.09	3.77	4.21
68.	Greece	3.63	3.95	4.07	5.00
69.	Israel	3.91	4.30	4.79	5.45
70.	Portugal	3.20	3.83	4.11	4.86
71.	Spain	3.67	4.25	4.58	5.11
72.	Turkey	2.12	2.81	3.17	3.67
73.	Yugoslavia	3.26	3.49	4.15	4.86
74.	Kuwait	2.92	3.12	3.81	4.62
75.	Saudi Arabia	1.52	1.67	2.26	2.98
76.	Australia	4.48	4.44	5.24	5.77
77.	Austria	4.06	4.44	5.12	5.85
78.	Belgium	4.41	4.54	5.16	5.73
79.	Canada	4.36	4.69	5.17	5.96
80.	Denmark	4.43	4.67	5.35	6.05
81.	Finland	4.19	4.48	4.88	5.60
82.	France	4.27	4.54	5.33	5.67
83.	West Germany	4.30	4.69	5.25	6.02
84.	Ireland	4.31	4.59	4.61	5.00
85.	Italy	3.90	4.23	5.25	5.38
86.	Japan	3.88	4.54	5.09	5.56
87.	Netherland	4.34	4.37	5.39	5.88
88.	New Zealand	4.61	4.82	5.24	5.64
89.	Norway	4.68	4.62	4.82	5.80
90.	Sweden	4.53	4.86	5.45	6.16
91.	Switzerland	4.43	4.81	5.15	5.98
92.	U.K.	4.44	4.87	5.20	5.78
93.	U.S.A.	5.00	5.14	5.53	6.28
94.	China	1.74	2.64	2.84	3.58
95.	Chechoslovakia	3.83	4.30	5.09	5.88
96.	East Germany	3.91	4.27	5.25	5.77
97.	Hungary	3.56	4.11	4.84	5.25
98.	Poland	3.35	3.97	4.28	5.14
99.	Romania	2.93	3.62	4.04	4.84
100.	USSR	3.31	3.98	4.35	5.17

Table 3.5: **Time Series Model of Alpha**

No.	Countries	Alpha = a exp (b t) a	b	corr. coef.
1.	Benin	.3138	.0269	.851
2.	Burundi	.1505	.0365	.931
3.	Cent. African Rep	.3380	.0268	.971
4.	Chad	.3516	.0240	.887
5.	Ethiopia	.0862	.0401	.998
6.	Ghana	.3434	.0280	.886
7.	Guinea	.1308	.0380	.952
8.	Ivory Coast	.1853	.0349	.980
9.	Kenya	.6371	.0176	.921
10.	Madagascar	.7326	.0170	.883
11.	Malawi	.3029	.0246	.955
12.	Mali	.2948	.0266	.948
13.	Mozambique	.5609	.0199	.959
14.	Niger	.1072	.0401	.917
15.	Nigeria	.3320	.0227	.973
16.	Rwanda	.0776	.0431	.939
17.	Senegal	.2810	.0297	.999
18.	Sierra Leone	.0776	.0456	.989
19.	Somalia	.5605	.0191	.619
20.	South Africa	.8752	.0201	.993
21.	Sudan	.3867	.0227	.978
22.	Tanzania	.2234	.0315	.963
23.	Uganda	.2152	.0325	.995
24.	Upper Volta	.1446	.0337	.838
25.	Zaire	.6265	.0130	.442
26.	Zambia	.1580	.0371	.931
27.	Algeria	.5913	.0197	.970
28.	Egypt	.5552	.0234	.981
29.	Iran	.1302	.0423	.974
30.	Iraq	.3021	.0299	.978
31.	Morroco	.5468	.0216	.986
32.	Syrian Arab Rep	.6964	.0196	.979
33.	Tunisia	.4713	.0256	.992
34.	Yemen Arab Rep	.3314	.0240	.502
35.	Hongkong	.6788	.0259	.987
36.	Indonesia	.1857	.0345	.980
37.	Korea	.6613	.0205	.805
38.	Malaysia	.4434	.0277	.993
39.	Papua New Guinea	.2482	.0306	.914
40.	Philippine	.5361	.0230	.967
41.	Singapore	1.0590	.0189	.953
42.	Taiwan	.6055	.0241	.781
43.	Thailand	.5690	.0217	.983
44.	Afghanistan	.1869	.0314	.785
45.	Bangladesh	.6128	.0138	.871
46.	Burma	.3858	.0260	.995
47.	India	.2010	.0335	.994
48.	Nepal	.4513	.0180	.638
49.	Pakistan	.4285	.0224	.922
50.	Sri Lanka	1.3420	.0117	.873

Table 3.5: **Time Series Model of Alpha (continued)**

No.	Countries	Alpha = a exp (b t) a	b	corr. coef.
51.	Argentina	1.0970	.0206	.997
52.	Bolivia	.1614	.0393	.994
53.	Brazil	.5054	.0279	.976
54.	Chile	.4899	.0289	.992
55.	Colombia	.2397	.0368	.934
56.	Dominican Republic	.2585	.0352	.978
57.	Ecuador	.6538	.0222	.863
58.	El Salvador	.5092	.0257	.907
59.	Guatemala	.2677	.0335	.988
60.	Haiti	.1581	.0381	.994
61.	Honduras	.2588	.0329	.978
62.	Mexico	.6577	.0238	.882
63.	Nicaragua	.4958	.0255	.853
64.	Paraguay	.4617	.0279	.966
65.	Peru	.2889	.0335	.947
66.	Uruguay	1.5370	.0158	.937
67.	Venezuela	.4389	.0298	.957
68.	Greece	1.2080	.0180	.932
69.	Israel	1.2000	.0196	.999
70.	Portugal	.7969	.0235	.976
71.	Spain	1.2110	.0188	.971
72.	Turkey	.3504	.0310	.934
73.	Yugoslavia	.7352	.0245	.980
74.	Kuwait	.5213	.0282	.975
75.	Saudi Arabia	.1202	.0415	.973
76.	Australia	1.6050	.0165	.894
77.	Austria	1.0760	.0220	.992
78.	Belgium	1.6220	.0163	.962
79.	Canada	1.4160	.0185	.995
80.	Denmark	1.3840	.0191	.980
81.	Finland	1.4790	.0171	.992
82.	France	1.4660	.0177	.942
83.	West Germany	1.2850	.0200	.988
84.	Ireland	2.6610	.0102	.935
85.	Italy	1.1490	.0205	.878
86.	Japan	1.1370	.0209	.957
87.	Netherland	1.4440	.0184	.979
88.	New Zealand	2.1980	.0122	.988
89.	Norway	2.0700	.0128	.772
90.	Sweden	1.4800	.0185	.994
91.	Switzerland	1.5460	.0174	.990
92.	U.K.	1.7870	.0152	.996
93.	U.S.A.	2.1480	.0137	.957
94.	China	.1795	.0393	.902
95.	Chechoslovakia	.8140	.0258	.990
96.	East Germany	.9132	.0232	.995
97.	Hungary	.9012	.0232	.954
98.	Poland	.7944	.1242	.984
99.	Romania	.5412	.0286	.980
100.	USSR	.7396	.0253	.982

Table 3.6: **Converted Gamma Scores**

No.	Countries	1960	1965	1970	1977
1.	Benin	2.05	1.97	2.16	2.24
2.	Burundi	2.11	2.07	2.27	2.39
3.	Cent. African Rep	1.91	2.11	2.37	2.51
4.	Chad	1.98	2.10	1.98	2.02
5.	Ethiopia	1.90	2.11	2.37	2.51
6.	Ghana	2.17	2.50	2.64	2.86
7.	Guinea	2.44	2.60	2.85	3.13
8.	Ivory Coast	2.17	2.47	2.76	3.02
9.	Kenya	2.02	2.37	2.48	2.65
10.	Madagascar	1.82	2.09	2.18	2.27
11.	Malawi	1.85	2.13	2.32	2.45
12.	Mali	2.10	2.18	2.19	2.29
13.	Mozambique	1.99	2.10	2.56	2.76
14.	Niger	2.14	1.97	2.26	2.37
15.	Nigeria	2.19	2.66	3.07	3.41
16.	Rwanda	2.05	2.05	2.21	2.31
17.	Senegal	2.33	2.47	2.60	2.81
18.	Sierra Leone	2.40	2.56	2.89	3.19
19.	Somalia	2.46	2.41	2.56	2.76
20.	South Africa	2.50	2.73	2.91	3.20
21.	Sudan	2.20	2.34	2.58	2.78
22.	Tanzania	2.09	2.31	2.38	2.53
23.	Uganda	1.94	2.24	2.36	2.50
24.	Upper Volta	2.20	2.14	2.32	2.45
25.	Zaire	2.45	3.06	3.29	3.70
26.	Zambia	3.28	3.27	3.45	3.91
27.	Algeria	3.18	2.91	3.27	3.67
28.	Egypt	2.14	2.38	2.27	2.39
29.	Iran	2.99	3.02	3.13	3.49
30.	Iraq	3.24	3.17	3.49	3.95
31.	Morroco	2.81	2.67	2.95	3.26
32.	Syrian Arab Rep	2.13	2.33	2.78	3.04
33.	Tunisia	2.59	2.66	2.81	3.07
34.	Yemen Arab Rep	2.66	2.43	2.42	2.58
35.	Hongkong	2.24	2.69	2.65	2.87
36.	Indonesia	2.11	2.28	2.72	2.97
37.	Korea	1.95	2.25	2.55	2.75
38.	Malaysia	2.23	2.66	2.73	2.97
39.	Papua New Guinea	2.14	2.38	2.53	2.72
40.	Philippines	2.16	2.52	2.69	2.93
41.	Singapore	2.04	2.58	2.57	2.77
42.	Taiwan	2.02	2.34	2.54	2.74
43.	Thailand	1.66	2.36	2.52	2.71
44.	Afghanistan	1.89	2.21	2.48	2.65
45.	Bangladesh	1.76	2.27	2.21	2.30
46.	Burma	1.73	2.08	1.99	2.03
47.	India	2.30	2.55	2.57	2.77
48.	Nepal	1.78	1.93	1.97	2.00
49.	Pakistan	1.95	2.42	2.45	2.62
50.	Sri Lanka	1.69	2.02	2.33	2.47

Table 3.6: **Converted Gamma Scores (continued)**

No.	Countries	1960	1965	1970	1977
51.	Argentina	1.84	1.89	2.22	2.32
52.	Bolivia	2.69	2.77	3.01	3.34
53.	Brazil	4.24	2.33	2.48	2.65
54.	Chile	2.66	2.61	2.68	2.91
55.	Colombia	2.33	2.35	2.55	2.75
56.	Dominican Republic	2.14	2.30	2.60	2.82
57.	Ecuador	2.16	2.15	2.18	2.27
58.	El Salvador	2.00	2.20	2.16	2.24
59.	Guatemala	2.19	2.26	2.52	2.71
60.	Haiti	2.45	2.34	2.58	2.79
61.	Honduras	2.21	2.17	2.47	2.65
62.	Mexico	2.19	2.40	2.45	2.62
63.	Nicaragua	2.18	2.26	2.32	2.46
64.	Paraguay	1.75	1.82	1.96	1.99
65.	Peru	2.59	2.72	2.85	3.13
66.	Uruguay	1.81	1.93	2.08	2.14
67.	Venezuela	2.77	3.02	3.13	3.49
68.	Greece	1.96	2.28	2.34	2.48
69.	Israel	2.19	2.43	2.57	2.78
70.	Portugal	2.26	2.35	2.44	2.60
71.	Spain	2.47	2.33	2.58	2.78
72.	Turkey	2.27	2.29	2.47	2.65
73.	Yugoslavia	2.32	2.46	2.55	2.74
74.	Kuwait	3.63	3.47	3.75	4.29
75.	Saudi Arabia	3.66	3.47	3.64	4.15
76.	Australia	2.02	2.29	2.56	2.76
77.	Austria	2.50	2.46	2.52	2.71
78.	Belgium	2.53	2.52	2.68	2.92
79.	Canada	2.19	2.46	2.63	2.85
80.	Denmark	2.04	2.30	2.45	2.62
81.	Finland	2.19	2.30	2.46	2.63
82.	France	2.42	2.42	2.49	2.67
83.	West Germany	2.61	2.53	2.71	2.95
84.	Ireland	1.73	2.12	2.48	2.65
85.	Italy	2.46	2.46	2.69	2.92
86.	Japan	2.28	2.33	2.42	2.58
87.	Netherland	2.26	2.48	2.74	2.99
88.	New Zealand	1.80	1.91	2.11	2.17
89.	Norway	2.29	2.58	2.72	2.96
90.	Sweden	2.40	2.48	2.53	2.72
91.	Switzerland	2.28	2.37	2.67	2.90
92.	U.K.	2.46	2.45	2.53	2.72
93.	U.S.A.	2.31	2.23	2.33	2.47
94.	China	2.58	2.86	2.98	3.30
95.	Chechoslovakia	2.59	2.56	2.80	3.06
96.	East Germany	2.69	2.63	2.83	3.11
97.	Hungary	2.52	2.40	2.76	3.02
98.	Poland	2.37	2.40	2.76	3.03
99.	Romania	2.44	2.56	2.81	3.08
100.	USSR	2.47	2.87	3.02	3.35

Table 3.7: **Time Series Model of Gamma**

No.	Countries	Gamma = a + b t a	b	corr. coef.
1.	Benin	1.1710	.0137	.701
2.	Burundi	.9360	.0187	.845
3.	Cent. African Rep	-.2360	.0362	.964
4.	Chad	1.8351	.0023	.683
5.	Ethiopia	-.2730	.0367	.963
6.	Ghana	-.1080	.0389	.957
7.	Guinea	-.0630	.0414	.994
8.	Ivory Coast	-.8070	.0501	.985
9.	Kenya	-4.3000	.0350	.914
10.	Madagascar	.3856	.0250	.875
11.	Malawi	-.1790	.0348	.940
12.	Mali	1.4790	.0140	.946
13.	Mozambique	-.9780	.0489	.937
14.	Niger	.9713	.0178	.571
15.	Nigeria	-2.0400	.0710	.975
16.	Rwanda	1.0100	.0168	.912
17.	Senegal	.6416	.0281	.999
18.	Sierra Leone	-.5150	.0481	.987
19.	Somalia	1.2340	.0193	.819
20.	South Africa	.0676	.0406	.998
21.	Sudan	.0820	.0351	.988
22.	Tanzania	.6576	.0245	.948
23.	Uganda	.1167	.0315	.921
24.	Upper Volta	1.1280	.0168	.798
25.	Zaire	-1.6500	.0702	.953
26.	Zambia	.8780	.0382	.855
27.	Algeria	.9334	.0341	.621
28.	Egypt	1.5240	.0113	.495
29.	Iran	1.1390	.0296	.879
30.	Iraq	.4068	.0448	.854
31.	Morroco	.8781	.0300	.747
32.	Syrian Arab Rep	-1.2500	.0562	.969
33.	Tunisia	.8242	.0287	.967
34.	Yemen Arab Rep	1.8557	.0089	.681
35.	Hongkong	.4003	.0325	.768
36.	Indonesia	-1.1100	.0534	.965
37.	Korea	-.8520	.0474	.968
38.	Malaysia	-.0940	.0403	.900
39.	Papua New Guinea	.1700	.0334	.979
40.	Philippine	-.3980	.0437	.960
41.	Singapore	-.0960	.0380	.774
42.	Taiwan	-.4130	.0415	.963
43.	Thailand	-1.5900	.0574	.827
44.	Afghanistan	-.7300	.0446	.953
45.	Bangladesh	.3144	.0267	.590
46.	Burma	1.0230	.0137	.407
47.	India	.8173	.0254	.919
48.	Nepal	1.0970	.0120	.807
49.	Pakistan	-.0580	.0355	.808
50.	Sri Lanka	-1.0100	.4620	.936

Table 3.7: Time Series Model of Gamma (continued)

No.	Countries	Gamma = a + b t		
		a	b	corr. coef.
51.	Argentina	-.0540	.0312	.903
52.	Bolivia	.2626	.0395	.966
53.	Brazil	1.4110	.0155	.701
54.	Chile	1.6640	.0154	.706
55.	Colombia	.7046	.0263	.941
56.	Dominican Republic	-.3580	.0415	.983
57.	Ecuador	1.7330	.0670	.790
58.	El Salvador	1.3400	.0118	.673
59.	Guatemala	.2121	.0324	.965
60.	Haiti	.9691	.0231	.751
61.	Honduras	.3952	.0291	.870
62.	Mexico	.7967	.0237	.950
63.	Nicaragua	1.2030	.0162	.989
64.	Paraguay	.8599	.0150	.911
65.	Peru	.6749	.0315	.985
66.	Uruguay	.6343	.0199	.943
67.	Venezuela	.3265	.0408	.981
68.	Greece	.3368	.0283	.875
69.	Israel	.1899	.0338	.984
70.	Portugal	1.0560	.0199	.995
71.	Spain	1.0630	.0217	.688
72.	Turkey	.8017	.0237	.943
73.	Yugoslavia	.8734	.0241	.994
74.	Kuwait	.9286	.0421	.739
75.	Saudi Arabia	1.6030	.0312	.600
76.	Australia	-.5750	.0438	.975
77.	Austria	1.6650	.0129	.717
78.	Belgium	1.0090	.0243	.893
79.	Canada	-.0540	.0380	.981
80.	Denmark	.0887	.0332	.964
81.	Finland	.6003	.0263	.995
82.	France	1.4710	.0151	.864
83.	West Germany	1.1930	.0221	.778
84.	Ireland	-1.4600	.0544	.938
85.	Italy	.6527	.0291	.920
86.	Japan	1.1840	.0179	.973
87.	Netherland	-.3390	.0434	.994
88.	New Zealand	.4395	.0229	.931
89.	Norway	.0466	.0381	.976
90.	Sweden	1.2840	.0183	.959
91.	Switzerland	-.0660	.0385	.969
92.	U.K.	1.4590	.0158	.848
93.	U.S.A.	1.5980	.0108	.626
94.	China	.1583	.0407	.983
95.	Chechoslovakia	.7124	.0300	.887
96.	East Germany	.9901	.0268	.829
97.	Hungary	.3767	.0337	.789
98.	Poland	.2736	.0360	.926
99.	Romania	.0799	.0388	.987
100.	USSR	-.4380	.0494	.968

DIFFERENCE BETWEEN PEARL CURVE AND ALPHA GROWTH CURVE

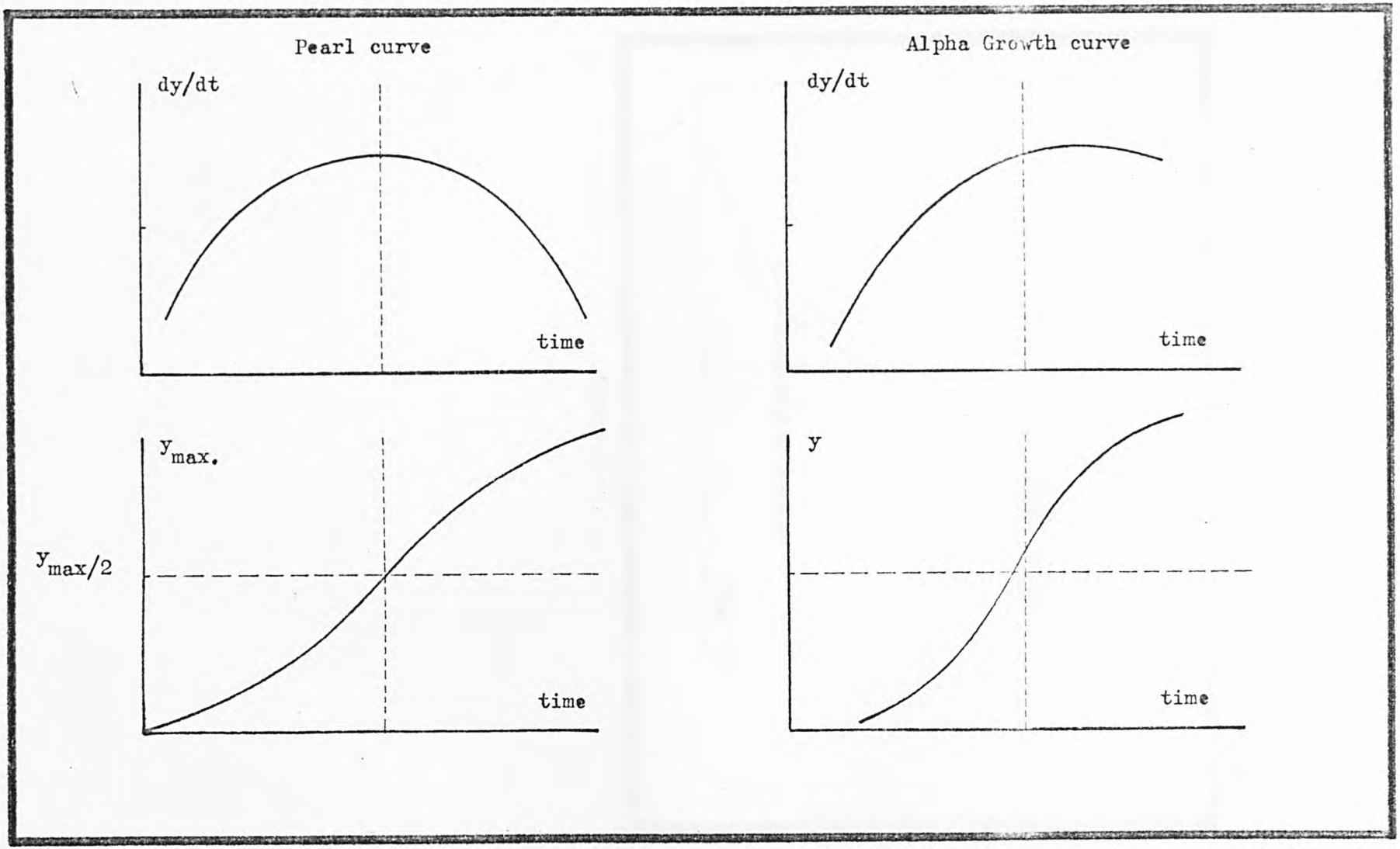


Figure 3.11

EXPONENTIAL GROWTH AS AN APPROXIMATION TO ALPHA GROWTH

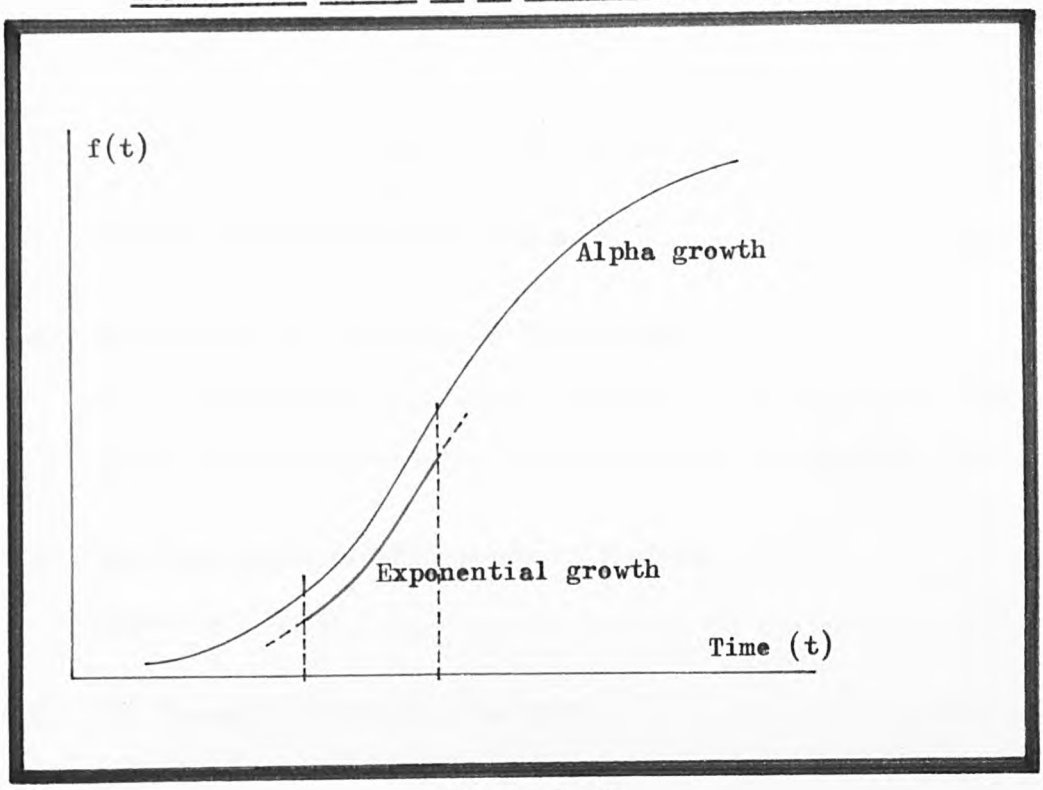


figure 4.11

CHAPTER 4

Validation of 'National Engine Model'

4.1. Introduction..... 208

4.2. Approach to Efficiency in Process Conversion Model.... 214

4.3. Process Conversion Model Hierachy..... 222

4.4. Efficiency as a measure of Technology

4.4.1. Technology in Economic Theory..... 228

4.4.2. Process Efficiency as a measure of Technology.. 234

4.5. The Components of Efficiency in Process Conversion Model..... 238

4.6. The Economic Efficiency Vectors..... 244

4.7. Operational and Application of National Engine Model

4.7.1. Process Efficiency' Rate of Change compared to Economist's Technical Change..... 250

4.7.2. Rate of Efficiency Change for UK, US and Sweden..... 251

4.8. Population Data used to estimate Labour Economic Efficiency..... 254

4.9. Discussion..... 262

CHAPTER 4

VALIDATION OF 'NATIONAL ENGINE MODEL'

4.1. Introduction

Only recently has some serious attempt been made to study the relationship and contribution of energy to the economy. Strong correlations exist both on the cross sectional and time series data on energy consumption and GNP as can be deduced from figure 4.1 (page 210) and figure 4.2 (page 211).

Classification based on international statistics reveals that each country operates on different output per energy consumption ratios. This can be described in a simple exponential model as table 4.1 (page 212). This table also shows the correlation of best fitted line on some selected industrialised countries between 1950 - 1977.

The consequence of this observation prompted the formulation of the 'Black Box National Engine Model' by Prof. M'Pherson (14). This is basically a system approach based on the idea of thermo engine (figure 4.3, page 213). The model assumes a black box consisting energy utilising sector and energy producing sector. The inputs of energy producing sector are inland resources or imported energy, they can be in the form of fossil fuel, nuclear, or hydro electricity. The energy utilisation sector used this energy to transform raw materials and to provide services. The results of these activities can be accounted in the form of GNP.

Dividing the GNP with the number of population give us a useful comparative indicator of GNP per capita (G). The relationship between this value and per capita energy consumption give us some indication of the 'Engine' characteristics. To make a comparison to an ordinary engine, this 'National Engine Model' is similar in every respect.

In this chapter the concept of efficiency as a performance measure of this 'Engine' is developed and compared against the economist' Technical Change.

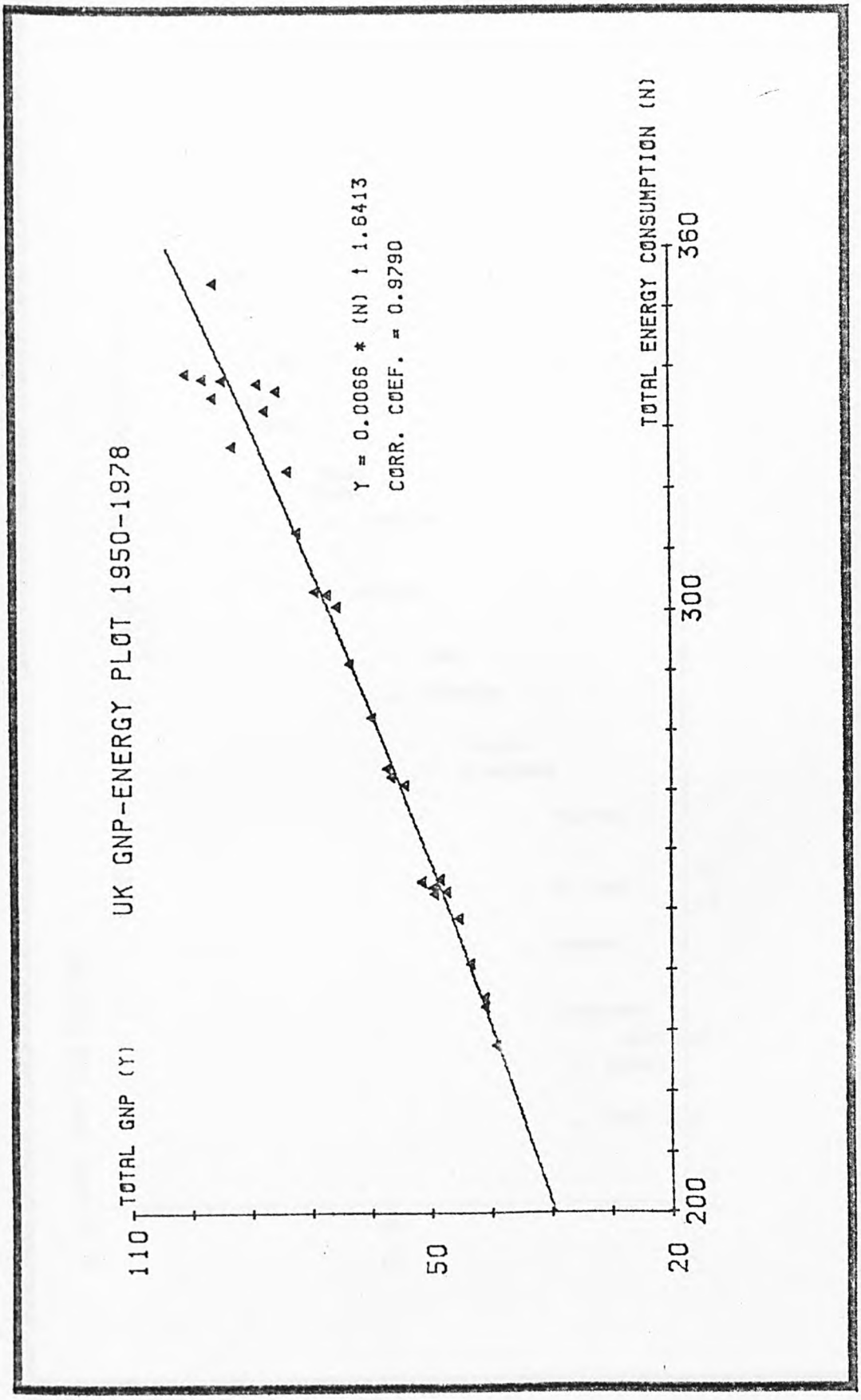

UK GNP-ENERGY PLOT 1950-1978
TOTAL GNP (Y)
110
50
20
200
300
360
TOTAL ENERGY CONSUMPTION (N)
Y = 0.0066 * (N) + 1.6413
CORR. COEF. = 0.9790

Figure 4.1

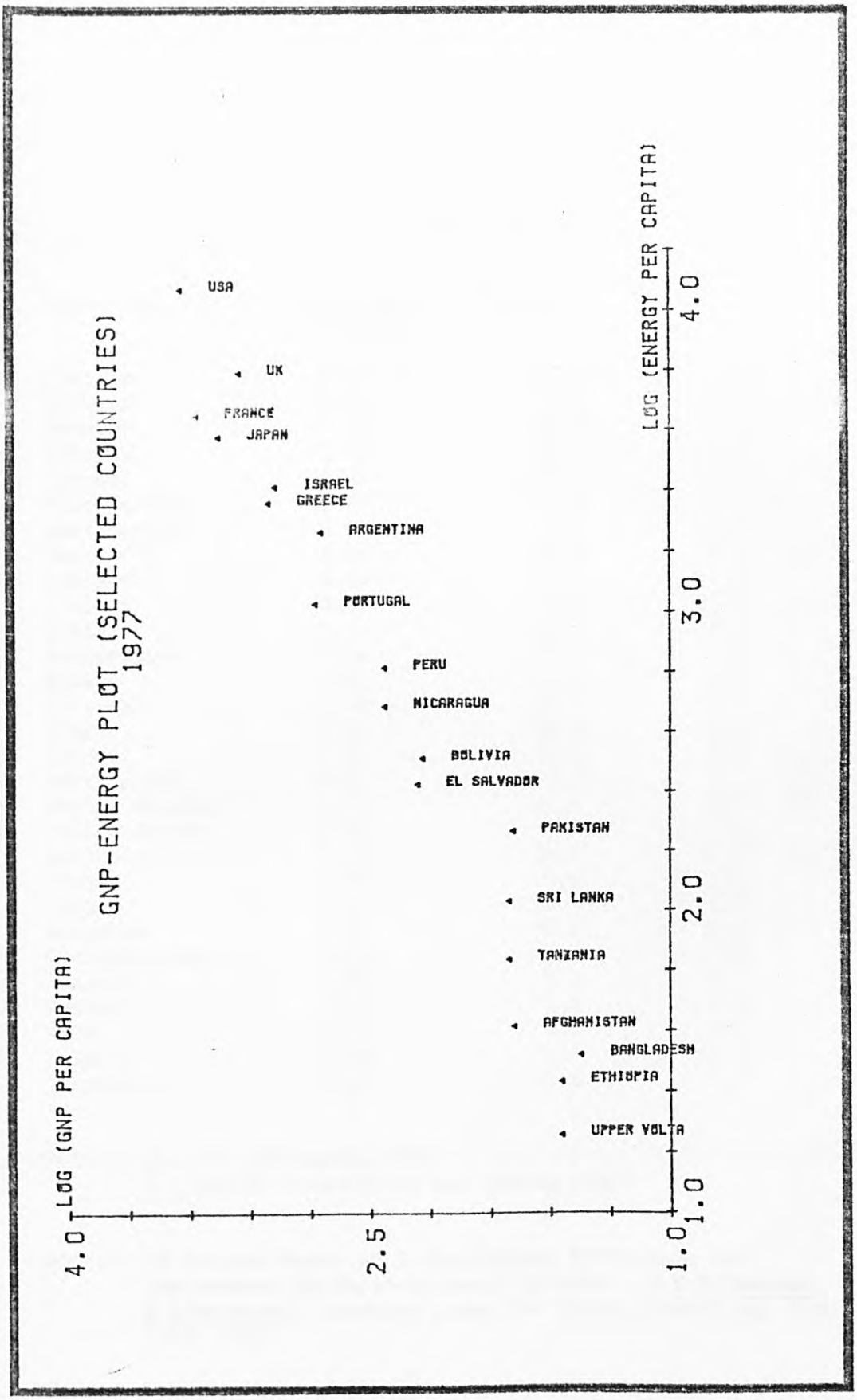

GNP-ENERGY PLOT (SELECTED COUNTRIES)
1977
LOG (GNP PER CAPITA)
LOG (ENERGY PER CAPITA)
4.0
2.5
1.0
1.0
2.0
3.0
4.0
USA
UK
FRANCE
JAPAN
ISRAEL
GREECE
ARGENTINA
PORTUGAL
PERU
NICARAGUA
BOLIVIA
EL SALVADOR
PAKISTAN
SRI LANKA
TANZANIA
AFGHANISTAN
BANGLADESH
ETHIOPIA
UPPER VOLTA

Figure 4.2

Table 4.1

Simple Energy - GNP Growth model

model $g = a (n)^b$

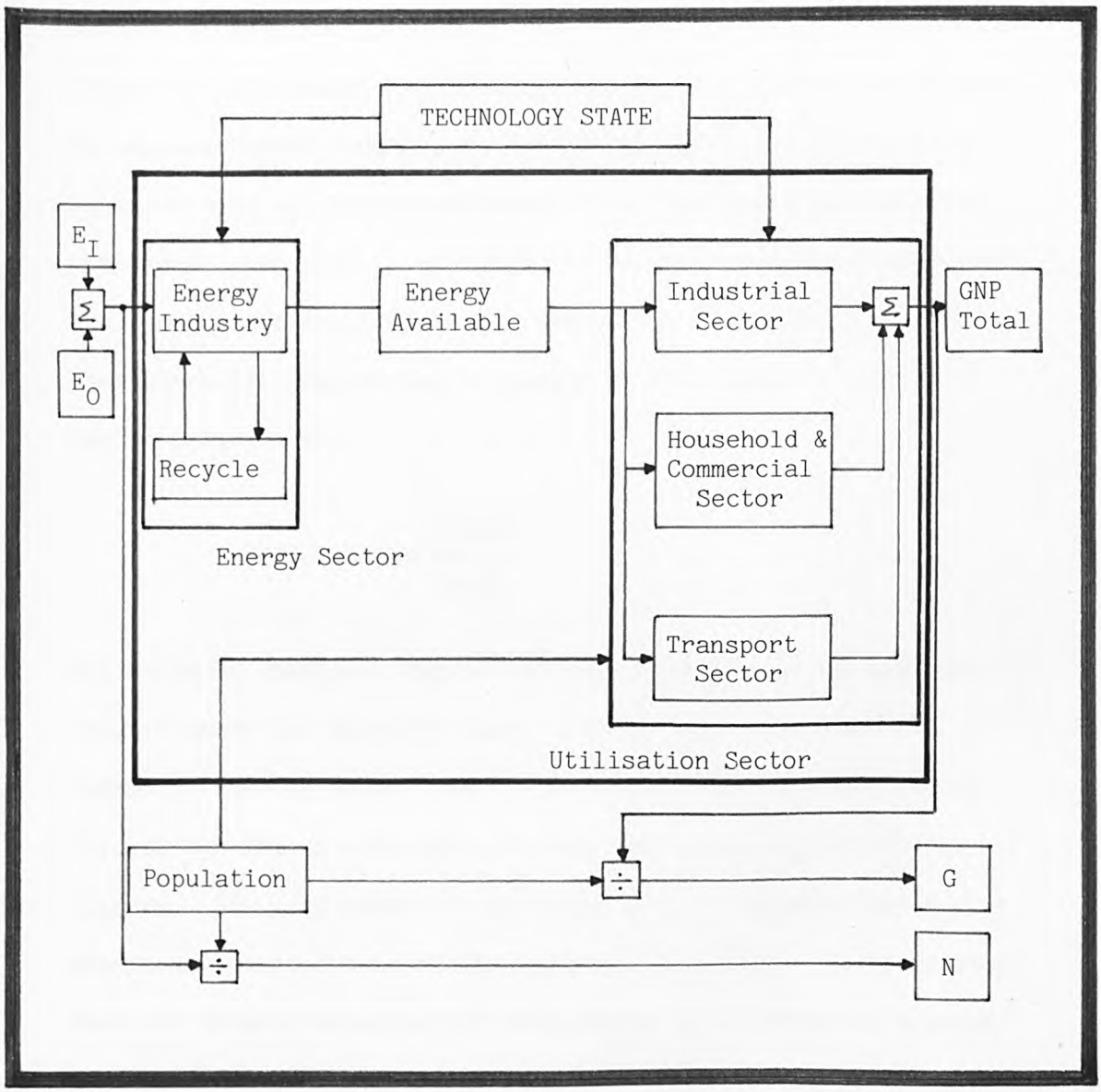
Countries	Correlation Coeff.	constant a	constant b
Austria	0.98	15.5	1.0
Belgium	0.92	5.5	1.5
Denmark	0.95	25.0	0.7
Finland	0.98	27.8	0.5
France	0.97	13.6	1.2
East Germany	0.94	2.0	1.7
West Germany	0.94	7.0	1.4
Greece	0.98	20.6	0.6
Iceland	0.91	7.3	1.3
Ireland	0.93	16.6	0.8
Italy	0.94	20.1	0.5
Netherlands	0.94	21.5	0.7
Norway	0.97	27.4	0.7
Portugal	0.98	24.0	0.7
Spain	0.94	20.8	0.8
Sweden	0.97	32.2	0.7
Switzerland	0.97	71.0	0.4
United Kingdom	0.75	50.8	0.7
United States	0.97	7.5	1.1
Australia	0.96	25.7	0.7
Canada	0.96	0.3	1.1
Japan	0.99	18.9	0.9
Bulgaria	0.97	10.6	0.7
Czechoslovakia	0.96	3.1	1.4
Hungary	0.84	7.3	1.1
Poland	0.97	3.0	1.6
USSR	0.98	4.7	1.2
Romania	0.98	3.1	1.2
Yugoslavia	0.98	11.5	1.0

Note: g = GNP per capita (US$)
n = Energy consumption per capita (TCE)

Source: 'A Process Model of Technological Efficiency and Improvement in Socio-Economic Systems', P K M'Pherson, E Limantoro, a working paper for IIASA, Laxenburg, June 1980 (162).

figure 4.3

Simple Engine Model



4.2. Approach to Efficiency in Process Conversion Model

In common with normal engine, this 'National Engine' has performance characteristics as well. Thus it is possible for example to measure the 'capacity or size', 'capability', and of cause its efficiency. To engineers it is obvious that if we want to improve the performance of our 'National Engine', we need to know not only all these characteristics, but also its mechanism and dynamic behaviour. We start our study with a broad survey of the types and characteristics. One of the most commonly used characteristic engineering indicator is Efficiency. Loosely it can be defined as:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

The model of 'National Engine' is only plausible if we can show that it obeys all physical laws. It has been shown that it indeed follows an energy input - work done (output) characteristics (15). This is the sort of behaviour shared by all normal engines. The usefulness of this model can be extended further by developing a hypothesis of its internal mechanism. It is assumed that the dynamic behaviour of this engine is affected by certain important factors, which will be looked in detail in this section.

Within the boundary described in chapter 1, efficiency of this 'Engine' gives some indication of the level of technological capability. At this stage we need to define two commonly used system performance. The first one is defined by Monetary

Conversion Process model, which is commonly used by the accountants and economists. This model assumes that in every production system there is a method of calculating value added in the form of profitability. In the national economy, this value added is the GNP itself (figure 4.4, page 218). In contrast, the engineers view any process conversion as an entropy reduction process. In doing so, it looses its energy. Therefore however efficient any conversion system is, the overall efficiency can never be larger than unity. Theoretically this model measure the 'true' energy contents of both inputs and outputs. Therefore any losses during the conversion process can be regarded as inefficiency. This way we know exactly the 'ultimate' efficient process (efficiency = 100 percent). This second model can be described as figure 4.5 (page 219). In mechanical process conversion (steam engine) this absolute efficiency has been shown to increase with time (figure 4.6, page 220). Similarity between mechanical system efficiency and input-output efficiency in the economic system is the basis of the approach used in this study.

Although the second method (energy accounting) is proven to be reliable and inflation proof as in the case of mechanical conversion, we have been using the monetary system for our economic accounting. In fact all economic data available are mostly in some form of monetary units. The energy accounting requires labour and other factor inputs to be measured in term of their energy contribution which require a special method and tools not available at present. Without any of these inputs pure energy accounting model for the economic system is not feasible.

With the substantial rate of inflation as we experience in this decade, the accounting profession has been faced with the need to adjust monetory figures for difference in its actual value over time. Accounting methods such as CCP (Current Purchasing Power), CCA (Current Cost Accounting), LIFO (Last In First Out), and FIFO (First In First Out) need to be developed in order to counter act the effect of inflation on the accounting system. Arguably one may say that this kind of evaluation method has many defects. It is not the accounting methods that is defective, rather it is the actual money standard itself which is not stable. A part used asset may be the same whether at the first of April or at the first of January, but its price may be different depending on which way it is viewed - at historic cost when purchased, at what it would bring if sold, at what it would cost to replace, or even the currency in which expressed. The more complicated the system is, the more adjustment the accountants and the economists have to make.

From the economic development point of view, this method of evaluation has been with us ever since the history began. This system has been established as the only evaluation criteria of process transformation within the economy. However a highly profitable 'efficient' system, evaluated by this method may not necessarily be technologically the most efficient one. Thus one may decide on investing into an inefficient process as long as it gives the highest return (measured by this criteria). Yet this inefficient system may need to be replaced with a more technologically efficient system often before it produces the

required return. It is argued that at the moment we do not have any tool to analyse this kind of technologically related decision making with some degree of precision. The realisation of this fallacy therefore is through the long term results which can be years after the policy implementation.

To most decision makers (at national level) the factor of technology at present is more often considered as a constraint rather a forecastable variable. Given that technology is a constraint rather another factor or variable, there is limited actions that any decision can be made upon. It is not therefore surprising to find out that many economic systems go downhill on apparently good management.

To overcome this problem, a combination of engineering and accounting method is proposed to build the Engineering - Economic Process Model (figure 4.7, page 221). Essentially, this is a hybrid engineering-accounting methodology which utilises economic and accounting data to include unknown factor 'Technology' into the model. It is developed to overcome the drawback of present economic accounting fallacy and to bridge the gap between a true engineering approach and 'universal' economic-accounting system. To measure system efficiency we use productivity instead of value added. With relative productivity we have included the essential economic (monetory) information, and at the same time utilising engineering (efficiency) concept. The basic Process Conversion Model used for this study is a direct decendent of the 'Engine Model'

figure 4.4

Simple Monetary Conversion Process Model

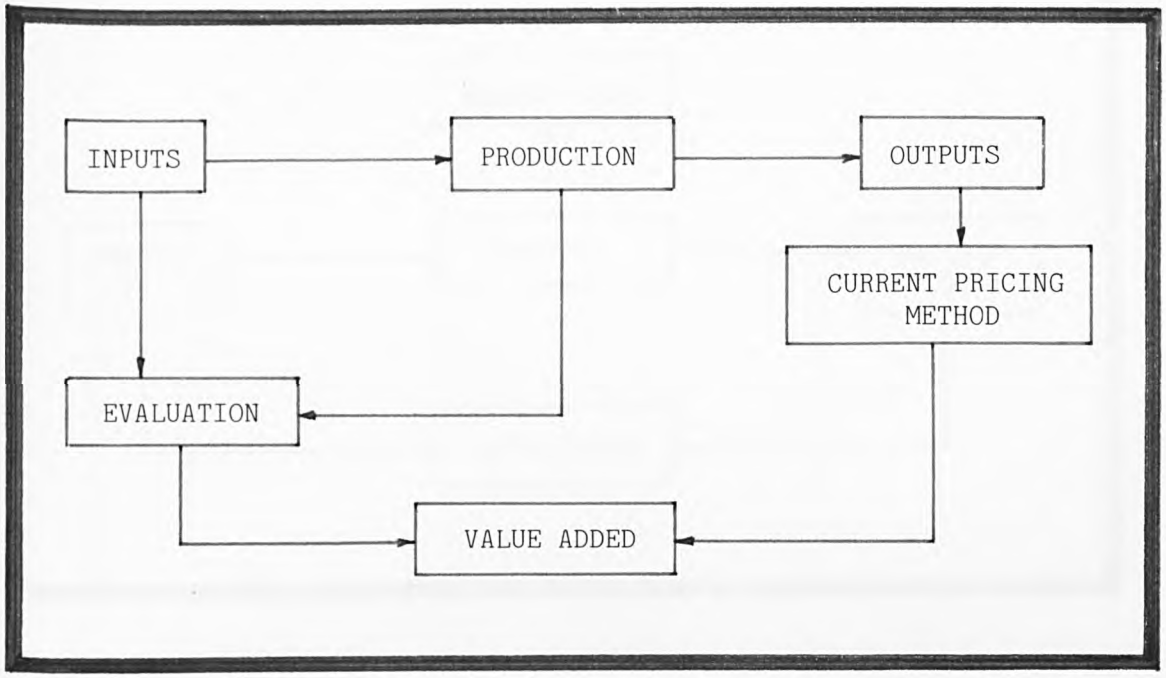
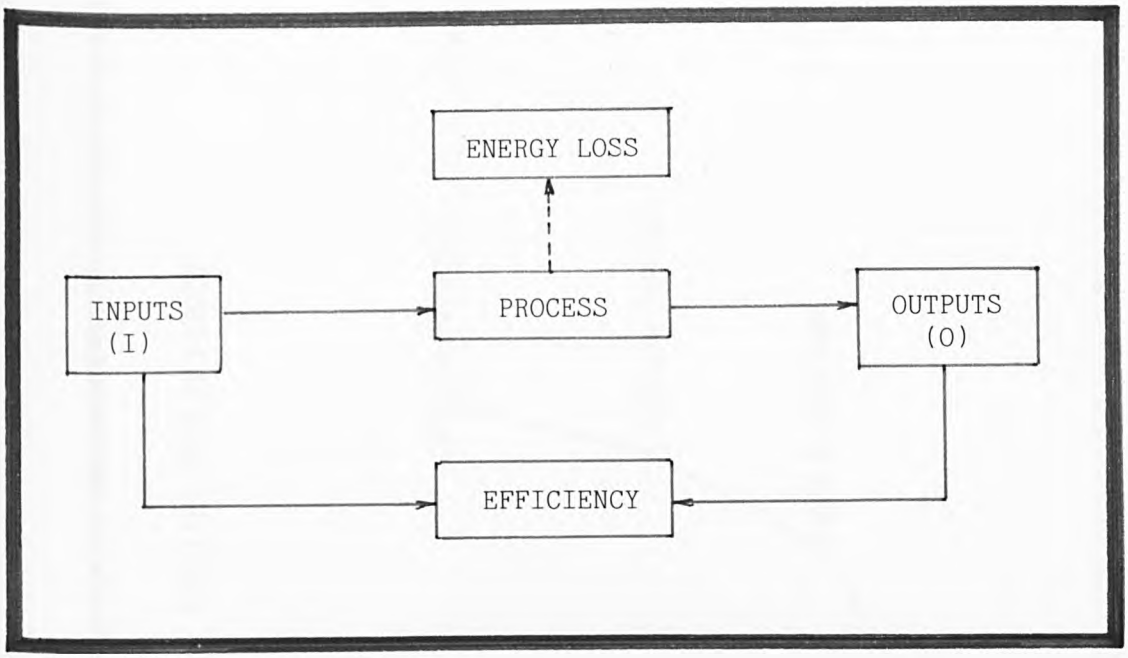
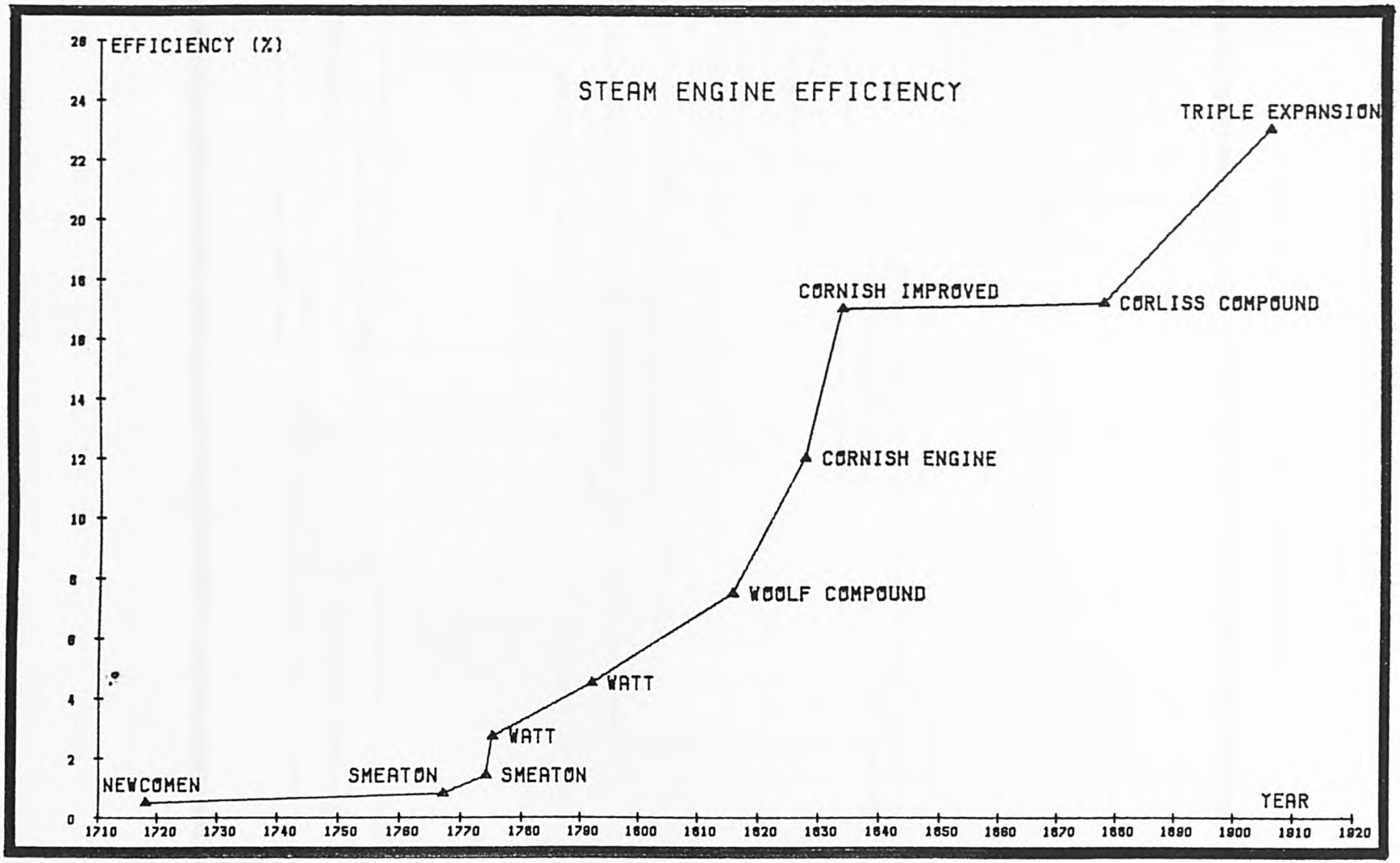


figure 4.5

Simple Engineering Process Conversion Model




EFFICIENCY (%)
STEAM ENGINE EFFICIENCY
TRIPLE EXPANSION
CORNISH IMPROVED
CORLISS COMPOUND
CORNISH ENGINE
WOOLF COMPOUND
WATT
WATT
SMEATON
SMEATON
NEWCOMEN
YEAR
0
2
4
6
8
10
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16
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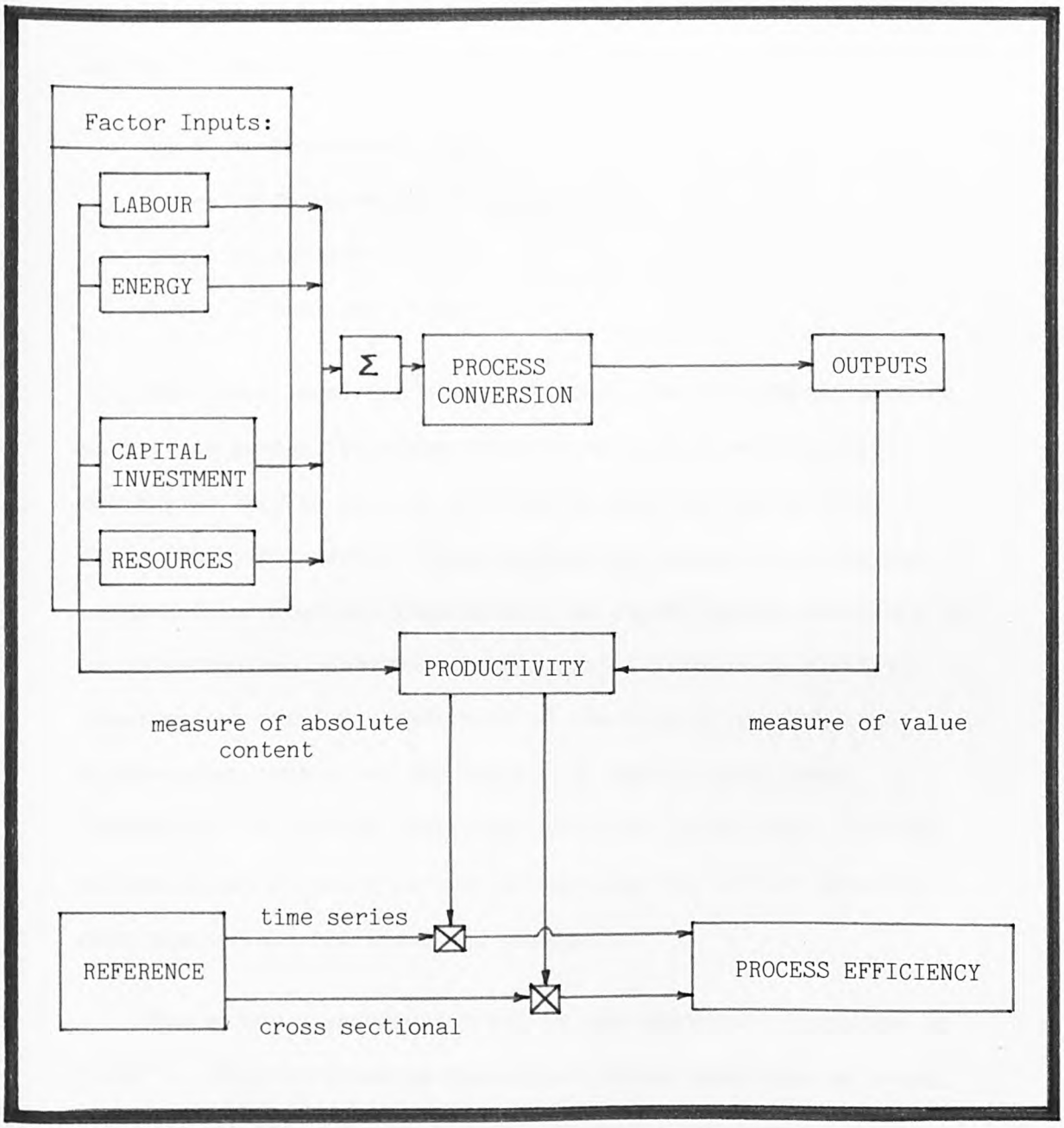
1900
1910
1920

Figure 4.6

figure 4.7

Simple Engineering Economic Process Model



4.3. Process Conversion Model Hierachy

As described in earlier (chapter one), there are four levels of system hierachy which utilisation of the efficiency concept is useful. These are:

level 1: Individual level

level 2: Entrepreneur (company) level

level 3: Industrial level

level 4: National level

The first level has human system as the 'central processing unit'. As productive human being in an economically active society we have to do work in order to meet our daily needs (figure 4.8, page 225). These include our basic physiological needs such as shelter, food as well as psychological ones such as satisfaction and happiness (Moslow, 16). Technology at this level enters our individual life in the form of information. As a processing centre, we are capable of manipulating these information to produce additional stock of technology. Through education and learning process we can make use of our know-how to make appropriate decisions and judgement.

The second hierachical level is the aggregate of systems at level 1. This is known as company or entrepreneur system level. Although the basic system remains the same, the boundary has enlarged to include collective interactions between each individual factor. It can be represented as figure 4.9 (page 226). At this level all the collective terms can be referred as production factors. The standard function classifies these

factors into labour, capital investment, resources and energy. From this level upwards the concept of efficiency as a measurement standard is relevant to this thesis (described in chapter 4.4 and 4.5). At this level we defined four different efficiency sectors. Each sector's efficiency is independent to other's. The investment efficiency leads to profitability measure similar to accounting's system. The three other main efficiency measures are Labour, Material Resources, and Energy. It is possible to subdivide the labour efficiency sector as Operator, Management, and Technical efficiency depending on the purpose of the system. The overall performance of the system level depends on the combination of each subsystem efficiency. The knowledge of these measures relative to other similar systems provides useful policy guidance and aid to decision making.

If we move to a higher level (figure 4.10, page 227), the efficiency concept becomes increasingly more important for measuring the performance of the industry. Market demands may provide initial idea of invention and innovation. The measure of efficiency provides comparative performance measure to other industry or the same industry in other countries. The overall efficiency figures at this level may be useful for those responsible for the running and maintenance of collective system at level four. System at level four is considered as the highest level, although it is possible to consider global level as the next one up, which is beyond the scope of this thesis. At level 4, the system is very complex. We need to know the exact detail of all the lower levels (subsystems) to have a complete under-

standing of system at this level. Interactions do not only come from political, social and industrial levels, but also its sub-levels and sub-sub levels, including at those at level 1.

The usual practice to approach this kind of problem is through complex modelling. In the past or even at present time for this matter, this kind of modelling (such as many econometric models) are very popular among the economists. Mathematically most of these models are elegant and impressive. However because they are complex and more often based on untested assumptions, their practicallity and use are very limited.

Thus there is a paradox here. We need to have a model which is both powerful in term of its capability to represent the 'world' and yet it has to be simple to be practical. The present techniques (econometric and economic models) have been proven to be less than satisfactory. In chapter 2 part of this problem is solved by providing a method which is capable of simplification and reduction of large scale variables.

In this chapter an Efficiency measure to describe the state of Technology at national level is developed, with which we can analyse national system performance.

figure 4.8

Technology at Level 1

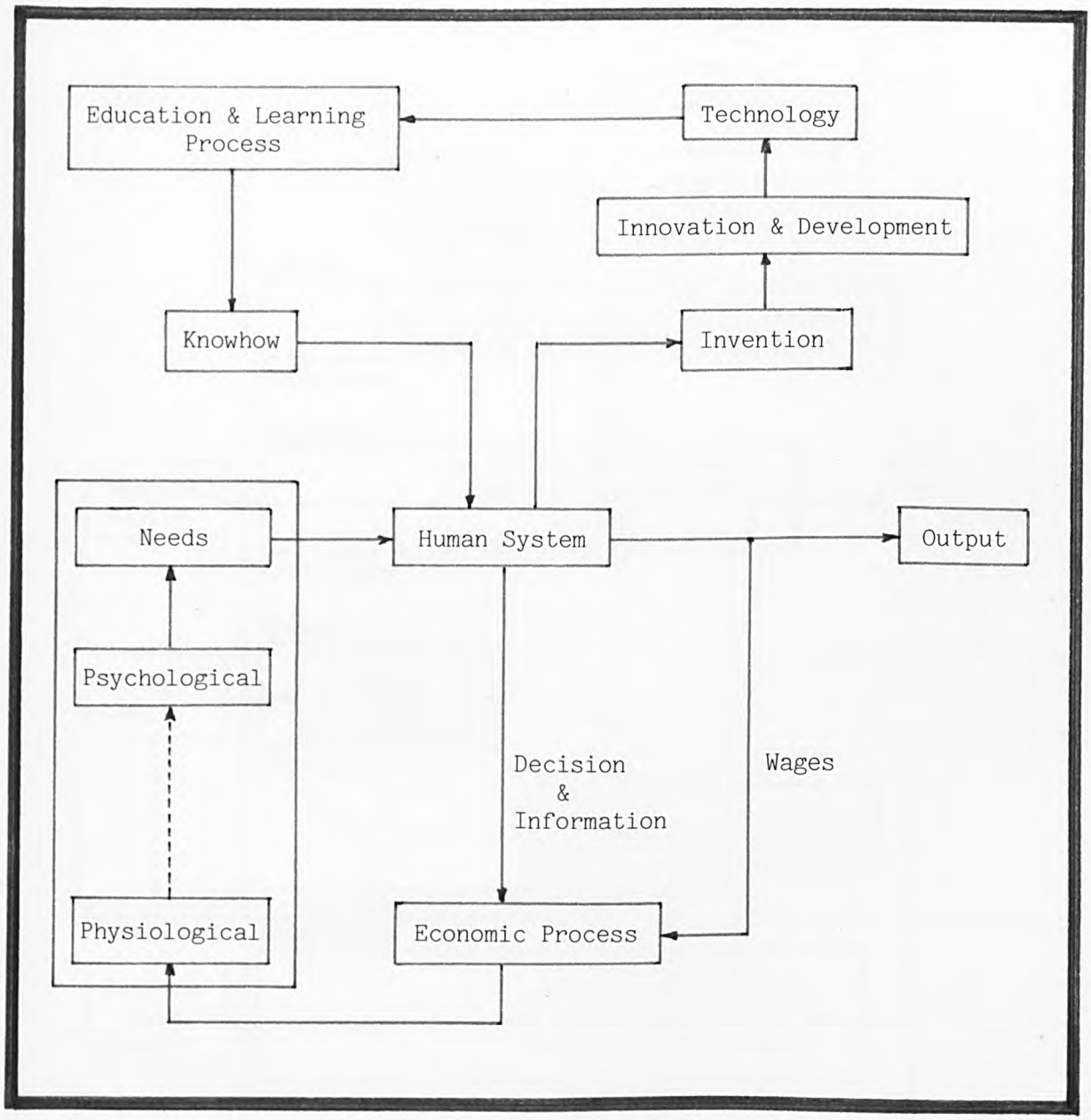


figure 4.9

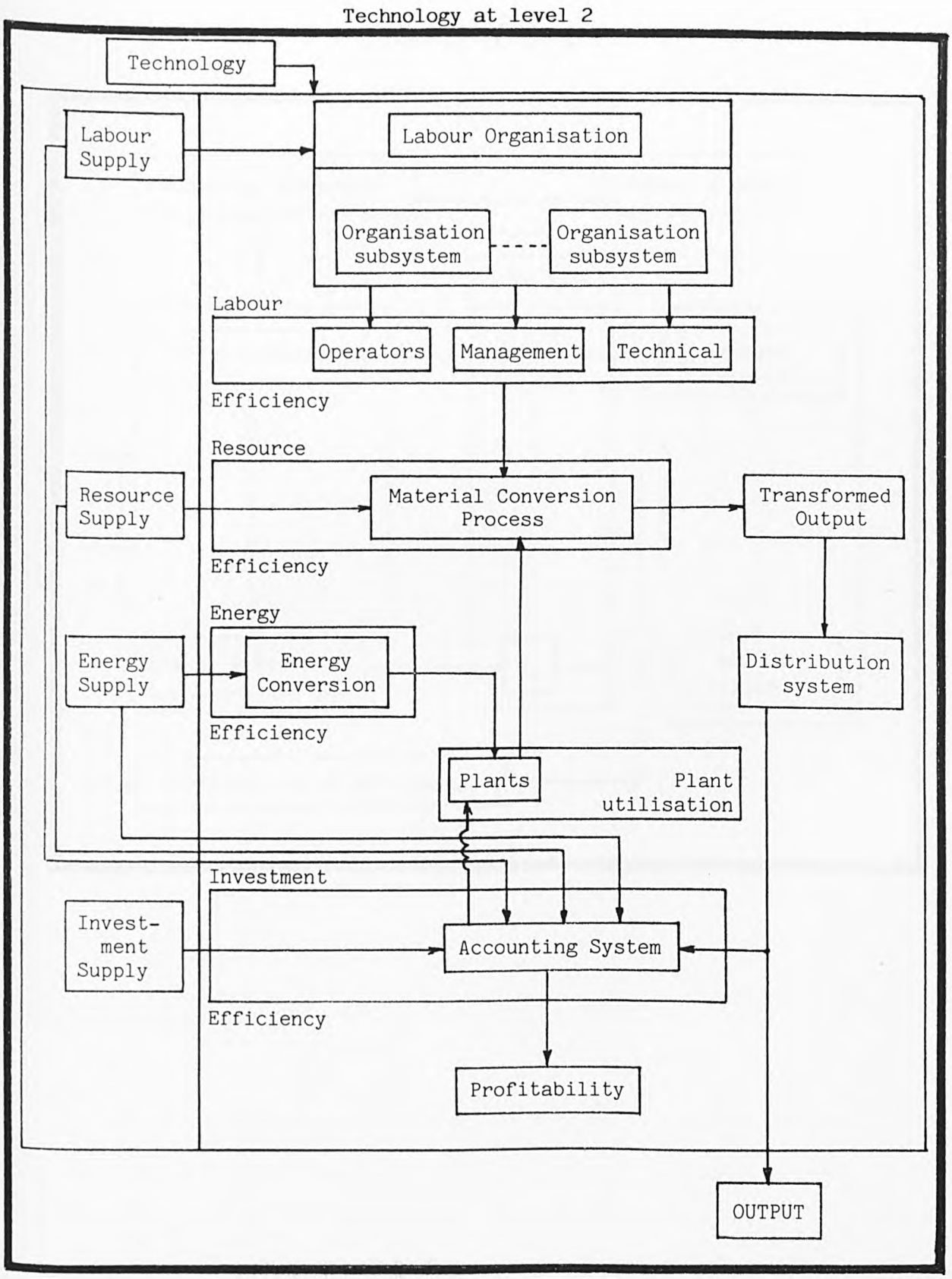
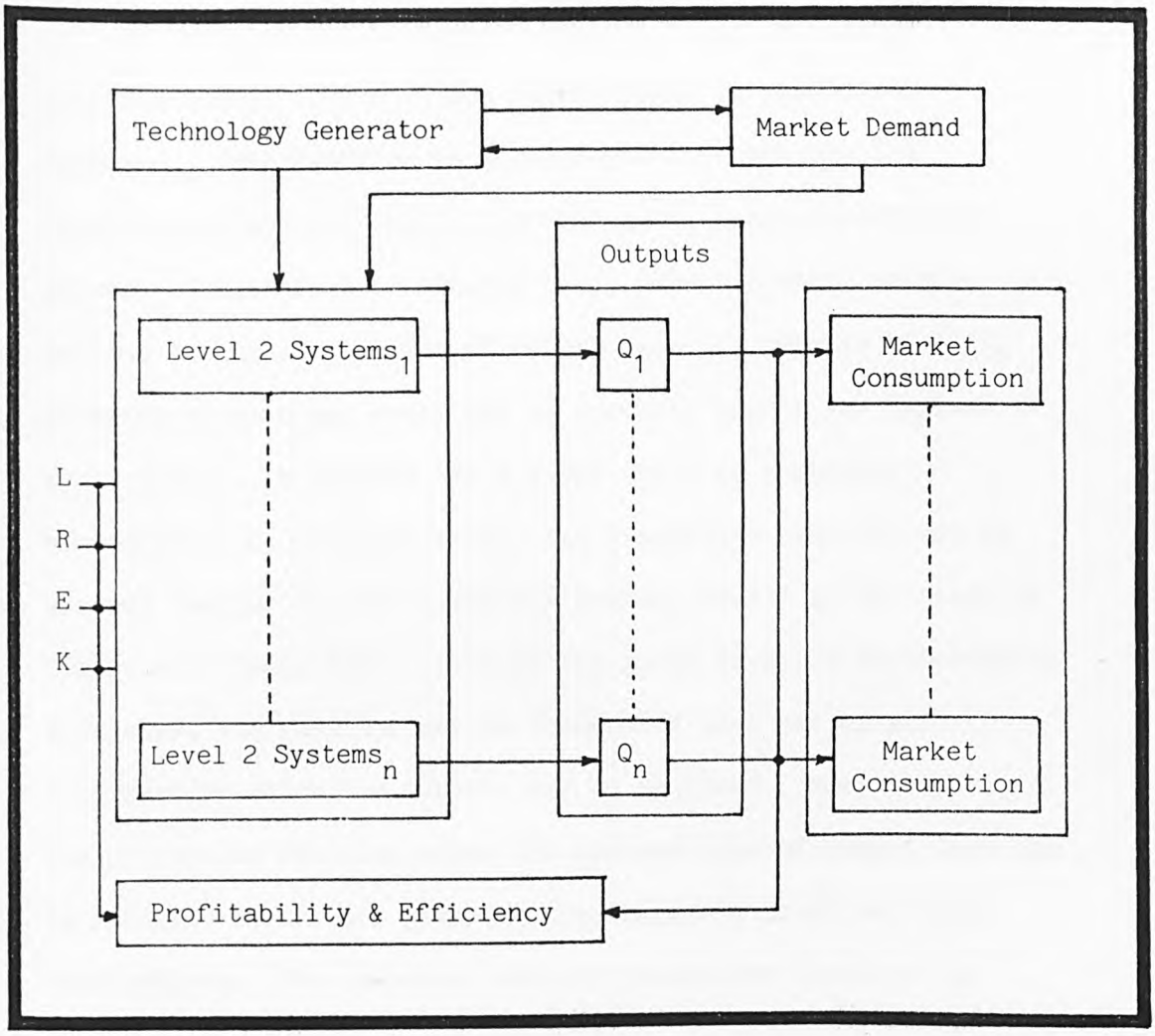

Technology at level 2
Technology
Labour Supply
Labour Organisation
Organisation subsystem
Organisation subsystem
Labour
Operators
Management
Technical
Efficiency
Resource
Resource Supply
Material Conversion Process
Transformed Output
Efficiency
Energy
Energy Supply
Energy Conversion
Distribution system
Efficiency
Plants
Plant utilisation
Investment
Invest-ment Supply
Accounting System
Efficiency
Profitability
OUTPUT

figure 4.10

Technology at level 3



4.4. Efficiency as a measure of Technology

4.4.1. Technology in Economic theory

In the past the economists used to refer technology quantitatively in term of its relationship to production function. This function is a description of the physical relationship between inputs and outputs in a given production system. Samuelson (17) defines it as 'the technical relationship telling the maximum amount of output capacity capable of being produced by each and every set of specific inputs (or factors of production). It defines for a given state of technical knowledge'. At national level, the production function can be assumed similar to 'the black box process model' as described in figure 4.11 (page 232). Thus at any given level of technological knowledge, the function may be thought of as a set of all 'recipes' by which the outputs may be produced. More properly the production function shows the maximum rate of output that can be achieved by certain given, technologically possible, input combinations. The classical form of production function is:

$$Q = f (K, L) \qquad (4.1)$$

where Q = output

K = capital

L = labour

As mentioned earlier quantitative relationship at micro level has been looked at and studied by a large number of economists from as early as the end of nineteenth century (Cobb-Douglas (18),

Solow (19) among many others). Clearly the above model is a very simplified model of real production system. In any modern production system as we have today, we do need to use external energy as part of the inputs. However, as we shall see, the above equation has some important basic characteristics which we can learn. The first is the assumption inherent to the equation. As there there are only two input factors on the right hand side, then the outputs can be accounted sufficiently by the combination of these factors. It implies that a perfect production knowledge is possessed by the decision makers and used to optimised these combinations. Thus technology in the economists' production function is exogenous.

The above model is fine if only it is used to show that technology does indeed exist as external factor. This external factor can be described in term of isoquant as shown in figure 4.12 (page 233). The existing output is the product of combination of inputs in the manner described by line A_1. Any change of the external factor implies a change in the shape of the curve, for example to line A_2.

With this basic model, it is possible to add a cost function such that a simple graphical optimization can be found. Thus we can mix an isocost line in the equation to give optimum pricing and cost solution given by point X in the figure 4.13 (page 233). This point is often referred by economists as the economically optimum point. Thus the most optimum combination can be achieved from:

maximising $Q = f (K, L)$

subject to $C = p_k K + p_l L$

where C = total cost

p_k = cost of capital

p_l = cost of labour

The economists went further by classifying the type of technological change. Generally any innovation or technological change results some changes in these combinations. A neutral technological change refer to a shift in the isoquant line as shown by line A_2 in figure 4.14 (page 233). Other types of technological change are referred as labour saving and capital saving. These can be represented as line A_3 and A_4 respectively. Hicks (20), Robinson (21), Harrod (22), Domar (23) and many others have in fact followed their research along this line.

For the purpose of understanding the mechanism of technological change from different point of view it is worth noting the limitation of this basic economist's model. Firstly each type of innovations and technical change produces a different types in input markets and the proportion of income going to capital and labour. Since the theory does not tell us anything about the behaviour of the innovations, it is also vague on their ultimate effects. Secondly and more importantly is the time factor. Once technological change has occurred, not all systems adapt the technique straight away. Thus there are time lags with in the system. Therefore it is very difficult to calculate the effect of technology in a large system. Thirdly

this theory fails to account on the pricing effects after technological change has occurred. In our experience one of main consequence of technological change is an increase in labour productivity. Surely it has some effects on the wages rate. The bargaining power of trade unions surely must have strong effects on fixing the new level of labour cost.

Obviously this theory seems to raise more questions than it can answer. Indeed, one critic has referred to the theory as 'nothing more than a hodge-podge of suggestions' (Blaug (24), pp.88). The list of researchers who could do not accept this theory are endless notably among the engineers. Obviously the mathematical manipulations which enhanced this theory have made impacts on the economic world. Yet, so far the mechanism of technological change is still far from clear. Surely there must be a need to review the approach more urgently rather than pursuing further with this theory.

BLACK BOX PROCESS MODEL

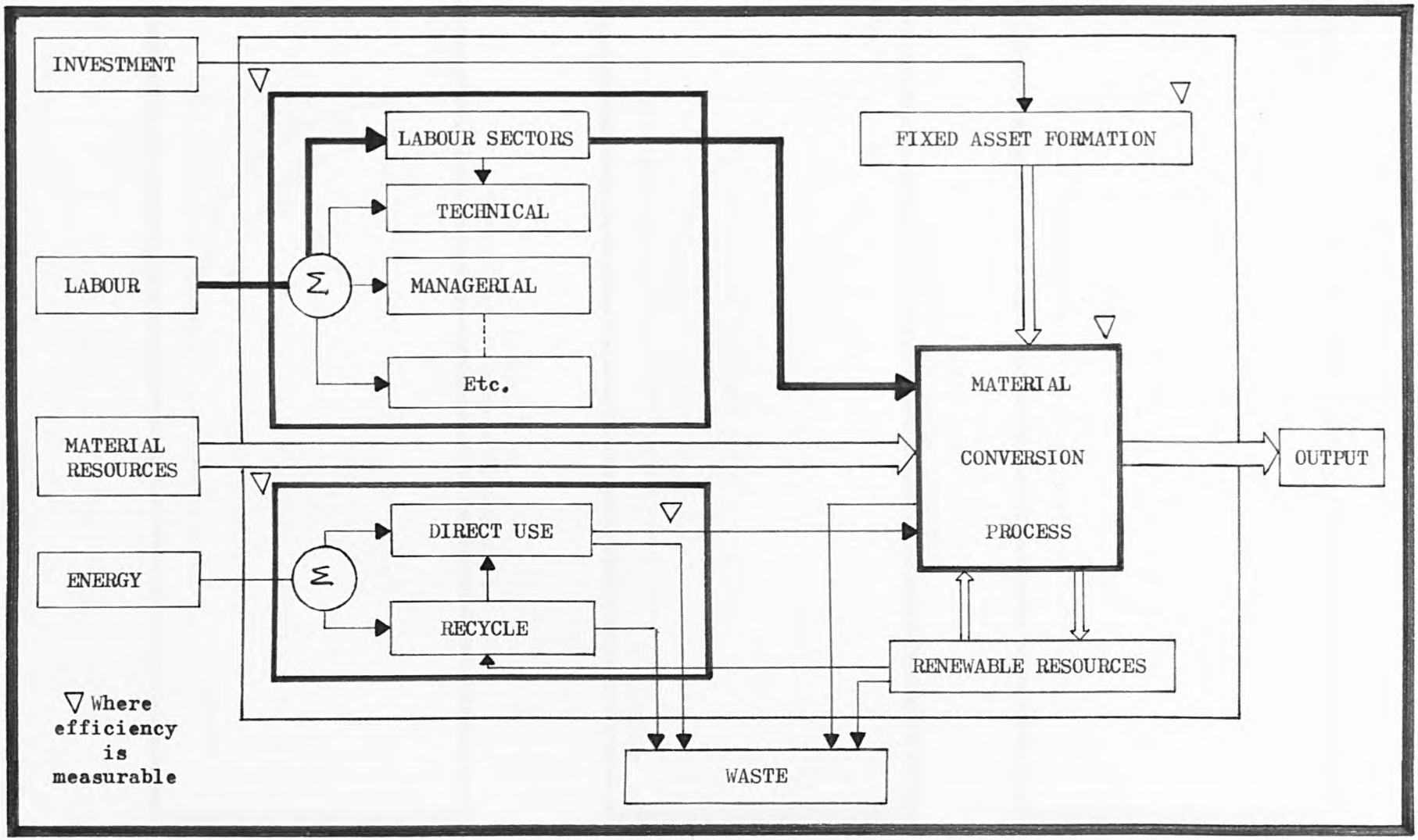


figure 4.12
The Isoquant

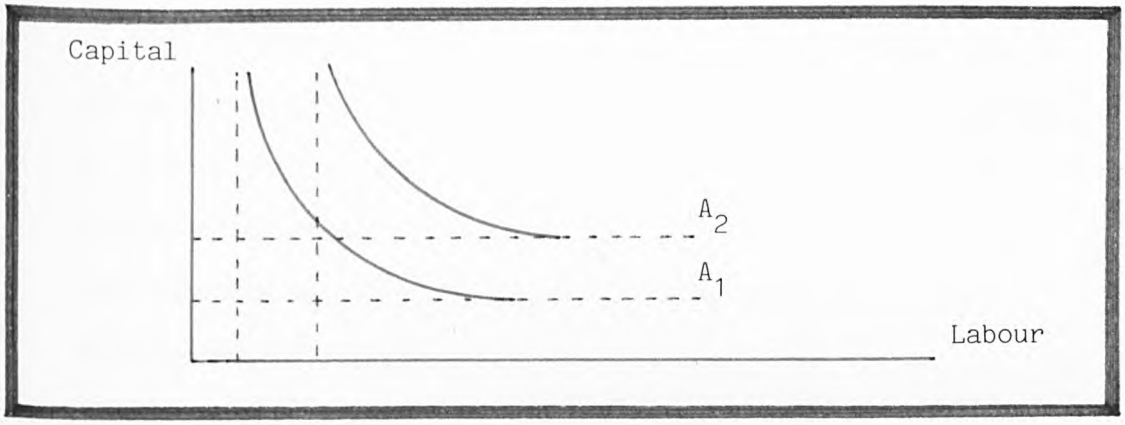


figure 4.13
Optimum Point along Isoquant

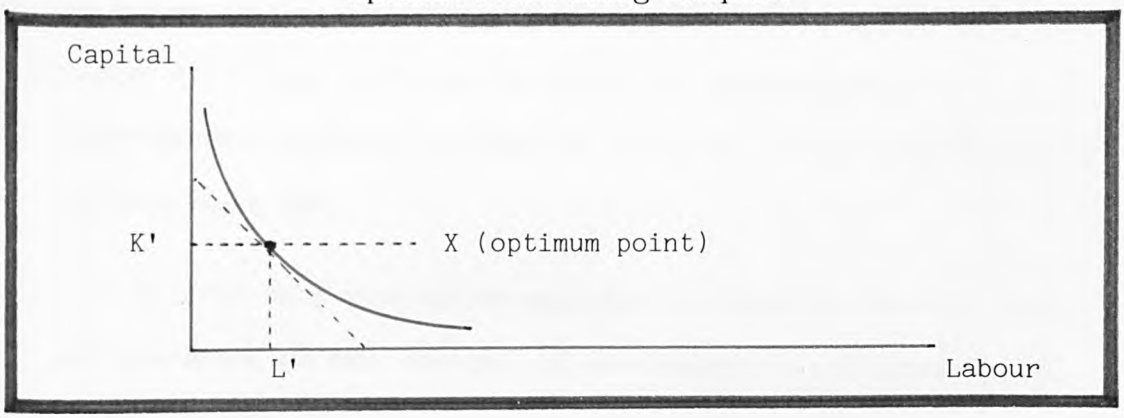
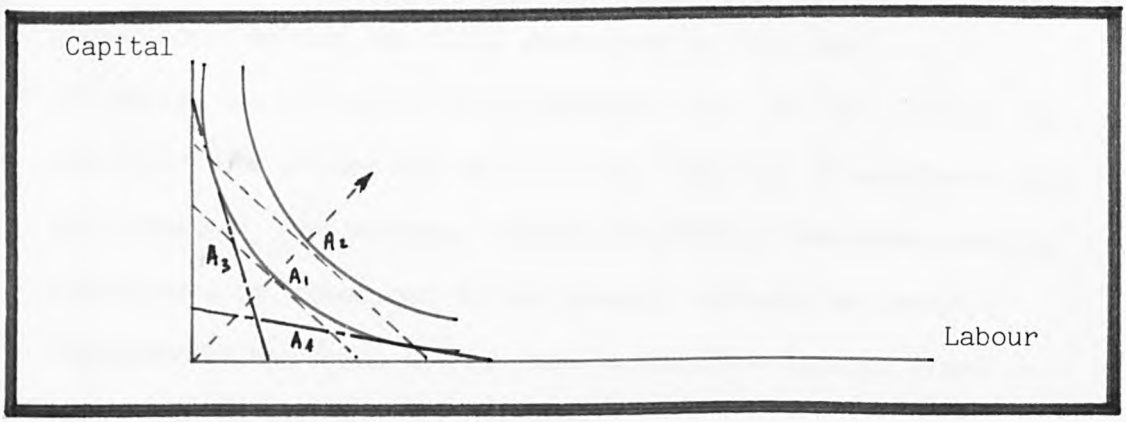


figure 4.14
Technological Change On Isoquant



4.4.2. Process Efficiency as a measure of Technology

It is suggested that a black box - 'Process Engine' can be used as an approach to model Technology in the Economic system. It is a process because it involves conversion of inputs to outputs of different form. The term 'Engine' is based on the fact that the basis of this model is exactly similar as any ordinary engine (energy conversion system). Since the production systems in our economy are basically physical processes, they are subject to all physical laws as well as physical limitations. If we assume that all processes contain components as described in figure 4.11 (page 232), we can apply the engineering thermodynamic approach to describe the total performance criteria of this black box.

Briefly this alternative approach is based on the fact that all processes consume energy. If we compare the industrialised society to pre industrialised one, the most significant difference is that the inputs to the pre industrialised production system are mainly mainly labour. The economics' production function was first developed in this pre industrialisation period (Cobb-Douglas, 18). In this period the main source of income was agriculture. The use of machinery were very limited. The external energy consumption therefore was not significant in comparison to the present consumption level. Consequently the total energy cost in was also insignificant in comparison to capital cost (interest) or labour cost. Needless to say there was no need to formulate external energy independently.

Arguably the commonly used economic models lack of some understanding on physical processes which inherent in nature and the world we live. In the past agriculture provides the main source of income. The apparent cost of this agriculture system is purely labour and capital interest on the land. What classical economists did not realise was the fact that agriculture was a process conversion which used external energy from the sun. Since this energy was provided free, the economist's accounting just could not justify the theory by including this factor in the monetary balance.

In our alternative model, all these physical factors are included not for the reason of completeness but accountability. Basically there are four main input components namely Labour, Energy, Material and Capital Investment. Each of these factor inputs have to go to their appropriate channels before they can be mixed to produce the required output. Energy for example needs to be treated and distributed before it can be suitably used in factories. Similarly labour force needs to be educated and trained before they are of any use. These divisions are looked at in more detail in the following sections.

The origin of the Efficiency concept is thermodynamics. Accordingly any physical process conversion obeys the thermo dynamic laws which can be summarised as follows:

1. Law of conservation of energy

The first law states that energy can neither be created or destroyed, but is always conserved. For a close system it can be written as:

$$dE = 0$$

In the socio techno economic system it is sufficient to assume that the boundary of the system is approximately that of the world and the atmosphere around it.

2. Second Law of thermodynamics

It is a matter of common observation that while work is readily turned into heat the reverse is far from ease. The first quantitative relationship was formulated by Carnot, a French engineer. His theory states that the maximum amount of work one could get out of the heat depends on the temperature of the heat and the temperature of the surroundings. Mathematically this is the basic representation of the efficiency formulation,

$$n = \frac{E_1 - E_0}{E} \qquad (4.2)$$

where n = fraction of heat available to do the work

E_1 = temperature of heat supply

E_0 = temperature of surroundings

The concept of Process Conversion Model is adopted from the 'National Engine' model. If the model has any value at all, it

must show to follow a similar characteristics according to the above laws.

According to the second law, the amount of output can never be more than the input. For example an electric motor may operate at better than 90 percent efficiency whereas a diesel engine might only attain 35 percent efficiency. Applying this analogy to a simple production process of level 2 (figure 4.9, page 226), it is possible to construct some useful system performance measures. These measures are described in section 4.5 and 4.6.

The basis of efficiency concept is the measure of technology itself. With this model we do not make assumption on the nature of the technology, rather the state of technology is measured by the efficiency. The higher the efficiency, the more advance is the technology being used in that system.

4.5. The Components of Efficiency in Process Process Conversion Model

Consider a basic multi-inputs single-output model. Mathematically they can be represented as similar to a production function,

$$q = f\left(\sum_{i=1}^{n} x_i\right) \qquad (4.3)$$

where q = output

n = no. of input

x_i = factor inputs

The classical economists strongly influenced by the actual conditions at the time they live suggested that apart from labour and capital, agriculture is a major factor input for the above equations. Hence land ranked first among other inputs (Ricardo (25), Malthus (26), etc.). The classical production is generally of the following pattern;

$$q = f(N, K, L) \qquad (4.4)$$

where q = output

L = labour

K = capital

N = land

It was the major deflation and low interest rate at towards the end of the nineteenth century which proved that this production function was not a correct representative of the production system. The cost of capital had become more and more insignificant. The economists then proposed a production

function with only land and labour as factors, treating capital as a more or less 'free' good available in unlimited quantities. At around the end of nineteenth century, the economic condition changed. This time a number of manufacturing firms sprang up. Since that time, capital has become so much more significant than before, not only in industry but also in agriculture. Cobb - Douglas (18) and C.E.S.(27) production functions belong to this category. The suggested equation is;

$$q = f (K,L) \qquad (4.5)$$

External energy then plays more and significant role in any production process. Almost in all production processes, a different types of energy are somehow employed (eg. electricity to drive the machinery, petrol to drive the transport engine). Along this line, some radical economists such as Georgescu - Roegen (28) suggested an alternative theory. He made a distinction between the usual classical inputs and other factors normally associated with capital such as natural resources (including 'free' goods such as air and water, intermediate goods (materials) and product used for maintenance. The function can be represented as :

$$Q(t) + W(t) = f (N(t), L(t), K(t); R(t), I(t), M(t)) \qquad (4.6)$$

where $0<t<T$ = time

Q = output

W = waste

N = land

L = labour

K = capital

R = natural resources

I = intermediate product

M = maintenance products

This equation reveals the entropic nature of the production process. The ultimate effect of the system therefore is to transform into waste a flow from the earth's stock of raw materials and energy, using up a fund of service generating factors.

At this point a similarity is observed between the Second Law of Thermodynamics and this process. The only difference lies in the fact that entropy in the universe is 'blind' and without purpose, whereas the entropy of the economic process has reason, namely human enjoyment of life.

However any of the above model is critizied for not mentioning any technology within the function. Indeed it is the technology which has become the area of major interests recently. The evidence of a 'residual factor' in empirical measurement has indicated that there must be another factor present in the true production function. Many suggested these residual factors are the technology itself. This is confirmed by Solow (19), Abramovich (29), Griliches (30), Denison (31) among others.

Along this line we define technology in the economic roughly as the application of knowledge in relation to production and management. A distinction however must be made between 'state of art' and the level of technology utilized. It therefore implies that a very efficient and productive system which has a high technology utilization level may not necessarily possess the 'state of art' in the technical know-how. The technology therefore may be represented as ;

$$T = f\left(q, \sum_{i=1}^{n} x_i \right) \qquad (4.7)$$

where T = technology

q = output

x_i = factor of production

n = number of factors of production

At this point we depart from the commonly used production function to an engineering concept of performance measure. Efficiency has been regarded as one of the most stable, simple and powerful concept in engineering principle. Any energy related input-output system can have its performance measured in term of efficiency. If this concept is applicable to this system, it should therefore equally applicable to the 'Process Engine Model'. For this purpose the factors above can be written more specifically as;

$$T = f\left(q/x_1 \ , \ q/x_2 \ , \ q/x_3 \ \ldots\ldots, \ q/x_n \right) \qquad (4.8)$$

where n = number of factor of productions.

We can not mix directly the concept of profitability and value added to the efficiency measure used in this approach. Although profitability is one way of measuring whether an economic system is working accordingly, it is an artificial performance measure. Profitability and value added are a normative measure of which no standard can be scientifically deduced. It is possible that the same profitable system at one time become a unprofitable one at another time just because the

valuation methodology is different.

Yet we live in this kind of system whether we like it or not, and most of the economic data are measured in monetary units. For this reason, we have no choice but to make use of all data the best we can. Instead of using pure monetary units or engineering measure as such, it is possible to use a combined / converted measure in the form of index. For example the GNP of UK in 1977 is £ 125 412 (M) at factor cost can be expressed as a ratio of GNP at 1960. From (CSO, 32) GNP at 1960 at factor cost is £ 21 506 (M). Thus output of 1970 relative to 1960 is given by;

$$q_{60}^{70} = \frac{\text{£ } 125\ 412}{\text{£ } 21\ 506} = 5.831$$

Along the same line, we can measure all inputs relative to a fixed reference. This way we eliminate all the ambiguity in the standard of valuation used.

By this method, there is no further need of evaluating difference in the quantity of output produced at different time. Thus the question such as whether GNP of 100 pounds is the same as 110 pounds a year later with inflation running at 10 percent per annum becomes irrelevant. The efficiency ratio between output and input at time t indicates with the sort of inputs we feed to the system, we can expect to produce outputs reflecting the condition of the system. With better the inputs, (eg. better labour quantity, more efficient management) we can expect more

outputs.

This approach assumes that the time lag between input and output measurement is sufficiently small for any one input-output measurement. In practice, it implies that the method is sufficiently accurate to measure the inputs and outputs as far as the data available. In most cases, this time lag assumption should not induce large error, because either on cross sectional or time series comparison, these errors cancel each other.

In our 'engine model', there are basically 4 types of inputs which keep the 'engine' alive. The material resources needs no explanation for its role in any production process. In fact what we have as our outputs are the 'converted form' of our inputs. Obviously for any single conversion process (as level 2) this output is less than the material inputs. There will be material waste to some degree due to process inefficiency. In a higher level, we have some of the material waste of process A used as the inputs to process B. At national level, this input-output system is shown in figure 4.11 (page 232).

4.6. The Economic Efficiency Vectors

As mentioned earlier it is not possible at present to measure the ratio of outputs to inputs in term of thermodynamic exclusively. For this reason a hybrid efficiency - economic productivity model is constructed instead of purely engineering efficiency model. This model is derived from engineering principle while for the actual computation accounting ratios are used to overcome data limitation mentioned earlier. This method requires a reference (basis) to which the value is comparable. Thus a productivity figure of $100 per labour force per annum of country A means nothing unless a reference productivity of, say country B, or productivity at different time is known. This method does not determine the absolute level of operating efficiency. At this preliminary stage however, it would be sufficient to prove the basis hypothesis of efficiency - technology relationship.

Briefly the Productivity can be defined as:

1. Labour Economic Productivity (LEP):

$$P_{L(x)} = \frac{Q_x}{L_x} \qquad (4.9)$$

where Q_x = Output (unit = $)

L_x = Labour input (unit = persons)

2. Energy Economic Productivity (EEP):

$$P_{E(x)} = \frac{Q_x}{E_x} \qquad (4.10)$$

where E_x = Energy input (unit = TCE)

3. Material Resources Productivity (MEP):

$$P_{M(x)} = \frac{Q_x}{M_x} \qquad (4.11)$$

where M_x = Material input (unit = $)

Capital can be thought as some commulative investments over the productive life of the asset. At national level, it is difficult if not impossible to evaluate the value of capital stock (Solow, 19). The matter is made worse by the fact that this capital stock may appreciate and depreciate with time. At the moment there is no universally acceptable way of estimating the depreciation of these stock. Although investment data is available, without the knowledge of total asset and how they depreciate or appreciate, they are more or less useless for our purpose.

In our efficiency concept, capital is in fact the usable asset. This asset must already exist before any process conversion can be carried out. It is therefore not appropriate to include capital efficiency as part or component of the total operational efficiency.

These measure of productivity without any comparative basis is meaningless. In order to know how productive a country is, a index comparison is constructed. They are described as:

Index of Labour Economic Efficiency (ILEE)

$$I_{L(x)} = \frac{P_{L(x)}}{P_{L(r)}} \qquad (4.12)$$

where $P_{L(x)}$ = Labour Economic Productivity of country x

$P_{L(r)}$ = Labour Economic Efficiency of Reference country r.

Index of Energy Economic Efficiency (IEEE)

$$I_{E(x)} = \frac{P_{E(x)}}{P_{E(r)}} \qquad (4.13)$$

where $P_{E(r)}$ = Energy Economic Productivity of Reference country r.

Index of Material Resources Economic Efficiency (IMEE)

$$I_{M(x)} = \frac{P_{M(x)}}{P_{M(r)}} \qquad (4.14)$$

where $P_{M(r)}$ = Material Resources Economic Productivity of Reference country r.

Material waste at level two upwards can be either reprocessed or thrown away some of which in the form of pollution. The processed material waste consumes both labour and external energy. The non processed material waste for one conversion process may be used as other inputs. It is therefore sufficient and reasonable to assume that the efficiency of material utilisation is reflected and absorbed in energy and

labour efficiency. The exact total amount of material waste at national level in this preliminary investigation is not going to be estimated.

The measure of Energy and Labour Economic Efficiency can be thought in term of independent vectors. Its independency does not however imply that labour is not convertible or related to energy. These independent efficiency vectors indicate that they are derived from two seperate independent origin. Energy such as electricity, coal may be thought as originated from external sources. We can reduce our efficiency model into two dimensions, namely Energy and Labour Efficiency. The Overall Economic Efficiency Vector (OEE) is given by:

$$\bar{I}_{o(x)} = \bar{I}_{L(x)} + \bar{I}_{E(x)} \qquad (4.15)$$

We can represent the above equation in term of vector. In two dimensional it can be represented as figure 4.15 (page 249).

The scalar value of Overall Economic Efficiency is

$$D_x = I_{o(x)} = (I^2_{L(x)} + I^2_{E(x)})^{1/2} \qquad (4.16)$$

For time series measurement we can include the time dimension on the equation, thus the above equation becomes:

$$D_{x(t)} = (I^2_{L(x(t))} + I^2_{E(x(t))})^{1/2} \qquad (4.17)$$

The difference between one efficiency level to another can be defined as Relative Economic Efficiency Distance (REED). Thus

the difference in efficiency at time (t+1) to one at time (t) is given by:

$$dD_{x(t)} = \frac{D_{x(t+1)} - D_{x(t)}}{D_{x(t)}} \qquad (4.18)$$

The Relative Economic Efficiency Distance (REED) can be interpreted as the difference in the relative overall efficiency at different time. If our **Overall Economic Efficiency vector is a representation of the state of technology then REED represents the change of the state of technology through time.**

If we take an Overall Economic Efficiency at year (t) as a reference value (equal to 100 percent), we can relate all Relative Economic Efficiency Distance (REED) in term of this reference value. The unit of this standardised Overall Economic Efficiency therefore is constant. The time series relationship can be described as figure 4.16 (page 249). In term of the Efficiency components, these values are described as figure 4.17 (page 249).

The analogy of 'process conversion efficiency' to any physical efficiency implies that it must have a similar behaviour. Earlier we know that generally efficiency tends to improve with time (shown in example of steam engine, as figure 4.6, page 220). Theoretically therefore the direction of overall process conversion efficiency must be towards maximum state (point furthest from the origin).

figure 4.15
Overall Economic Efficiency Vector

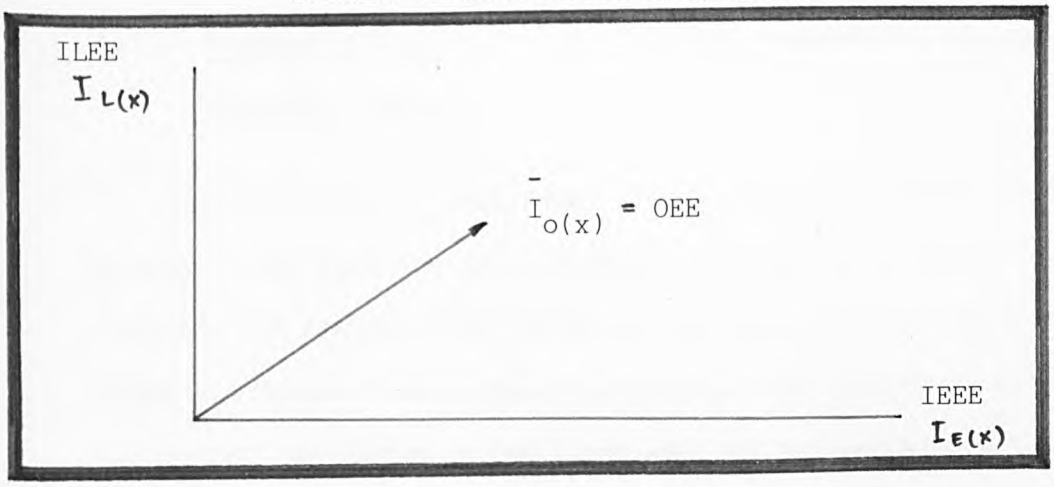


figure 4.16
Time Series of OEE

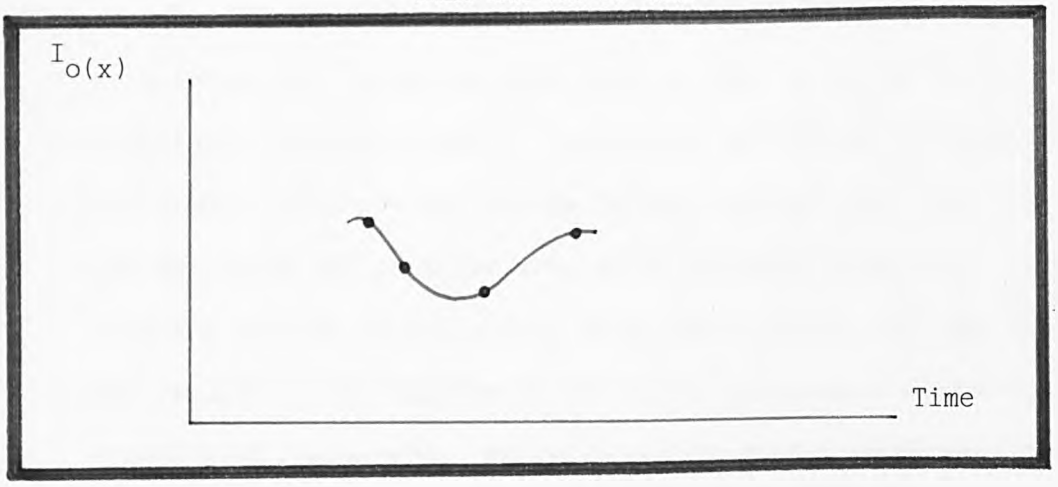
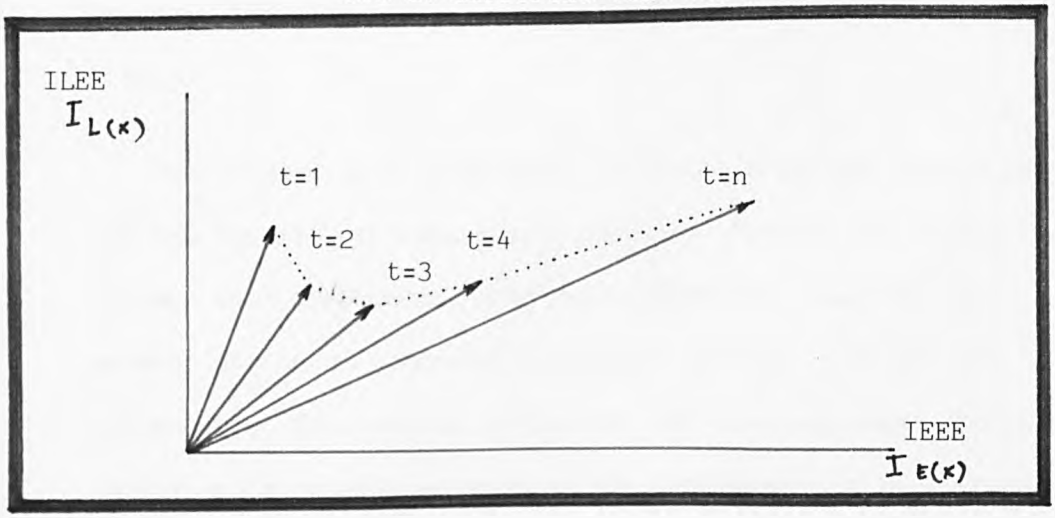


figure 4.17
OEE at different time bench



4.7 Operational and Application of National Engine Model

4.7.1. Process Efficiency' Rate of Change compared to Economist's Technical Change

Solow (19) in his well acknowledged research used a 'Cobb-Douglas' type function which contained capital and labour factors. In his research, he found the rate of technological change in United States industry between 1909 to 1949 to be equal 1.2 percent per annum in the first half of the period and 1.9 percent in the second half.

In this section we test the validity of Efficiency model 4.18 (page 252) using the same data as used by Solow in his experiment (United States). Instead of using Capital as one of the production function, we use energy consumption. The rest of the variables are kept the same as in Solow's experiment. These data are applied on efficiency model (equation 4.17, page 247). The results of the experiment and Solow' finding are compared in figure 4.18 (page 252). The slope of each line represents the rate of technological change (Solow) and the rate Overall Economic Efficiency change as indicated by the model in equation 4.18.

The figure 4.18 (page 252) indicates that the trends of the two results are remarkably similar. In fact we obtain the average Rate of Economic Efficiency Distance equal to 1.62 percent per annum (compared to Solow' average 1.55 percent per annum). This result indicates that the engineer' efficiency indicator is equally as good as the indicators of technological

change used by the economists. This result also confirms that for the industrialised countries, the capital and the energy consumption indicators have similar nature.

The advantage of this model over the economist's model however is that it measures efficiency conversion in term of true energy content rather than monetary value, which can be interpreted as the technological capability itself.

4.7.2. Rate of Efficiency Change for UK, USA and Sweden

The applications of Overall Economic Efficiency (OEE) vector on UK, USA and Sweden data are shown on figure 4.19, 4.21, 4.23 (page 255, 257, and 259). The rate of change of OEE are:

Countries	Rate of change of OEE between 1922 - 1977
UK	1.09 percent
USA	1.70 percent
Sweden	2.00 percent

These figures represent the growth of the input - output efficiency conversion. It is noted that OEE is a relative measure equivalent to the level of technology used to drive the system relative to technology at certain time bench. Thus its value does not represent the absolute level of technology. As the Socio-Techno-Economic system under this study is not a purely physical system (it involves values, welfare, and many other non physical factors), the formulation of absolute efficiency concept

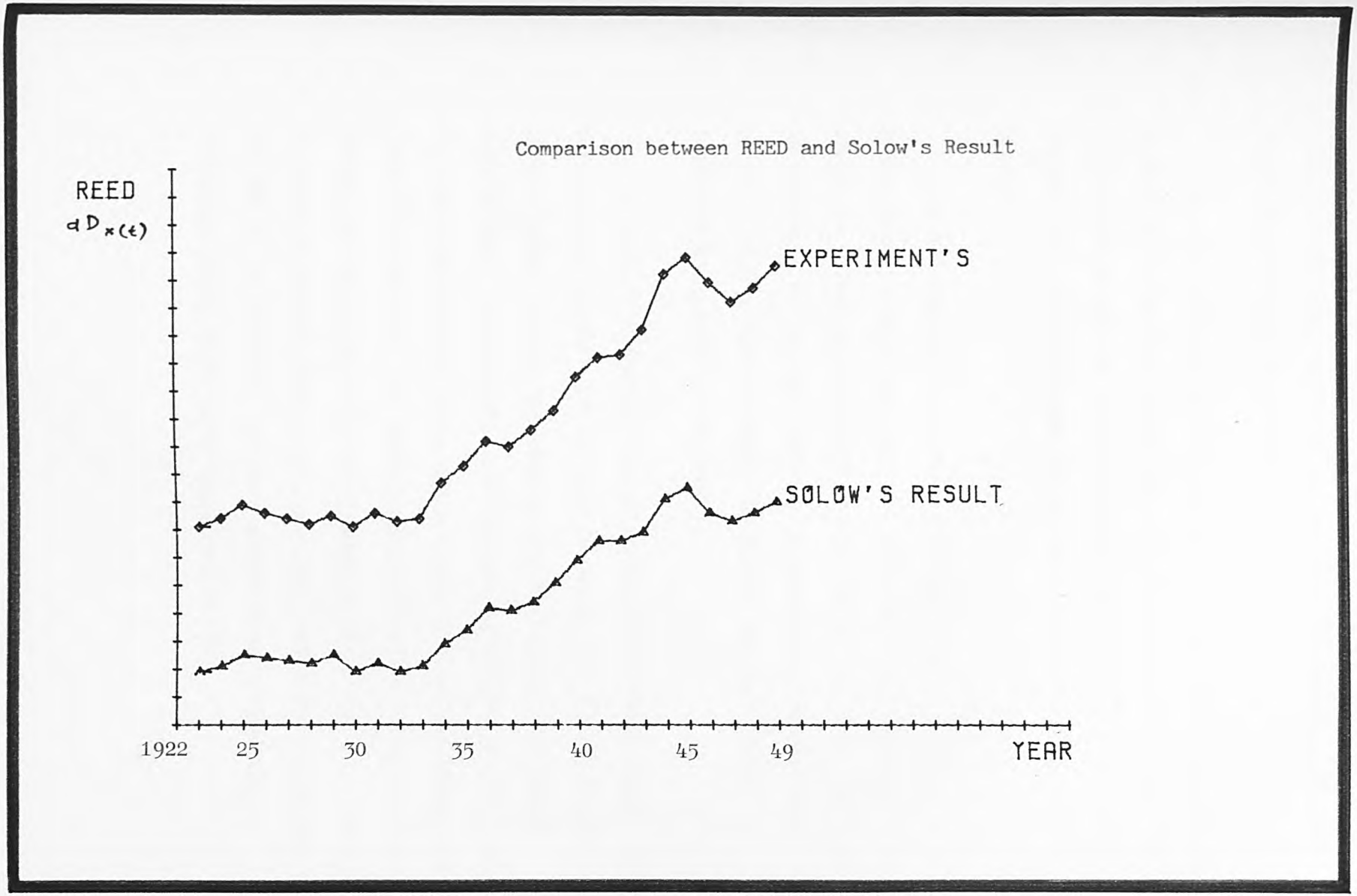

Comparison between REED and Solow's Result
REED
$dD_{x(t)}$
EXPERIMENT'S
SOLOW'S RESULT
1922
25
30
35
40
45
49
YEAR

Figure 4.18

needs further exploration of the efficiency concept. This is beyond the scope of this thesis.

In this section, we are able to show the inter-relationship between Efficiency of Labour use and Energy use with time. In a closed system such as Socio-Techno-Economic of a nation, this measure is a good indicator of the efficiency of the system itself.

One interesting observation of these results is that there seems to be a significant jump of efficiency just before second world war. This is particularly true for UK and USA. This may be explained by the fact that war preparation required extra output. With a limited amount of inputs, the efficiency therefore was pushed to increase.

In term of Energy and Labour Efficiencies these changes are reflected as figure 4.20, 4.22, 4.24 (page 256, 258, and 260). These figures explain the general trend of Labour and Energy utilisation. These results are interesting because we can study its trend and observe how a country mixes the use of energy and labour utilisation. The process of substitution between external energy and labour force is highlighted in these figures. Sweden is shown to produce more output per unit labour force compared to USA and United Kingdom. United Kingdom is the least labour productive among these three countries at 1977.

4.8. Population data used to estimate Labour Economic Efficiency

As described earlier one component of Overall Economic Efficiency is Labour Economic Efficiency. One major practical drawback with this method is in term of historical statistic available. Most under developing countries did not usually have accurate statistics of the total labour force, although census were taken in every ten of five years. For this reason it may be desirable to find an alternative indicator which is practical and readily available. The use of indexing method as described in equation 4.12 (page 245) proves that the number of labour productivity can be estimated by population data. The error involved in this estimation is given by:

Error of estimation =

$$\left(\left(\frac{Q_{(t)}}{P_{(t)}}\right) / \left(\frac{Q_{(r)}}{P_{(r)}}\right)\right) / \left(\left(\frac{Q_{(t)}}{L_{(t)}}\right) / \left(\frac{Q_{(r)}}{L_{(r)}}\right)\right) - 1 \qquad (4.19)$$

where $Q_{(r),(t)}$ = output at reference time (r) and (t) respectively

$L_{(r),(t)}$ = Labour force at reference time (r) and (t) respectively

$P_{(r),(t)}$ = Population at reference time (r) and (t) respectively

The application of this estimates to United Kingdom data between 1966-77 is described in figure 4.25 (page 263). As it can be seen the average error accumulated by replacing labour force index to total population is relatively small (around 1

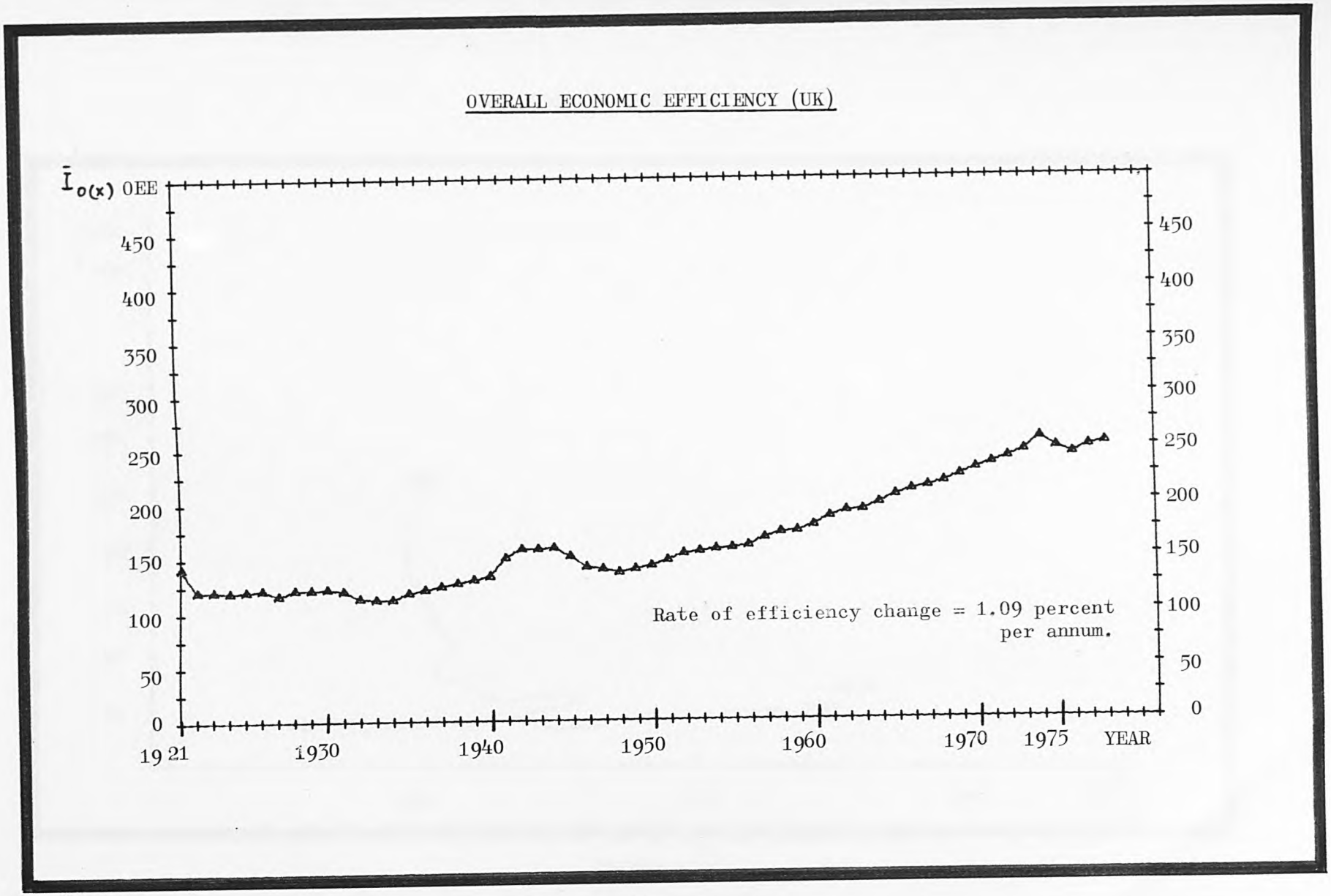

OVERALL ECONOMIC EFFICIENCY (UK)
$\bar{I}_{o(x)}$ OEE
450
400
350
300
250
200
150
100
50
0
19 21
1930
1940
1950
1960
1970
1975
YEAR
Rate of efficiency change = 1.09 percent per annum.

Figure 4.19

EFFICIENCY INDEX (UK)

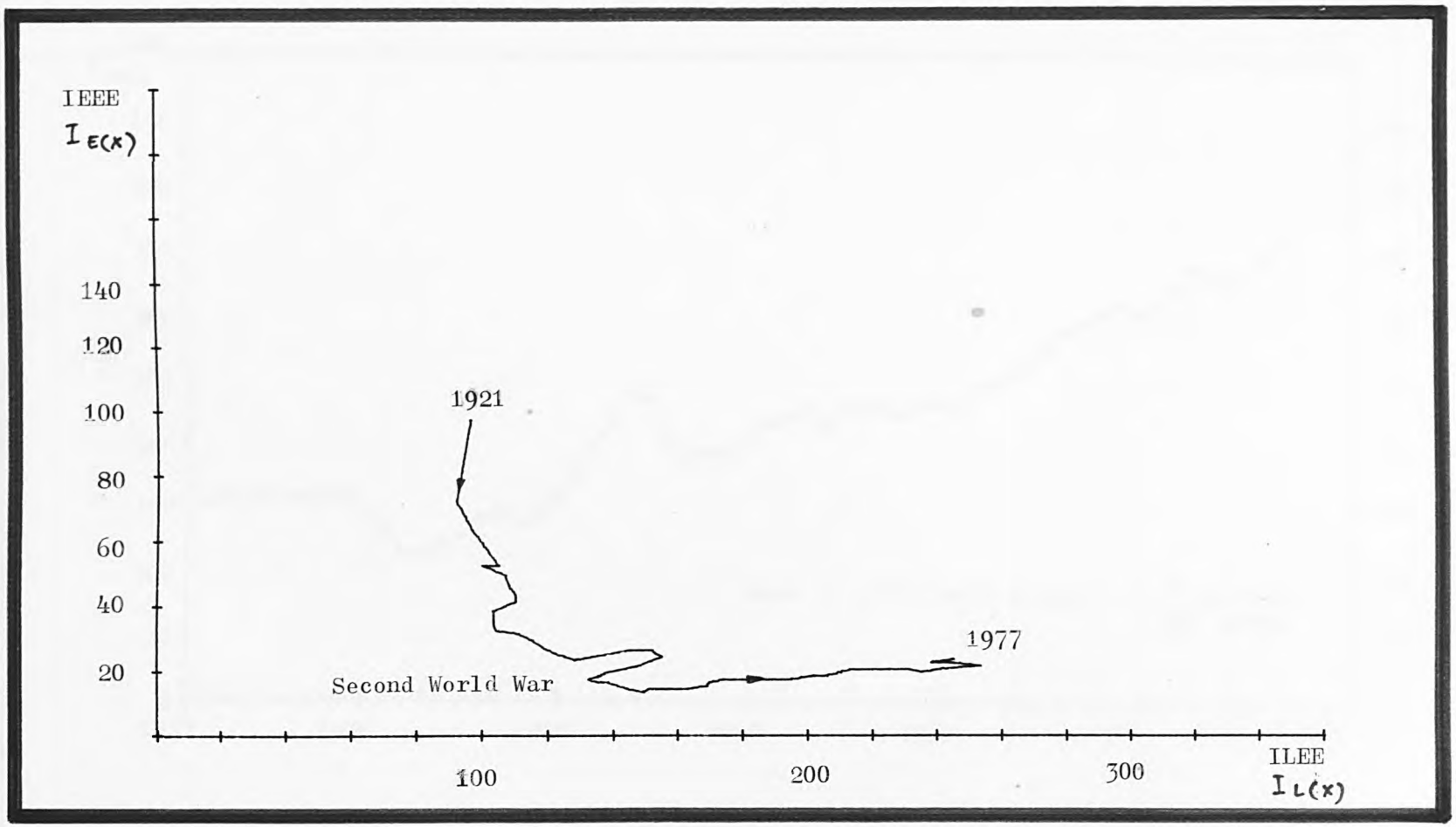


Figure 4.20

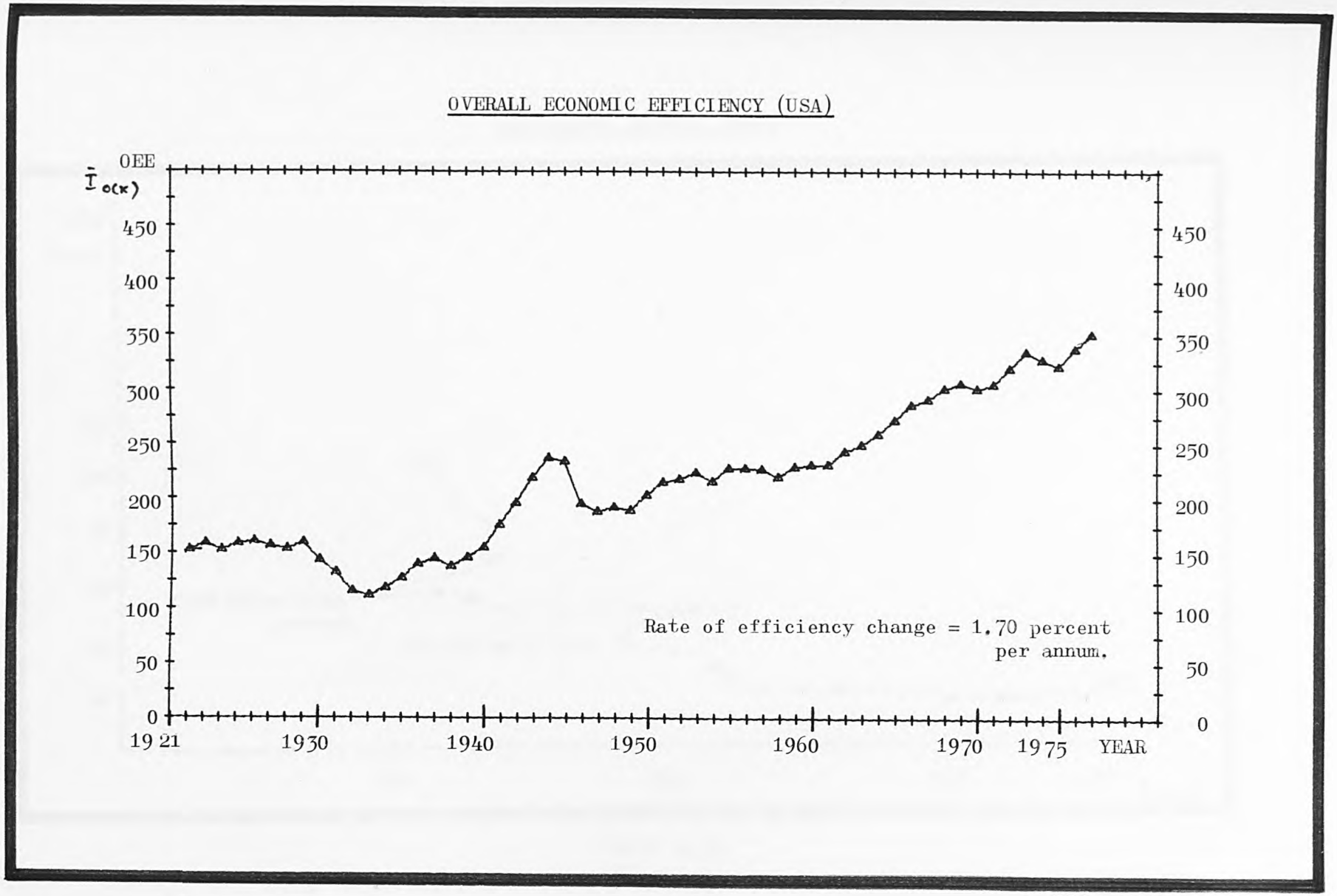

OVERALL ECONOMIC EFFICIENCY (USA)
OEE
$\tilde{I}_{o(x)}$
450
400
350
300
250
200
150
100
50
0
1921
1930
1940
1950
1960
1970
1975
YEAR
Rate of efficiency change = 1.70 percent per annum.

Figure 4.21

EFFICIENCY INDEX (USA)

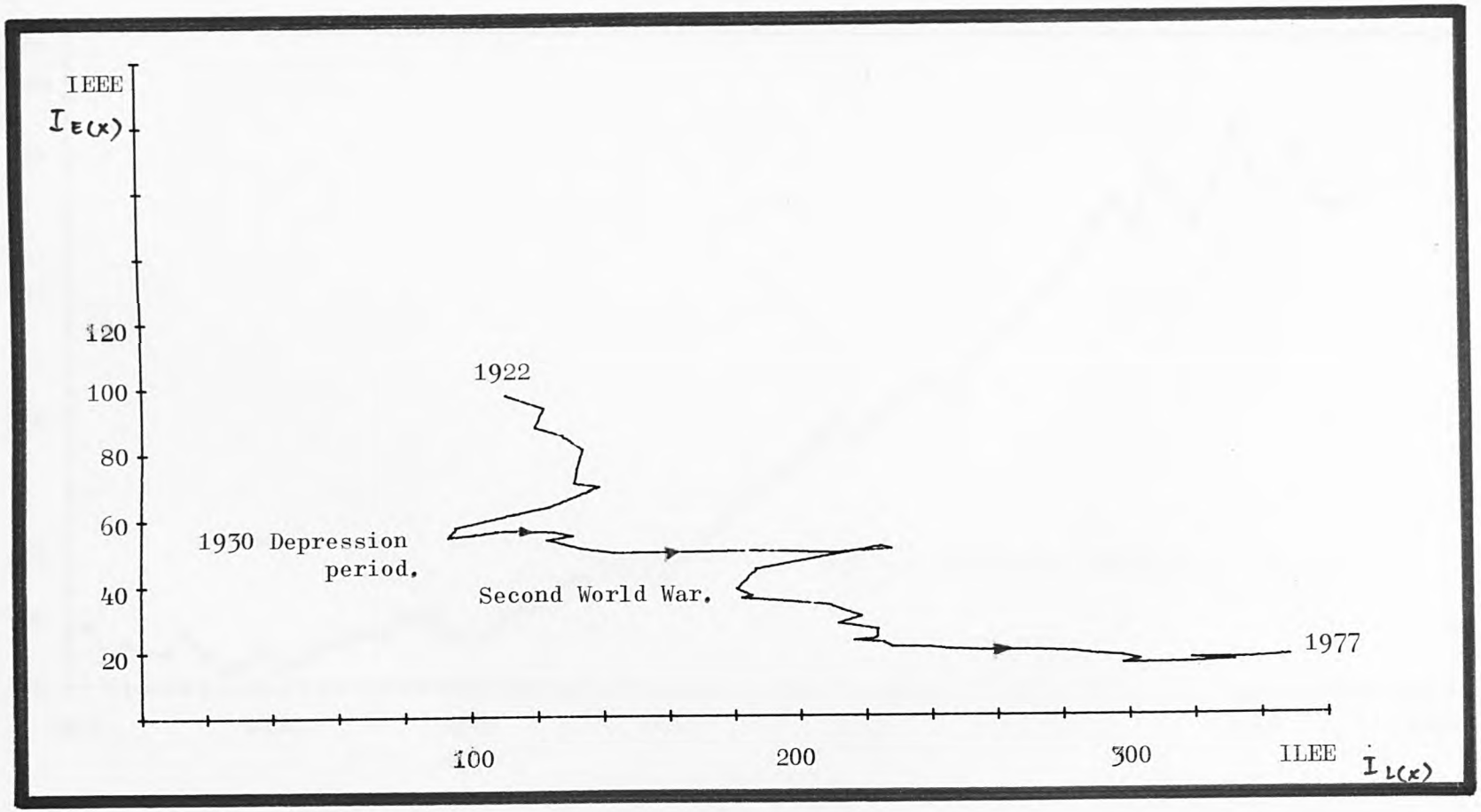


Figure 4.22

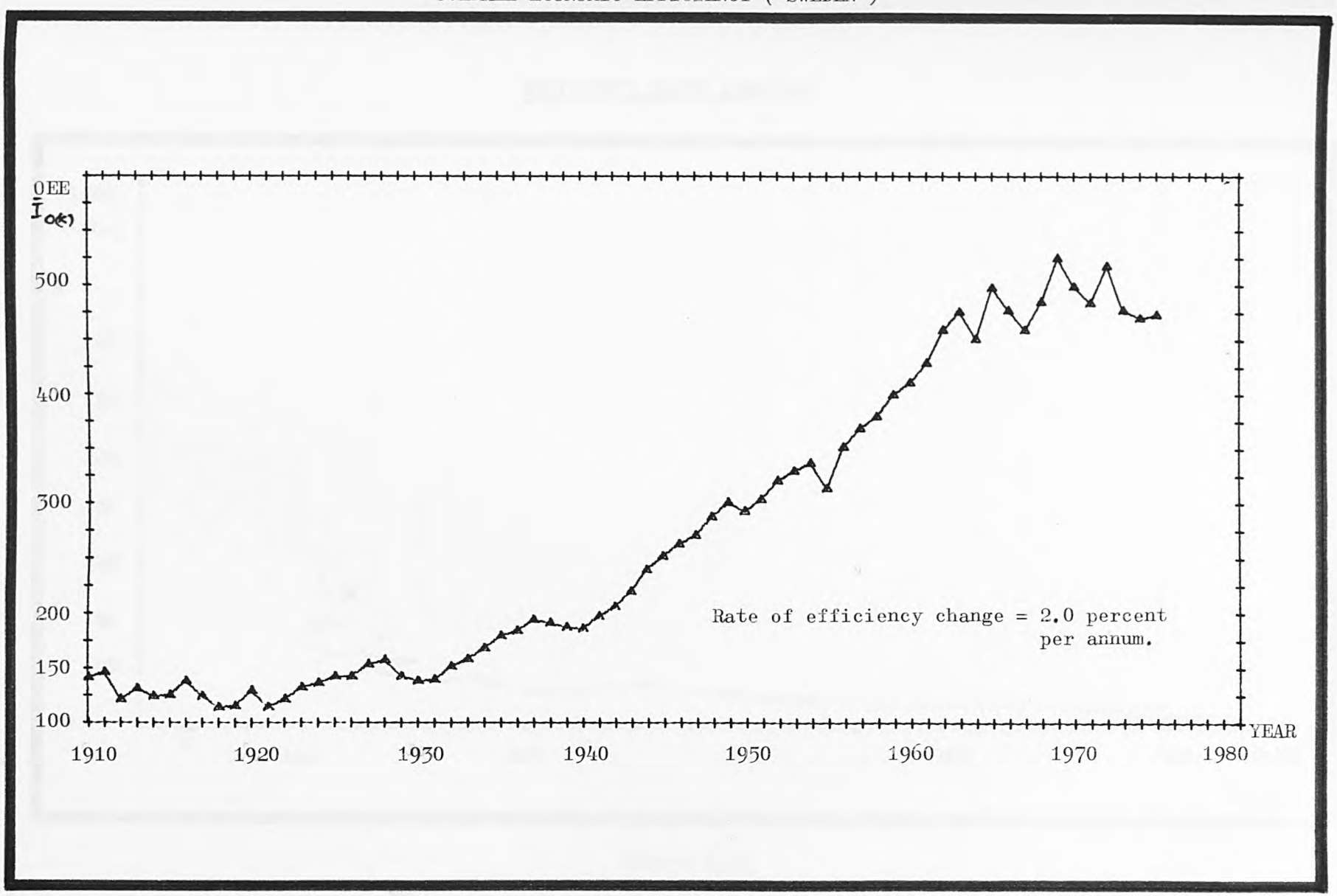

OVERALL ECONOMIC EFFICIENCY (SWEDEN)
OEE
$\bar{I}_{O(t)}$
500
400
300
200
150
100
1910
1920
1930
1940
1950
1960
1970
1980
YEAR
Rate of efficiency change = 2.0 percent
per annum.

Figure 4.23

EFFICIENCY INDEX (SWEDEN)

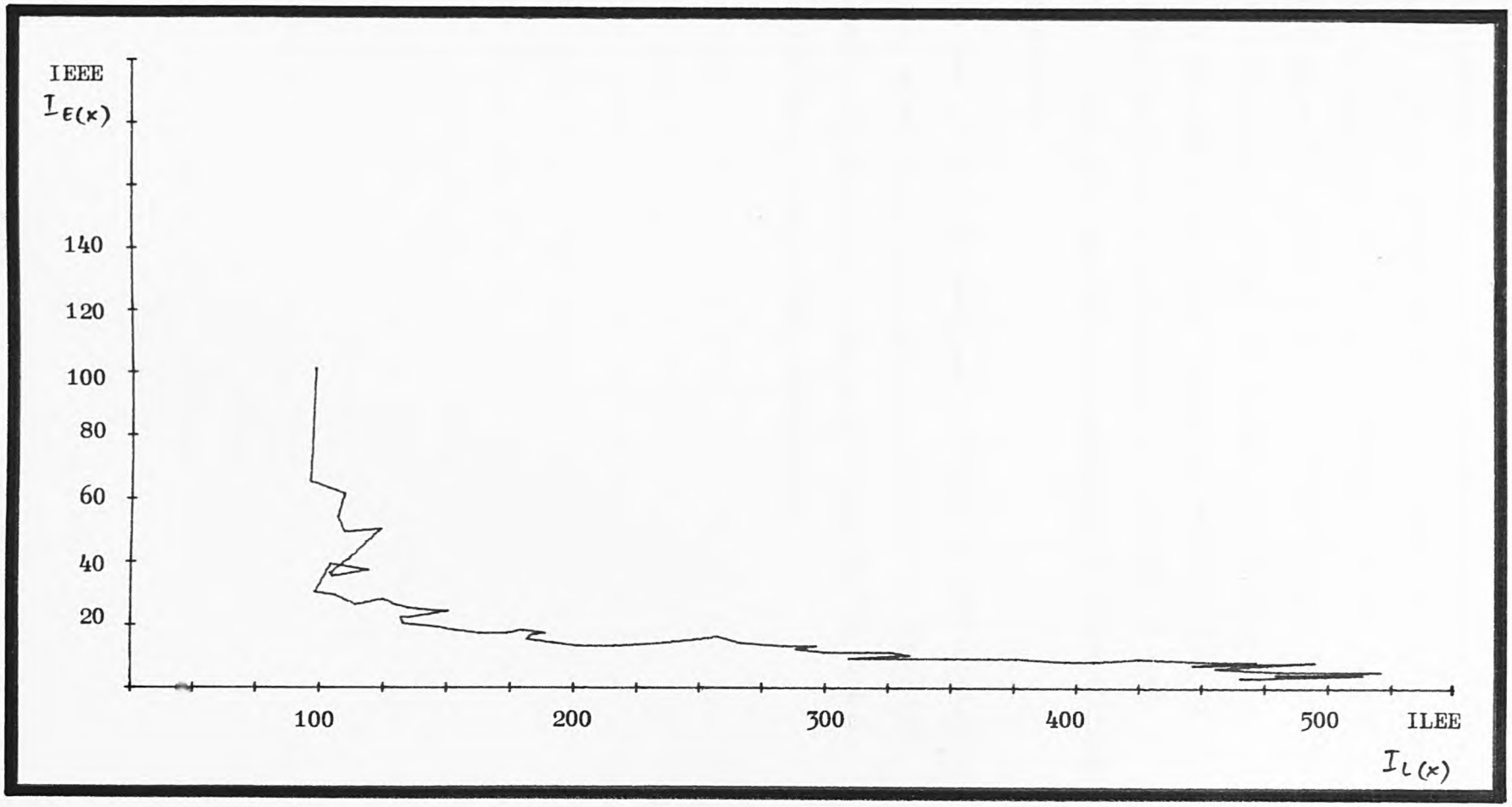


Figure 4.24

percent maximum at any time). The average of rate of efficiency change is a moving average estimate. Therefore the overall error average is also equal to its moving average. In the case of United Kingdom it is equal to be 0.44 percent. Suppose of the rate of technological change the average rate is around 1 percent, the size of the error induced by using alternative indicators therefore is (0.44 percent x 1 percent = 0.0044 percent). This error therefore is considered as relatively small to our purpose.

In some of the less developed countries or even developing countries where labour force data are difficult to obtain and unreliable, the population estimate with some distribution correction factor is a suitable alternative.

4.9. Discussion

The application of hybrid model of Engineering-Economic Efficiency was shown to produce similar result as the economist's approach. This is considered as one step foreward in bringing physical law to the economic system. Ideally, given that we could provide all data inputs and measure all outputs (in the form of energy value), the concept of engineering efficiency should work equally well in the economic system.

The concept of pure engineering efficiency (using energy input-output) is complicated enough even measured for systems at level 1 (individual system). The application of this concept at level 4 (national level) must therefore require a 'fair' amount of ground work before it becomes a practical tool. However as this is a physical concept with physical variables, therefore it has a definite advantage that its behaviour can be predicted controlled according to physical laws. In contrast the economic concepts are subjected to many weak assumptions many of which are misleading or needs to be tested. To this effect the engineers have so far prove themselves more successful in comparison to the economists in general. Ultimately the principle of physical law in the economic system must be one of the most important the tools that we can rely for the management of the economic system. This hybrid model is practical while more ground research on the area of energy study is being carried out.

ERROR IN USING POPULATION AS LABOUR FORCE INDEX

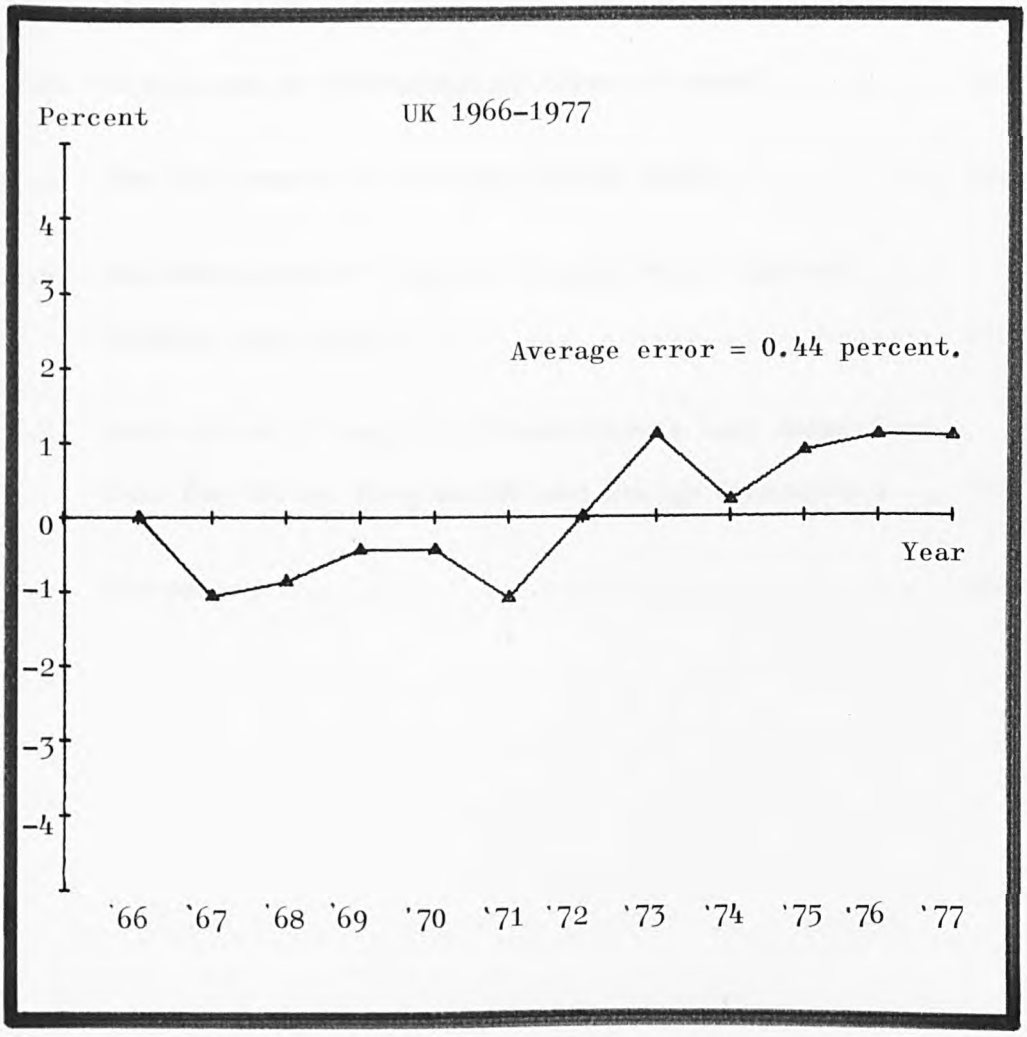


Figure 4.25

CHAPTER 5

The Logistic Growth of Techno Economic Development

5.1. Introduction..... 264

5.2. Objectives Of Technological Forecast Model..... 265

5.3. The Performance of Process Engine Model..... 266

5.4. Implementation of Logistic Growth Model (United Kingdom case study)..... 275

5.5. Application of Logistic Growth Model: Long Range Forecast for United Kingdom GNP and Energy Consumption.... 277

5.6. Discussion..... 288

CHAPTER 5

THE LOGISTIC GROWTH OF TECHNO ECONOMIC DEVELOPMENT

5.1. Introduction

In this chapter the Alpha and Gamma (chapter 3.5 and 3.6) are combined to produce a 'Performance Model' which represents the logistic growth of techno-economic development. The function of this model is equivalent to the performance measure of ordinary engine (such as speed, horsepower, etc.). This performance model is based on a time series model which opens up the possibility of constructing a time dependent forecast model.

The relationship between this model and the Economic Efficiency Vector expected to produce high correlations between Engineering - Economist' based Performance model and the combination of Technology (Alpha) and Resources (Gamma). It is shown that the result is both important and interesting, for example any country with low level of resources is possible to perform well well as long as it possesses high level of Technology (eg. Japan). On the other hand the combination of low level of Technology and high level of Resources (Gamma) should also produce high performance (OPEC's).

A case study based on this model for United Kingdom is looked at on this chapter, the result of which is a long term forecast of both GNP and Energy consumption growth based on logistic Technological growth. A back forecast is also conducted to substantiate the validity of this model.

5.2. Objectives of The Logistic Growth Model

The objectives of constructing this model are as follows;

1. To bring together the results of two different approachs: (a) factor reduction method (chapter 2 and 3), and (b) the 'national engine model' into an operational tool.

2. To build a simple technological forecast model by which the relationship between economic performance and technology can be measured. This relationship should permit a more accurate quantitative planning and technological forecasting.

3. To determine the behaviour of technology with respect to the stages of economic development. The model is expected to reflect the growth pattern of any individual country. This growth pattern will then be useful for determining the time and technology lag between any two countries or country groups.

4. The relationship between the technology and the level of economic performance can be used to determine the level of energy utilization and consumption. This model therefore also serves in two folds. Apart from overall technological forecasting it is also useful for long term energy planning.

5.3. The Performance of Process Conversion Model

Using the converted time indices of Alpha and Gamma (chapter 3.5 and 3.6) it is now possible to find the relationship between Process Efficiency Conversion of the 'engine' and the level of technology and resources utilisation. We define this relationship in the form of output or performance characteristics as described in equation 3.2 (page 184);

$$P_C = f (A, G; t) \qquad (5.1)$$

where P_C = Performance

A = Alpha

G = Gamma

t = time

It is noted that this equation is based on generally used Economist' production function with two new variables obtained from the reduction method. The simplest choice for this function is a linear one. It can be described as:

$$P_C = a + b (A) + c (G) \qquad (5.2)$$

Looking at from different angle, we can also use the well proven Thermodynamic theory to substantiate this model. From the Thermodynamic and Engineering Principle (chapter 4.2), performance (output) can also be defined as the product of inputs and conversion efficiency. The combination of this principle and equation 4.15 (page 247) yields;

$$P_C = f ((OEE), E; t) \qquad (5.3)$$

where P_C = Performance

OEE = Overall Economic Efficiency

E = Energy input

t = time

Applying equations 4.15 and 4.16 (page 247) to all samples between 1960 to 1977, we obtain the performance based on the equation 5.3 above directly for each individual country.

Theoretically equations 5.1 and 5.3 are identical, although one is based on the economic factors of production and the other is based purely on engineering principle. To prove it a test was constructed to show the validity of this relationship. Table 5.1 (page 269) convincingly shows that very high correlations between Performance (obtained by the Engineering method (OEE)) and the combination of Alpha and Gamma do exist. It must be noted that some countries such as Madagascar, Uganda, Yemen, Haiti, show low correlations. It may be due to poor statistical quality available, however as these are minority cases, the relationship therefore is valid. The Performance based on OEE were computed from;

$$P_C = (OEE)\ (\ E_x\ (t))\ /\ (\ E_{usa}\ ) \qquad (5.4)$$

where P_C = Performance percapita

OEE = Overall Economic Efficiency

E_x (t)= percapita Energy consumption of country x

E_{usa} = USA per capita energy consumption

(Reference time bench is year (t) = 1960)

The high correlations as shown in table 5.1 (page 269) also confirms the nature of the Economic Performance as a function of utilization of both Technology (Alpha) and Resources (Gamma) as well as the level of conversion efficiency. The implication of this equation however does not mean that abundant reserve of resources will guarantee national economic growth. Rather the actual utilization of these resources is the more significant factor. The Resources factor (Gamma) obtained from the reduction method in fact accounts for the utilisation of the resources (eg. export of energy) rather than measuring the actual reserves itself.

Another important deduction of this finding is that one of the major sources of economic growth seems to be either the technology itself or the utilisation of resources. Any country with little resources can only produce significantly high output if only it has sufficiently high technology (eg. Japan). While less technologically developed countries with high resources utilization are also expected to perform well (eg. Oil Producing countries). On this basis the sources of growth seem to be either through more resources utilization, better technology used or the combination of both. Since better technology also means higher resources conversion efficiency, and resources are limited and scarce, therefore it is only logical if the main socio-techno-economic growth path available is through better technology utilization.

The relationship between the Performance and GNP per capita it self is predictably near to unity. This is demonstrated by the results obtained in table 5.2 (page 271).

table 5.1: **Performance Characteristic Model**

Model P_c = a + b (Alpha) + c (Gamma)

No.	Countries	Corr. coef.	a	b	c
1.	Benin	.9398	4.2589	.2290	-.6176
2.	Burundi	.9651	-.3386	.1853	.9056
3.	Cent. African Rep	.8233	4.8262	1.2088	-1.5068
4.	Chad	.8230	3.8721	-.3476	-.4146
5.	Ethiopia	.9395	.0755	-.2600	.9203
6.	Ghana	.6773	7.8030	-1.3064	1.0309
7.	Guinea	.9971	-4.2326	-1.8186	3.9663
8.	Ivory Coast	.9908	-9.5637	-2.9067	9.9089
9.	Kenya	.8598	-3.6868	3.3517	-.1117
10.	Madagascar	.0779	5.2484	.1698	-.7571
11.	Malawi	.9913	.6253	1.0880	-.1987
12.	Mali	.9015	-1.9120	.0659	1.5771
13.	Mozambique	.9771	7.0152	-12.1080	10.7635
14.	Niger	.9844	7.6646	.1638	-2.2105
15.	Nigeria	.9978	-.7640	3.3574	.3882
16.	Rwanda	.9905	-9.0268	-1.1745	5.8879
17.	Senegal	.6210	-22.8060	-1.1641	18.7005
18.	Sierra Leone	.9863	-9.9100	-4.0782	7.4918
19.	Somalia	.7370	9.1376	1.4255	-3.9530
20.	South Africa	.9864	13.0314	22.3194	-24.7660
21.	Sudan	.9999	7.8983	4.3461	-4.5389
22.	Tanzania	.9901	2.7637	1.7709	-1.4643
23.	Uganda	.4978	.2235	-1.3161	3.1571
24.	Upper Volta	.7624	10.0771	1.7387	-4.7186
25.	Zaire	.8961	2.2628	-.7791	.3838
26.	Zambia	.9956	11.6862	1.6507	-2.1416
27.	Algeria	.9858	-7.0507	3.8321	4.3154
28.	Egypt	.9520	-3.7533	1.8152	1.2031
29.	Iran	.9973	3.7084	16.5396	-6.0811
30.	Iraq	.8983	-12.1390	5.6082	5.3406
31.	Morroco	.9918	-2.9641	3.9217	.3686
32.	Syrian Arab Rep	.9504	-14.7320	10.8924	-1.5179
33.	Tunisia	.9776	-21.0410	3.1443	8.0479
34.	Yemen Arab Rep	.2903	-6.6319	1.9848	3.0619
35.	Hongkong	.9806	-11.0340	23.2255	-21.0750
36.	Indonesia	.8282	-2.0111	1.0019	1.3959
37.	Korea	.9691	-16.8530	4.0612	6.1123
38.	Malaysia	.9101	-6.6610	7.1926	-1.7392
39.	Papua New Guinea	.9705	-5.0536	2.4002	2.4484
40.	Philippines	.9779	-.2170	3.3425	-.9398
41.	Singapore	.9654	-58.1800	48.7716	-40.6940
42.	Taiwan	.9139	-26.6350	2.4969	13.1796
43.	Thailand	.9892	-5.3154	5.1868	-1.2018
44.	Afghanistan	.6069	2.3220	.4826	-.0838
45.	Bangladesh	.9113	.8644	9.0836	.2932
46.	Burma	.6940	.8083	.3137	.3048
47.	India	.9786	1.4743	.6519	-.2095
48.	Nepal	.9997	1.0398	.0733	.3525
49.	Pakistan	.8712	-1.2431	.2871	1.4499
50.	Sri Lanka	.9577	.6608	-.2057	1.3636

table 5.1: **Performance Characteristic Model (continued)**

No.	Countries	Corr. coef.	a	b	c
51.	Argentina	.9980	-5.0133	4.1691	5.6087
52.	Bolivia	.9861	-1.8981	1.0991	2.2369
53.	Brazil	.9481	-50.6580	4.3505	20.7342
54.	Chile	.9051	65.4715	4.7826	-22.9520
55.	Colombia	.9727	-15.0560	.1077	9.6827
56.	Dominican Republic	.9743	44.7498	17.8846	-35.0490
57.	Ecuador	.9718	-90.6730	1.0702	44.0966
58.	El Salvador	.9261	-6.6251	1.0609	5.4955
59.	Guatemala	.9995	17.8705	7.4154	-11.2080
60.	Haiti	.1030	2.5152	-.0438	.5109
61.	Honduras	.8930	8.3999	1.4214	-1.9205
62.	Mexico	.9858	-10.4400	3.6824	5.7222
63.	Nicaragua	.9258	-29.0420	1.1022	16.2007
64.	Paraguay	.9744	42.0615	8.3451	-30.8900
65.	Peru	.9409	-4.2222	1.1738	4.5888
66.	Uruguay	.8830	26.4410	7.0799	-17.9090
67.	Venezuela	.9985	-28.2340	2.9415	19.4681
68.	Greece	.9504	-79.3050	13.8265	24.2634
69.	Israel	.9830	-61.4150	9.3687	22.9754
70.	Portugal	.9909	-135.6600	-3.1043	70.4856
71.	Spain	.9999	-82.6490	20.6153	12.2575
72.	Turkey	.9734	-32.4230	1.3145	17.4552
73.	Yugoslavia	.9939	-62.9260	6.3003	24.1660
74.	Kuwait	.9091	-1662.7000	-69.1410	541.9760
75.	Saudi Arabia	.9637	-89.1880	36.3630	16.1214
76.	Australia	.9984	-122.2300	15.3993	68.9895
77.	Austria	.9983	-139.2300	30.1001	29.2534
78.	Belgium	.9847	-113.9200	79.5423	-63.5330
79.	Canada	.9999	-230.9800	52.8860	46.1635
80.	Denmark	.9928	-173.3500	18.9486	84.5965
81.	Finland	.9999	-248.2200	8.1873	122.8320
82.	France	.9835	-269.5500	34.2366	80.5422
83.	West Germany	.9912	-56.9340	52.4935	-30.1780
84.	Ireland	.9685	-44.9070	8.3651	20.7859
85.	Italy	.9789	-76.3380	10.7793	27.6488
86.	Japan	.9842	-331.3100	26.5882	111.9370
87.	Netherland	.9952	-142.9100	41.7442	15.1226
88.	New Zealand	.9561	-35.7430	15.6614	13.2468
89.	Norway	.9912	-274.2200	26.6649	98.6299
90.	Sweden	.9477	290.5040	100.5520	-262.2000
91.	Switzerland	.8526	-70.5680	-29.1770	149.1810
92.	U.K.	.9882	-21.6480	25.9659	-12.8810
93.	U.S.A.	.9541	182.1120	114.4640	-264.3800
94.	China	.9974	-26.3410	-3.1953	13.6017
95.	Chechoslovakia	.9935	-106.2100	23.0120	19.8569
96.	East Germany	.9629	-193.5900	20.9594	57.3159
97.	Hungary	.9472	-69.5280	8.9824	22.2638
98.	Poland	.9950	28.7821	50.0677	-74.1090
99.	Romania	.9309	-68.6290	2.3135	27.6117
100.	USSR	.9955	22.4116	58.7731	-79.4190

table 5.2

Correlation obtained from Performance of Process Conversion Model and percapita GNP

Year	GNP = a + b (P_c)		
	a	b	Corr. coef.
1960	70.365	50.650	0.989
1965	93.751	49.501	0.990
1970	144.880	46.603	0.987
1977	290.820	42.672	0.981

GNP = Gross National Product percapita

P_c = Performance of Process Conversion Model

a, b = constants

The independency property of factor Alpha and Gamma permits independent time series extrapolation of equation 3.4 and 3.5 (page 188, 189). The results show that independently they Alpha behave as exponential growth, while Gamma shows linear growth. As they are independent, we can extrapolate to obtain values of Alpha and Gamma for time t+n. This extrapolated values of Alpha and Gamma can then be substituted into equation 5.2 (page 266) to give performance equivalence for time period t+n. This value is then substituted into equation 5.4 to give the corresponding forecast of components of Overall Economic Efficiency such as percapita Energy Consumption and percapita GNP. The equation 5.4 becomes:

$$E_x\ (t)\ /\ E_{usa} = P_c\ (t)\ /\ (OEE\ (t)) \qquad (5.5)$$

Since the Overall Economic Efficiency (OEE) is directly dependent on the level of technology utilization (Alpha), we can define the relationship between Alpha and OEE as:

$$OEE\ (t+n)\ /\ OEE\ (t) = A\ (t+n)\ /\ A\ (t) \qquad (5.6)$$

where n = time constant.

Thus for any time (t+n) we can evaluate the Overall Economic Efficiency.

From equation 5.4 we have;

$$P_c\ (t) = (OEE\ (t))\ (E_x\ (t))\ /\ (E_{usa}) \qquad (5.7)$$

at t=t+n we have;

$$P_C\ (t+n) = (OEE\ (t+n))\ (E_X\ (t+n))\ /\ (E_{usa}) \qquad (5.8)$$

Dividing equation 5.8 to 5.7 we have;

$$P_C\ (t+n) = \frac{(OEE\ (t+n))\ (E_X\ (t+n))\ (P_C\ (t))}{(OEE\ (t))\ (E_X\ (t))} \qquad (5.9)$$

Substituting equation 5.6 into 5.9 we are left with soluble solution at t=t+n:

$$P_C\ (t+n) = \frac{(A\ (t+n))\ (E_X\ (t+n))\ (P_C\ (t)}{(A\ (t))\ (E_X\ (t))} \qquad (5.10)$$

The forecast value for energy consumption can the be obtained from:

$$E_X\ (t+n) = \frac{(P_C\ (t+n))\ (A\ (t))\ (E_X\ (t))}{(P_C\ (t))\ (A\ (t+n))} \qquad (5.11)$$

where $E_X\ (t+n)$ = Percapita energy consumption at t=t+n

From 5.5 we can then obtain OEE at t=t+n, then,

$$OEE\ (t+n) = (P_C\ (t+n))\ (E_{usa}\ )\ /\ (E_X\ (t+n)) \qquad (5.12)$$

but from equation 4.17, 4.12, and 4.13 we can evaluate

$$OEE^2\ (t+n) = \left(\frac{(Q_X\ (t+n))/(L_X\ (t+n)}{(Q_{usa}\ )/(L_{usa}\ )}\right)^2 + \left(\frac{(Q_X\ (t+n))/(E_X\ (t+n)}{(Q_{usa}\ )/(L_{usa}\ )}\right)^2 \qquad (5.13)$$

where $Q_X\ (t+n)$ = GNP per capita of country x at t =t+n

Q_{usa} = GNP per capita of USA taken as reference value

L_x (t+n) = Labour force of country x at t=t+n

L_{usa} = Labour force of USA taken as reference value

Equating equation 5.12 to 5.13 we can solve GNP per capita at t=t+n;

$$Q_x(t+n) = \left(\frac{(P_c(t+n))(E_{usa})(Q_{usa})}{E_x(t+n)}\right)\left(\left(\frac{L_{usa}}{L_x(t+n)}\right)^2 + \left(\frac{E_{usa}}{E_x(t+n)}\right)^2\right)^{-1/2} \quad (5.14)$$

The combination of equation 5.11 and 5.14 enables us to forecast the future GNP as well as Energy consumption per capita on the basis of the contribution of technology to the economic efficiency.

GNP and Energy forecasts based on this method is useful for long-term trend rather than the short term fluctuations. This is due to the nature of the basic model (Alpha and Gamma).

5.4. Impementation of Logistic Growth Model (United Kingdom case study)

Earlier, the population data were shown to be useful as a substitute indicator for labour force with relatively little errors involved. We need to have this substitution because most of the less developing countries (LDC's) do not have reliable statistics on the actual number of labour force. Similarly the proportion of labour force to the population has to be assumed to increase at the same rate as the overall population. The proportion of labour force for United Kingdom at 1950 was 46.13 percents and at 1960 was 46 percents. Yet to assume proportional increase of total population equal to the one of labour force implies errors although they are very small for countries with stable population distribution. Although this errors are relatively small, correction factors are needed to produce an accurate forecast. This is done independently by mean of demographic trend projection. From equation 4.18 (page 247) the effect of changes in proportion of labour force to the overall Economic Efficiency can be described as:

$$OEE^{2}_{(t+n)} = \left(\frac{Q_{x(t+n)} / (L_{x(t+n)} * D_{(n)})}{Q_{usa} / L_{usa}}\right)^{2} + \left(\frac{Q_{x(t+n)} / E_{x(t+n)}}{Q_{usa} / L_{usa}}\right)^{2} \qquad (5.15)$$

where OEE = Overall Economic Efficiency

Q_x = Output of country x

L_x = Labour force of country x

E_x = Energy consumption for country x

$D_{(n)}$ = percentage difference in ratio of labour force at time t and at t+n

The net effect of any changes in the proportion of Labour Force to the total population is more significant for countries which are heavily dependent on external energy consumption and possesses a pyramid type population distribution with old age population at the top. The long term effect of this changes is a shift in the adult population distribution. These characteristics can usually be found in less developing countries. The reduction of the mortality rate and the increase of birth rate increase the proportion of 0 - 15 years age population. The net effect therefore is a reduction of labour force relative to the total population. Countries belonging to this class usually have small industrial sector and therefore utilise small energy consumption. From the equation (5.15) above, it can be seen that given an unchanged level Technology (Alpha) and Resources (Gamma), the Output per capita (Q_x) must be smaller to compensate the reduction on the proportion of Labour Force.

The case study of United Kingdom shows that although the proportion of Labour Force to the total population or even the working population is smaller (44.13 percent in 1980 compared to 46 percent in 1960), United Kingdom still manages to increase the output per capita. This is explained by the existence of very large and significant energy consuming sector (industrial sector). Secondly there is also technological improvement which significantly increases the efficiency of input - output conversion.

5.5. Application of Logistic Growth Model: Long Range Forecast for United Kingdom GNP and Energy Consumption

The validity of the above models are tested using data available for United Kingdom. The relationship between overall economic efficiency and factor dimensions are described in figure 5.1 (page 282). The overall economic efficiency is related to national characteristics by the process conversion model and performance. By inputing technological change generator we can obtain Alpha for different times. Many researchers (Fisher-Pry (78), Blackman (27), etc) have shown the growth of technology (Alpha) follows an 'S growth' characteristics. The 'S growth' does not necessarily imply limit of growth, however, the rate of growth diminishes to a low level after reaching the maximum growth rate (figure 3.11, page 206).

As most countries have not reach the saturation point along this growth curve, we can approximate a small part of this growth curve as an exponential growth. This is described as figure 3.12, page 207. The result of fitting this exponential model to the converted Alpha values is shown in the table 3.4 (page 198). The results of which are marked by the high correlation levels on most samples. For United Kingdom this approximation is shown to produce correlation of 0.996. Figure 5.2 (page 283) shows the curve plotted against the actual data between 1960-1977.

Similarly Gamma can also be converted into time series Gamma scores. Factor Gamma is dependent on the Resources activities. To some extend this factor is related very closely to the short term

economic climate which dictates the flow of resources. The application of linear model to fit Gamma shows that a number of countries do not in fact follow this trend very closely. Since this factor is dependent to the flow of resources, which in turn is highly sensitive to economic climate in general, we need more data points to justify the exact behaviour of Gamma with time.

For the purpose of long term forecast however, it is sufficient to take the growth of Gamma as a linear one as shown in figure 5.3 (page 284). The justification of this assumption is that long term Resources utilization can only either increase in exponential manner, increase in linear manner, decrease in both exponential and linear manner or stay stagnant. To increase Resources utilization in exponential manner is almost impossible under present economic climate without significant jump in the level of Technology used. The decrease of Resources utilization in exponential trend implies the economy is heading towards catastroph, which not be likely to happen under normal political condition. This left us with choice of linear model, which imply either the resources stay at the same level all the time or increase / decrease proportionally with time. Similar to the national economic climate, the assumed projected future value of Gamma is always be debatable as whether there is no political interruption to the economic growth. Therefore the extrapolated value of Gamma for a single time point t+a (a is time constant) is only valid if the country is politically stable.

The application of Gamma approximation to United Kingdom

data produces a correlation coefficient of 0.848. It is noticed that Gamma scores of 1965 is lower than those of any other year (2.45 as compared to 2.45 (1960), 2.53 (1970), 2.72 (1977)).

The combined equation 3.4 (page 188) and equation 3.5 (page 189) results a time series application of National Characteristic model as described by equation 5.1 and 5.2 (page 266). Using the individual factor growth equation it is therefore possible to extrapolate the value of Alpha and Gamma backward to 1950 and foreward to the year 2000. This extrapolation are represented by figure 5.2 (page 283) and figure 5.3 (page 284).

The relationship between Alpha, Gamma, Performance Output (GNP per capita) and Energy consumption per capita are described in equation 5.2 (page 266) and equation 5.13 (page 273).

The extrapolated value of Alpha and Gamma are :

	Model	Corr. coef.	Value at 1950	Value at 1980
Alpha	1.787 exp. (0.0152 (t))	0.996	3.8211	6.0287
Gamma	1.4597 + 0.0158 (t)	0.848	2.254	2.7306

From equation 5.2 (page 266) we can obtain Performance characteristic from the year 1950 to 2000. This is shown as figure 5.4 (page 285). The relationship between Alpha, Gamma and Performance can be shown as:

$$P_C = -21.64 + 25.96\ A - 12.88\ G$$

where P_C = Performance

A = Alpha

G = Gamma

A direct derivative of the performance characteristics is Energy consumption (E_x). The relationship described by equation 5.11 (page 273) produces a long term trend of Energy consumption forecast based on the level of efficiency of Technology utilisation (Alpha), Resources (Gamma), and the overall economic efficiency.

Figure 5.5 (page 286) described the forecasted values of Energy consumption per capita based on the technological change generator as well as linearity function of economy activity. It can be seen that the forecasted value of energy consumption is increasing less than linear growth. This is interesting because the direct implication means that given the present rate of change of technology there will be relative reduction in the consumption of the factor input per capita energy consumption. In the long term therefore there must be a maximum limit on energy consumption percapita.

The relationship between overall economic efficiency and energy consumption described by equation 5.14 produces forecast estimate of Output (GNP per capita). The actual and forecasted value of GNP percapita are shown in figure 5.6 (page 287). It can be seen that the forecasted values are remarkably near to the actual data. The direct result of technological change is improvement in the process conversion efficiency, which in turn also improves the amount of percapita output (GNP per capita). A

continuous technological change produces a near exponential growth of GNP per capita.

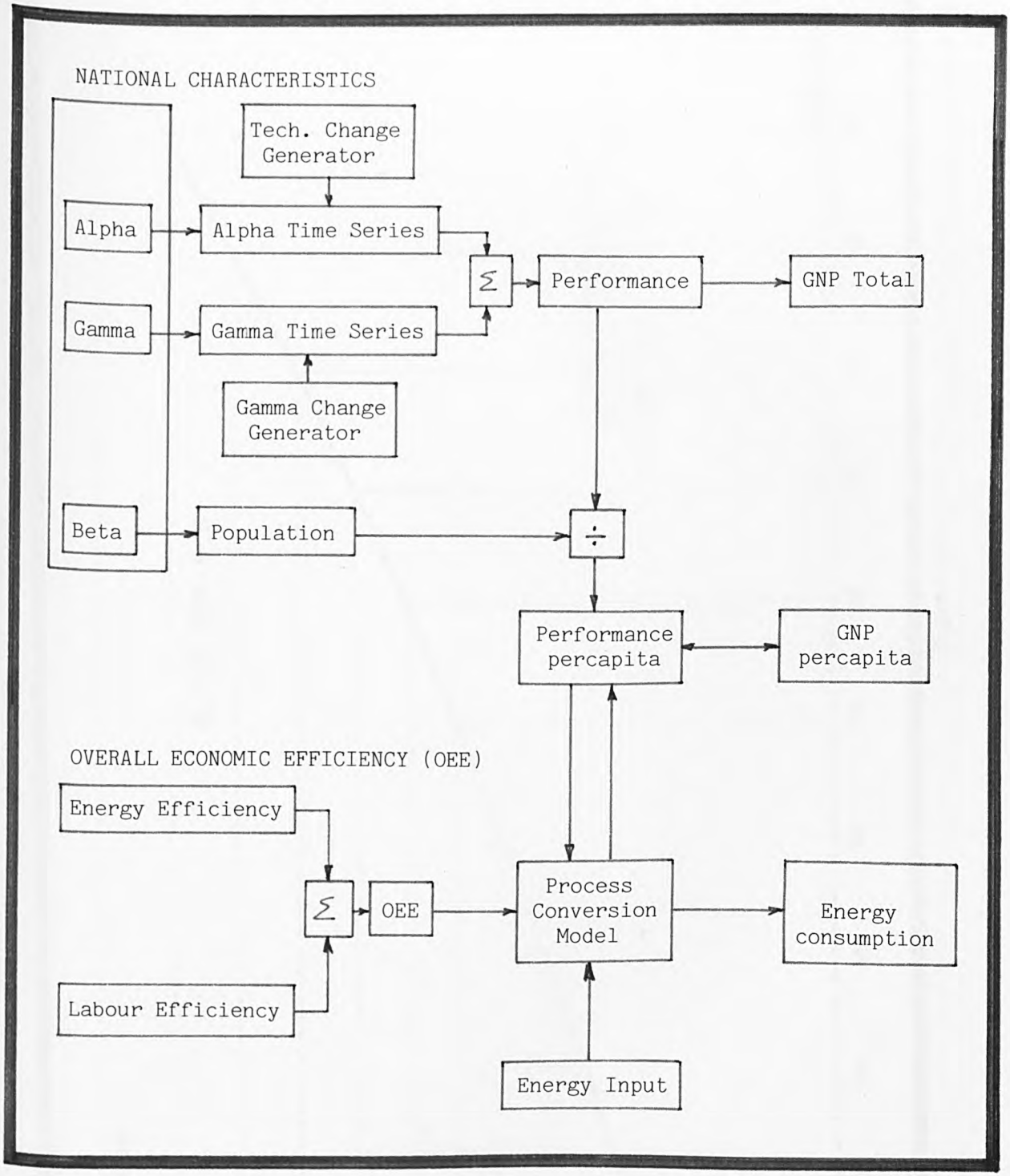
The errors of this forecast can be calculated using the past data. It is calculated by substituting the values of Alpha and Gamma for 1950 into the equation 5.11 and 5.14 (page 273, 274). It yields the expected values of Energy consumption and GNP per capita. The corresponding errors are given by:

	Predicted	Actual values	% differ
Energy consumption per capita	4657.22	4358 (1950)	
		4704 (1951)	
(1950) (tce)	4657.22	4531 (average)	2.78
GNP per capita (1950)	US$ 2507	US$ 2590 (1950)	3.20

The remarkable accuracy of both GNP and Energy consumption percapita (see figure 5.6 and 5.5, page 287, 286) are sufficient indicators that both Energy consumption and Output percapita are dependent on Technological changes. On this basis the long term forecast on both Energy consumption, Output, Efficiency, and other related indicators can be easily calculated.

Figure 5.1

Economic Efficiency and National Characteristic Relationship



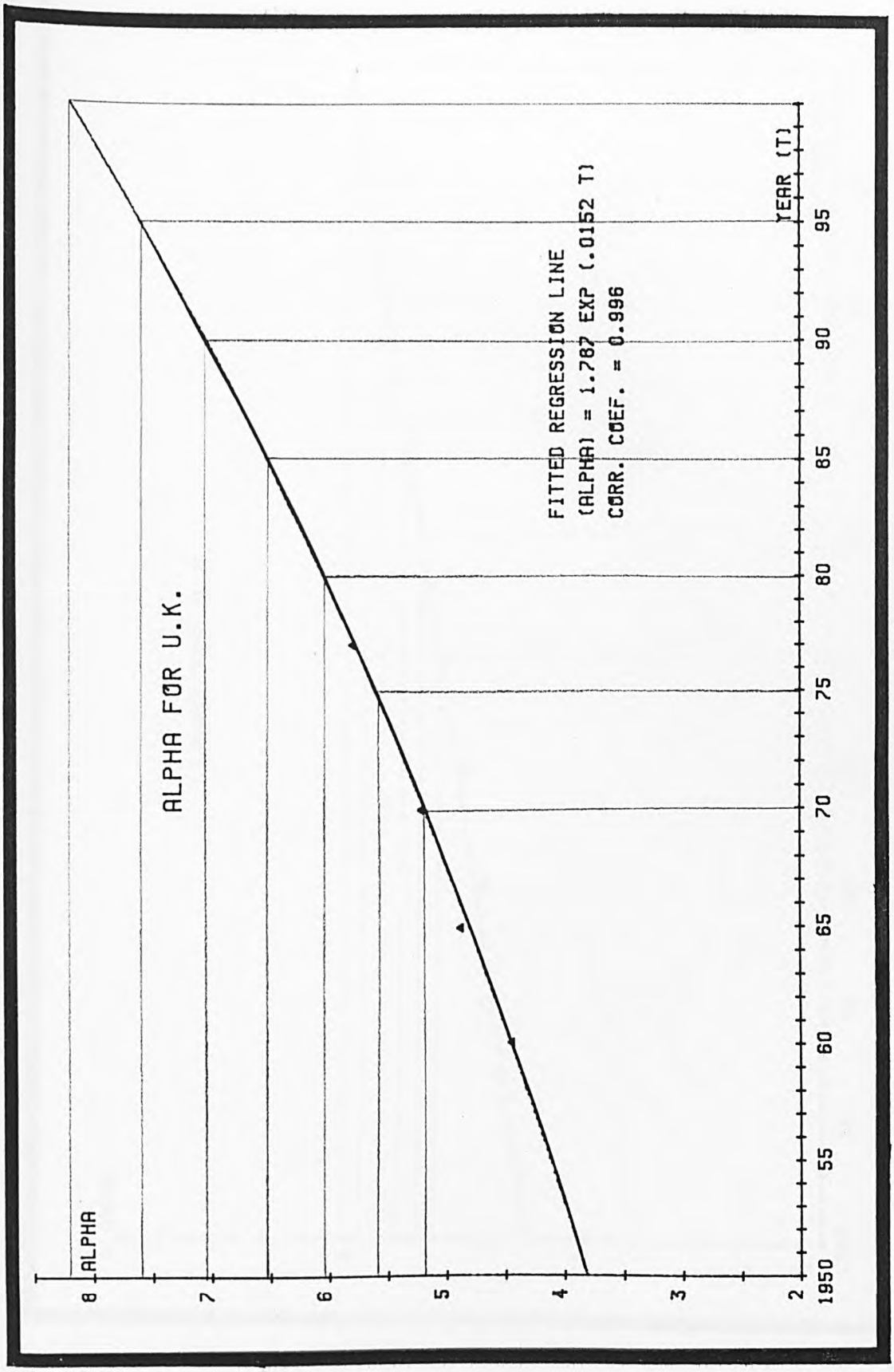

ALPHA FOR U.K.
ALPHA
8
7
6
5
4
3
2
1950
55
60
65
70
75
80
85
90
95
YEAR (T)
FITTED REGRESSION LINE
(ALPHA) = 1.787 EXP (.0152 T)
CORR. COEF. = 0.996

Figure 5.2

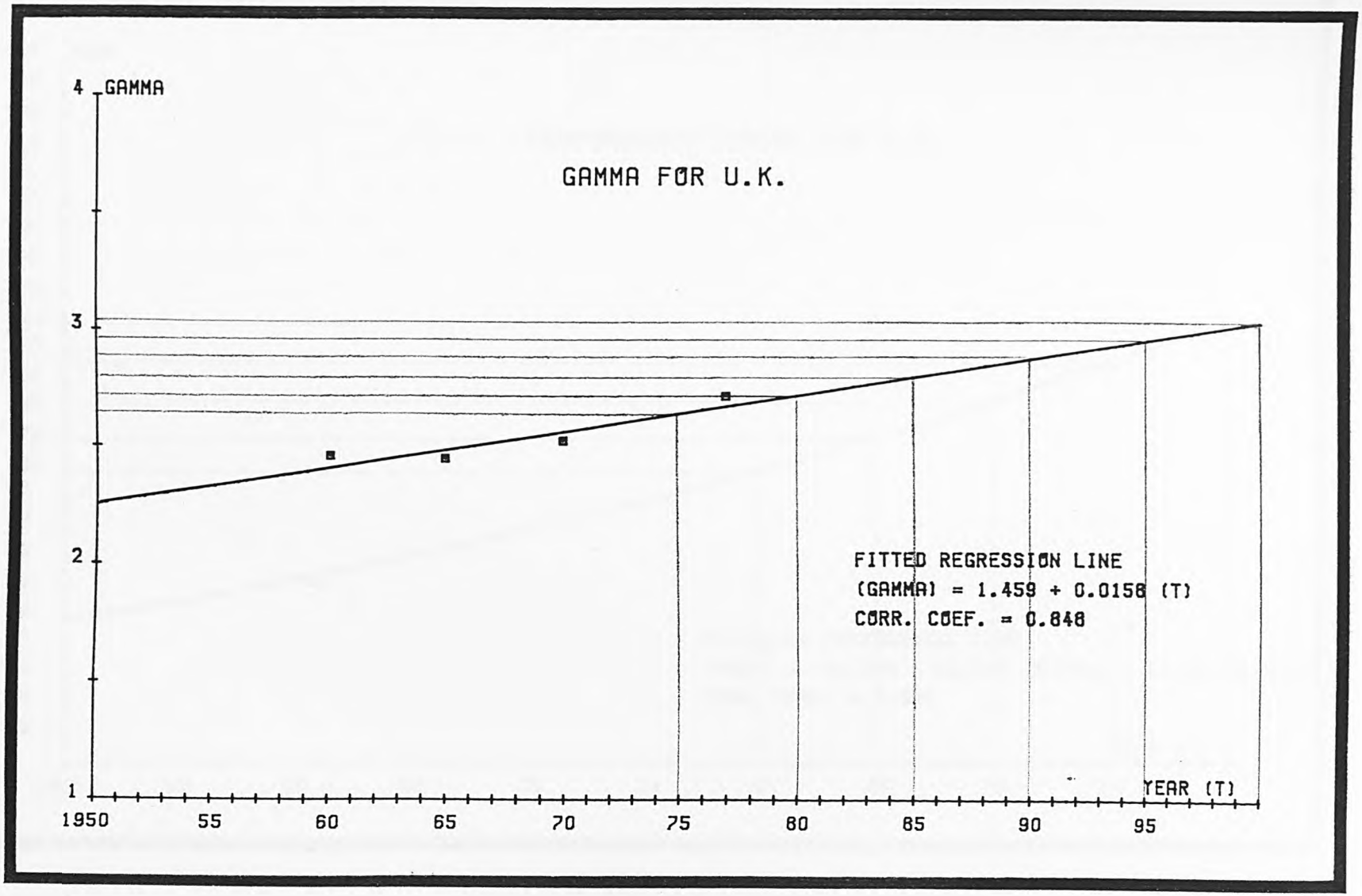

GAMMA FØR U.K.
GAMMA
4
3
2
1
1950
55
60
65
70
75
80
85
90
95
YEAR (T)
FITTED REGRESSION LINE
(GAMMA) = 1.459 + 0.0158 (T)
CORR. COEF. = 0.848

Figure 5.3

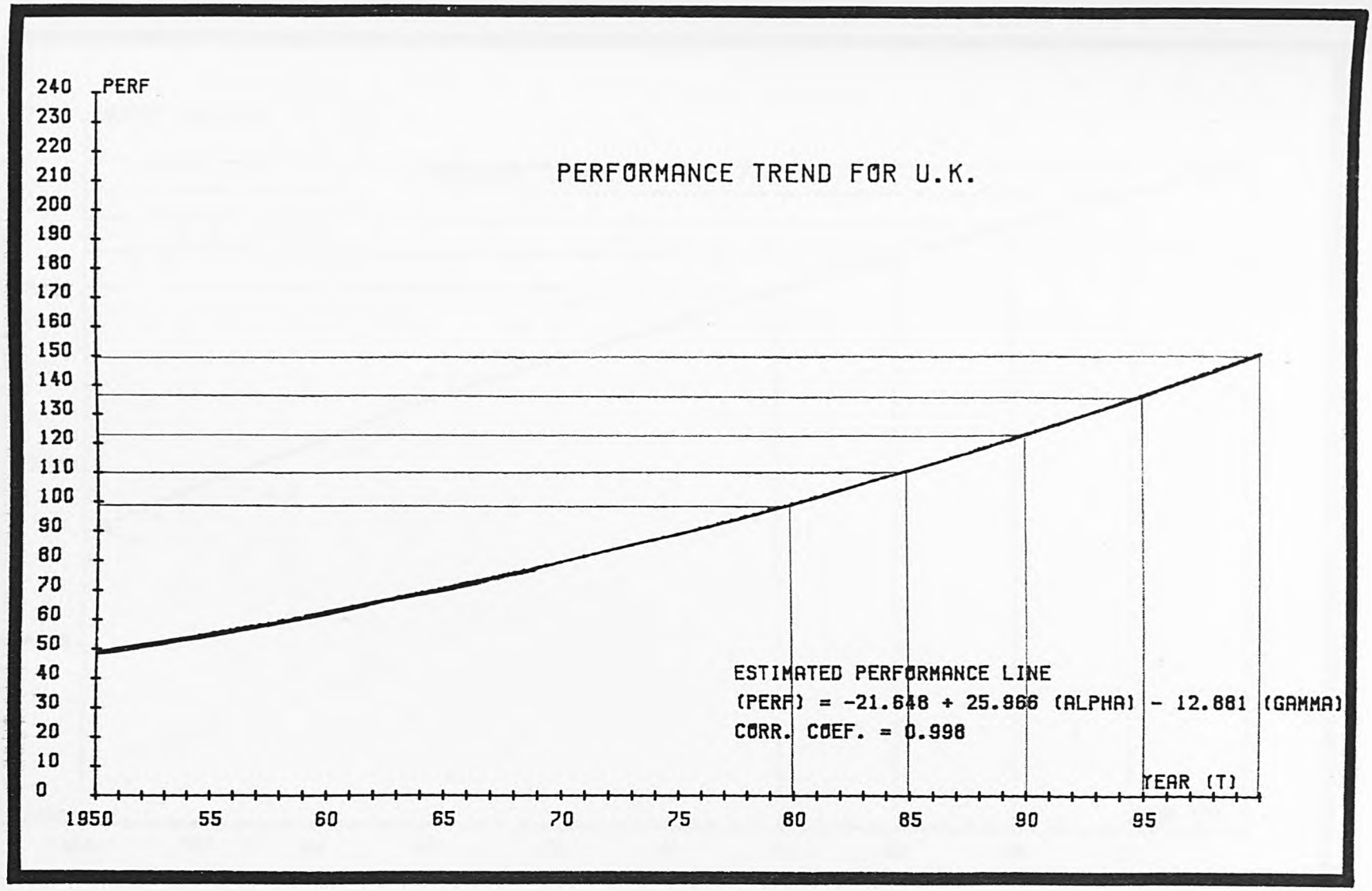

PERFORMANCE TREND FOR U.K.
PERF
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1950
55
60
65
70
75
80
85
90
95
YEAR (T)
ESTIMATED PERFORMANCE LINE
(PERF) = -21.648 + 25.966 (ALPHA) - 12.681 (GAMMA)
CORR. COEF. = 0.998

Figure 5.4

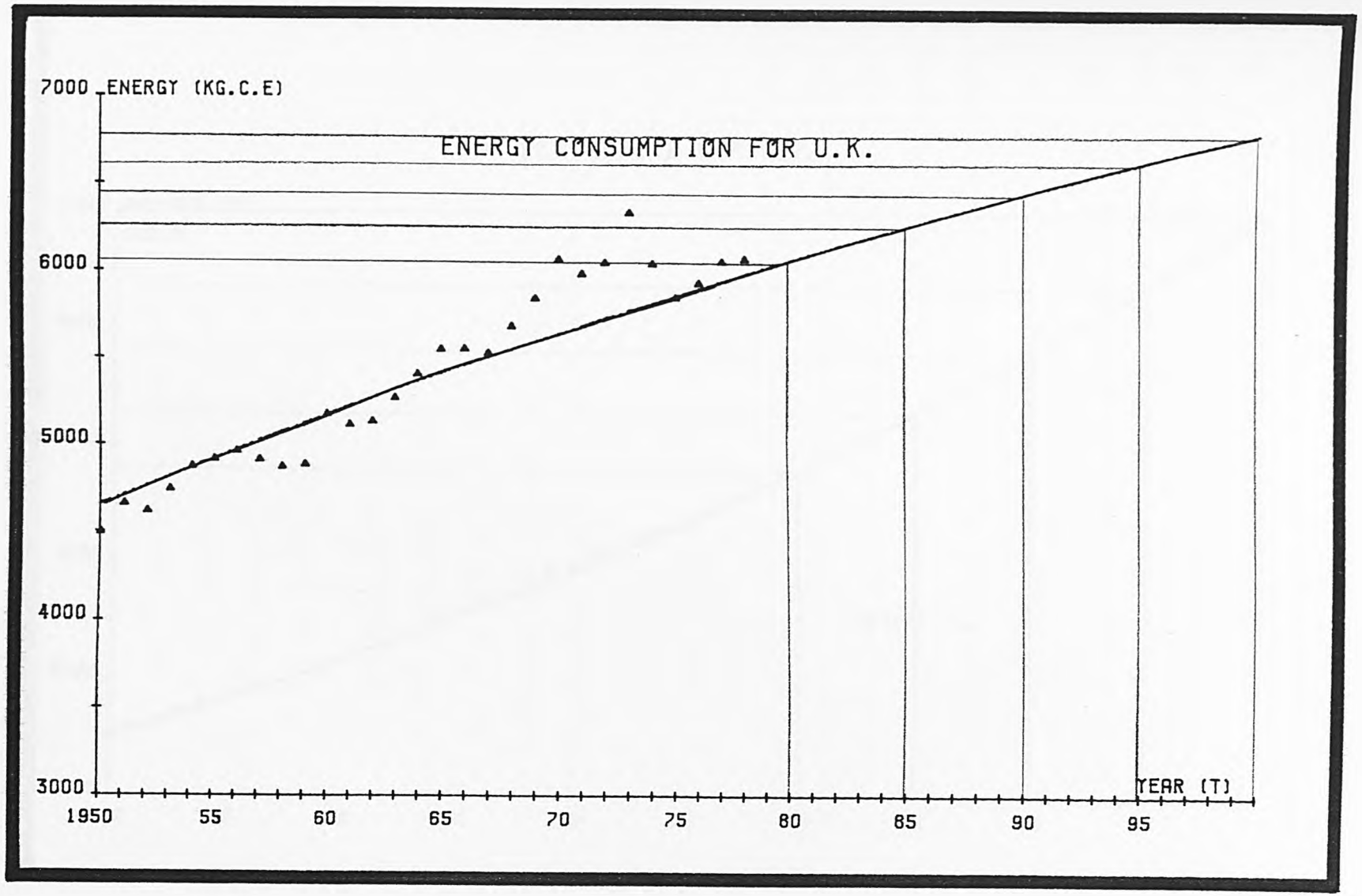

ENERGY CONSUMPTION FOR U.K.
7000
ENERGY (KG.C.E)
6000
5000
4000
3000
1950
55
60
65
70
75
80
85
90
95
YEAR (T)

Figure 5.5

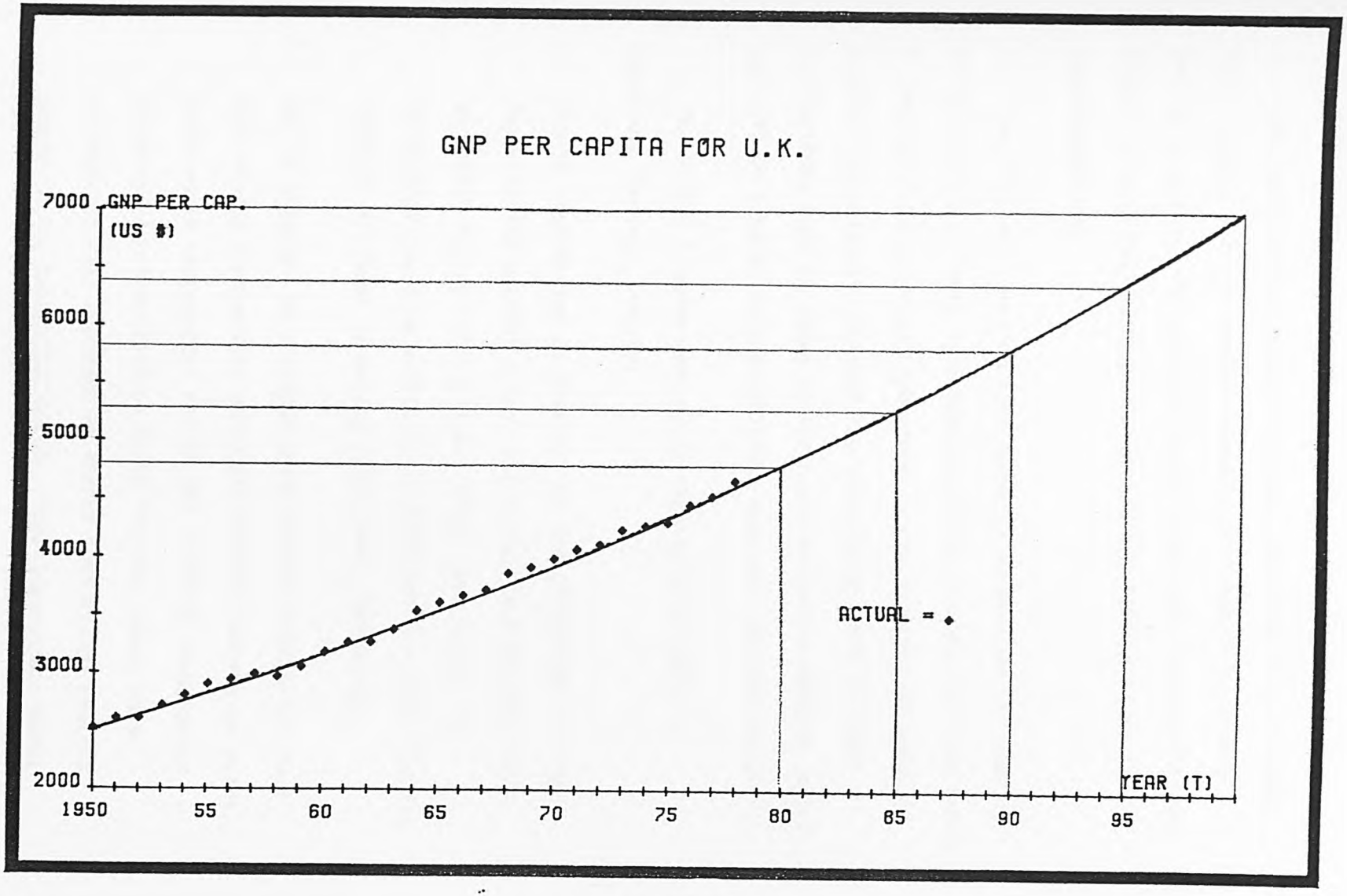

GNP PER CAPITA FOR U.K.
GNP PER CAP.
(US $)
7000
6000
5000
4000
3000
2000
1950
55
60
65
70
75
80
85
90
95
YEAR (T)
ACTUAL =

Figure 5.6

5.6. Discussion

The relationship between national characteristics (Alpha, Beta, Gamma) and the overall economic performance have been proven to exist. The combined model shows that 'national engine model' is both valid and has practical application which can be operationalised.

The forecast based on this model is as good as the quality of data inputs. There is 5 years interval between one time bench to another. The forecast therefore is not expected to predict yearly fluctuations. However the underlying trend of these fluctuations must be based on the characteristics changes, which can only be studied through holistic approach outlined earlier.

The United Kingdom case study highlights a number of important findings, namely;

1. Energy consumption is governed by the technology available. Based on the present trend, there will be a maximum limit percapita energy consumption. After this period the technology would be sufficiently efficient to cater for the marginal increase of energy requirement percapita.

2. GNP is observed to increase indefinetely despite the fact that energy consumption percapita reaches saturation point. Hence while exponential fit of GNP - Energy consumption produces high correlations using the past data, this correlation will decrease as energy consumption reaches nearer to its saturation point. Thus logarithmic model

commonly used to describe GNP-Energy consumption may have to be modified to cater for the increase in efficiency of energy conversion.

3. Major sources of growth were shown either trough technological improvement or resources expansion or the combination of both of these factors. Resources expansion also imply its utilisation which represents the resources currently available and utilised.

For the Less Developing as well as the Developing countries in the absence of possible resources expansion (for example in the absence of resources capable to be further processed), the programme of technological advancement must be properly coordinated. This is the only way to progress and reduce the gap to the more advance industrialised nations.

CHAPTER 6

CONCLUSION

6.1. Conclusion..... 290

6.2. Recommendation for Further Work..... 294

CHAPTER 6

CONCLUSION

6.1. Conclusion

From this analysis of there are a number of conclusions which can be drawn:

(a). Technology is a continuous process, the growth model can be represented as an 'S' shape curve. The growth curve starts with slow initial rise follows by rapid rise, and back to slow rise after the peak of rapid rise is reached. This Technology growth however can not be proven as a typical 'Limit to growth' curve (eg. typical substitution Pearl curve with upper limit), because it does not seem to possess saturation point.

(b). The contribution of technology to the economic development is not only on the state of the art of the technology that exists in the country rather on how the technology is utilized. A proper utilisation of technology induces higher national efficiency and therefore higher outputs per unit input.

(c). The validity and consistency of Factor Analysis method was demonstrated. It is proven to be a powerful method to handle models with large and complex variables. The results

of this reduction methodology can be plotted in Euclidean space to allow further vectors analysis.

(d). The Efficiency of Process Conversion at national level is closely related to the level of Technology (Alpha). Alpha is one of the factor characteristics obtained by dimensional reduction method. Any country with high Technology level (Alpha) always has a relatively more efficient input output conversion system.

(e). It is also demonstrated that National Efficiency is very closely related to the Economist's Technological Change. This finding could be a common ground for the Economists and the Engineers to solve the problems of economic development.

(f). Developing countries which already possess sufficient technology level would experience a transition period where the growth rate becomes relatively very high (take off period, Rostow (187)). The technologically developed countries (Western European & Northern American) which are on the higher part of the 'S curve' experience a slower rate of growth. Thus the developing countries are catching the more developed ones. However the slowest growth is experienced by most of less developed countries. Hence they are left further behind relative to the other two groups. The overall global condition of technological development therefore is rather grim. The underdeveloped countries (mainly African countries) are left further behind. Given

international political condition in a number of less developed countries as today, and the absence of their own natural resources, these countries have little or no chance of catching the technology and therefore the standard of living of the more developing countries.

(g). The results as shown in chapter 3 show that this approach has an unlimited potential for further study of this nature. The number of indicators that can be included depend only on the capacity of the data base, which is practically unlimited. Further more this method is shown to be stable and capable to produce consistence results. In future when there are more statistics available, direct modelling may become too complicated to be practical. This reduction model offers an alternative tool to solve problems of this nature.

(h). The Process Efficiency Model which is based on Integrated Model of Technological Change (IMTC) as outlined in chapter 4 is capable of explaining technological change and produces the same results obtained by economist's findings. The findings also indicate that energy consumption is a major indicator of the state of technology. The number of Scientists and engineers per population also indicates the level of technology, although a very high proportion of scientist-engineer per population ratio does not guarantee a proportionally superior technology level.

(i). The performance of any country (Output per capita) is shown

to be very closely related to the linear combination of Technology (Alpha) and Resources Utilisation (Gamma). Similarly it is also produces high correlation with the product of efficiency and energy input.

(j). The integration of Process Efficiency Model and the combination of factor Technology (Alpha) and Resources (Gamma) is capable to produce a valid long range forecast of Technology, GNP and Energy consumption. The credibility of this forecast was tested by 'backcast' (using data at 1960-1977 to forecast United Kingdom GNP and Energy Consumption at 1950). The results of which showed very little percentage difference between actual and predicted values.

(k). There is an indication of a saturation point on percapita energy consumption. After this point the technology used within the process conversion in the economic system is sufficiently high and efficient to absorb incremantal increase of energy requirement. Further more the external energy requirement for average 'good' standard of living could have been met. Thus the average energy requirement percapita increases at a very low rate if not stays at the same level. Given that conversion efficiency has not reached its maximum thermodynamic limit, the increase of output due to more efficient system implies that the energy requirement therefore must decrease.

6.2. Recommendation for further work

(1). Creation of larger database system to include more variables and achieving a global model (model higher than at national level). The global characteristics can then be useful for policy making at this level.

(2). The model can also be implemented to study the system characteristics at industrial level (model lower than at national level). This will be very useful for industrial planning.

(3). There are other characteristics which are yet to exploited. With more man hours resources, undoubtedly there will be more characteristics that can be identified. The combination of these characteristics with normal modelling procedure should yield very useful and promising results.

(4). The trend of long term energy consumption according to the change of technology should be further exploited. There are indications that energy conversion efficiency can be improved in many sectors of the economy. The study at this level would be very useful for energy policy and planning.

List of Notations

Unless referred specifically, the notations used throghout this thesis are listed below:

A : Alpha

A_{m*n} : Data Matrix of order n*m

B : Beta

c_{jk} : Covariance between Variable j and k

d_{jk} : Distance between any two Vectors X_j and X_k

D_x : Scalar value of Overall Econcomic Efficiency (OEE)

E : Energy

EEP : Energy Economic Productivity

E_j : Eigen Vector

G : Gamma

g : GNP percapita (unit: $ per capita)

$I_{E(x)}$ = IEEE : Index of Energy Economic Efficiency

$I_{L(x)}$ = ILEE : Index of Labour Economic Efficiency

$I_{M(x)}$ = IMEE : Index of Material Economic Efficiency

$I_{o(x)}$ = OEE : Overall Economic Efficiency

K : Capital

L : Labour

LEP : Labour Economic Productivity

L_j : Eigenvalue

M : Material

MEP : Material Economic Productivity

η : Efficiency

n : Energy Consumption percapita (unit: Tons of Coal Equivalent per capita)

OEE : Overall Economic Efficiency

P_c : Economic Performance percapita

$P_{E(x)}$ = EEP : Energy Economic Productivity

$P_{L(x)}$ = LEP : Labour Economic Productivity

$P_{M(x)}$ = MEP : Material Economic Productivity

Q, q : Output

R : Resources

r : Correlation Coefficient

r_{jk} : Coefficient of Correlation between Variable j and k

r^2_{jk} : Coefficient of Determination between Variable j and k

s_j : Standard Deviation of Variable X_j

T : Technology

t : Time

W : Waste

$x_{i,j}$: Value for case i, on variable j

$\underset{-}{X}_j$: Length of Vector X

$\bar{X}_j$: Mean of Variable j

X_j , X_k : Inner Product of Vector X_j and X_k

Y, y : Output

$z_{i,j}$: Standard Score for Case i,j

Z_j : Standardized Variable X_j

List of Figures

Chapter 1:

1.1. Pearl Curve..... 23

1.2. Fisher and Pry's Curve..... 34

1.3. Transformed Fisher and Pry's curve..... 34

1.4. Isenson's Information Growth curve..... 40

1.5. Hartman Information Growth model..... 41

1.6. Schematic diagram of the Process of Multilevel Substitution..... 49

1.7. Simplified basic structure of the Multilevel Substitution Model..... 50

1.8. Efficiency of Prime Movers..... 53

1.9. U.S. Energy Consumption..... 54

1.10. No-Nuclear Energy and new Coal at year 2000 for U.S... 55

1.11. The Effects of Speeding up World Nuclear Program..... 56

1.12. Black-box model of Logistic Growth Models..... 62

1.13. Production Process of the Nation..... 64

1.14. Internal Processes of the Production Function..... 75

1.15. System of Technological Change..... 76

1.16. Core model of IMTC..... 77

1.17. Technology Model..... 78

1.18. Gompertz Curve..... 83

1.19. Area of Research Investigation..... 88

1.20. Project Flowchart..... 89

1.21. Technological Indicators Model..... 90

Chapter 2:

2.1. Flowchart of Data Organisation..... 111

2.2. Missing Data Estimation Procedure..... 114

2.3. Typical Data Distribution..... 128

2.4. False Regression Line due to Extreme Values..... 129

2.5. Untransformed POPULA4 Distribution..... 130

2.6. Transformed POPULA4 Distribution..... 131

2.7. Effects of Transformation on Data Errors..... 132

2.8. Data Transformation used..... 133

2.9. Interpretation of Transformed Correlation between two Variables..... 134

2.10. Lower Half of Square Correlation Matrix 1960..... 137

2.11. Lower Half of Square Correlation Matrix 1965..... 138

2.12. Lower Half of Square Correlation Matrix 1970..... 139

2.13. Lower Half of Square Correlation Matrix 1977..... 140

2.14. Rotated Factor Loadings (1960)..... 149

2.15. Rotated Factor Loadings (1965)..... 150

2.16. Rotated Factor Loadings (1970)..... 151

2.17. Rotated Factor Loadings (1977)..... 152

2.18. Graph of Eigen-values and Total variance for 20 dimensions (1960)..... 153

2.19. Graph of Eigen-values and Total variance for 20 dimensions (1965)..... 154

2.20. Graph of Eigen-values and Total variance for 20 dimensions (1970)..... 155

2.21. Graph of Eigen-values and Total variance for 20 dimensions (1977)..... 156

Chapter 2: (continued)

2.22. Format of Individual Case Results..... 166

2.23. Distribution of Factor Scores..... 167

2.24. Format of Comparative Factor Distance for the Whole Sample..... 168

Chapter 3:

3.1. Relative Alpha Scores for 1960, 1965, 1970, 1977..... 178

3.2. Relationship between Alpha and Number of Scientists.... 181

3.3. Relative and Actual Alpha Scores for Different time periods..... 190

3.4. Actual vs. Predicted Performance 1960..... 191

3.5. Actual vs. Predicted Performance 1965..... 192

3.6. Actual vs. Predicted Performance 1970..... 193

3.7. Actual vs. Predicted Performance 1977..... 194

3.8. Performance (P_c) vs. Alpha in the absence of Gamma..... 195

3.9. Relationship between Alpha and Converted Alpha scores.. 196

3.10. Rate of Change of Alpha vs. Alpha Scores..... 197

3.11. Difference between Pearl's curve and Alpha Growth curve 206

3.12. Exponential Growth as an Approximation to Alpha Growth. 207

Chapter 4:

4.1. UK GNP-Energy Plot 1950-1978..... 210
4.2. GNP-Energy Plot (Selected Countries)..... 211
4.3. Simple Engine Model..... 213
4.4. Simple Monetory Conversion Process Model..... 218
4.5. Simple Engineering Process Conversion Model..... 219
4.6. Steam Engine Efficiency..... 220
4.7. Simple Engineering Economic Process Model..... 221
4.8. Technology at level 1..... 225
4.9. Technology at level 2..... 226
4.10. Technology at level 3..... 227
4.11. Black Box Process Model..... 232
4.12. The Isoquant..... 233
4.13. Optimum Point along Isoquant..... 233
4.14. Technological Change on Isoquant..... 233
4.15. Overall Economic Efficiency Vector (OEE)..... 249
4.16. Time Series of OEE..... 249
4.17. OEE at Different Time Bench..... 249
4.18. Comparison Between REED and Solow's Result..... 252
4.19. Overall Economic Efficiency (UK)..... 255
4.20. Efficiency Index (UK)..... 256
4.21. Overall Economic Efficiency (USA)..... 257
4.22. Efficiency Index (USA)..... 258
4.23. Overall Economic Efficiency (Sweden)..... 259
4.24. Efficiency Index (Sweden)..... 260
4.25. Error in Using Population as Labour Force Index..... 263

Chapter 5:

5.1. Economic Efficiency and National Characteristic Relationship..... 282
5.2. Alpha for U.K..... 283
5.3. Gamma for U.K..... 284
5.4. Performance Trend for U.K..... 285
5.5. Energy Consumption for U.K..... 286
5.6. GNP percapita for U.K..... 287

List of Tables

Chapter 1:

1.1. Analogy between Cellular Growth and Technological Progress..... 19

1.2. Bisexual Reproduction Analogy..... 20

1.3. Summary of Logistic and Substitution Models..... 59

1.4. Table of Education - GNP percapita result from Millendorfer-Gaspari..... 71

1.5. Empirical result from Generalized Production Function. 71

1.6. Result of Gompertz Logistic Applied to Engine Model... 84

Chapter 2:

2.1. Variables Groups and Classifications..... 103

2.2. Countries Geo-Economic Development Grouping..... 107

2.3. Statistical Data Descrepencies from Various Sources... 121

2.4. Unrotated Factor Loadings (1960)..... 145

2.5. Rotated Factor Loadings (1960)..... 146

2.6. Correlation Matrix between the new Dimensions (1960).. 147

2.7. Correlation Matrix between the new Dimensions (1965).. 147

2.8. Correlation Matrix between the new Dimensions (1970).. 148

2.9. Correlation Matrix between the new Dimensions (1977).. 148

2.10. Rotated Factor Loadings at different time bench..... 158

Chapter 3:

3.1. Rate of Growth of Alpha for Various Country Groups..... 173

3.2. Stock of Scientists and Engineers around 1965..... 180

3.3. Economic Performance Model fitted on Actual Data..... 184

3.4. Converted Alpha Scores..... 198

3.5. Time Series Model of Alpha..... 200

3.6. Converted Gamma Scores..... 202

3.7. Time Series Model of Gamma..... 204

Chapter 4:

4.1. Simple Energy - GNP Growth Model..... 212

Chapter 5:

5.1. Performance Characteristic Model..... 269

5.2. Correlation obtained from Performance of Process Conversion Model and percapita GNP..... 271

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APPENDIX

Index

1. Diagramatic and Theoretical Summary of Factor Analysis

   1.1. Definitions and Notation..... 2

   1.2. Vector and Matrix concepts..... 6

   1.3. Vector and Matrix application in statistics..... 11

   1.4. Graphical Approach to Factor Analysis..... 16

   1.5. Principle Factor Analysis Methodology..... 24

2. List of Variables Definitions and Sources..... 30

3. Description of Data Distribution, Extreme Values and Data Transformation..... 40

4. Factors Results

   4.1. Unrotated Factor Results..... 51

   4.2. Rotated Factor Results..... 59

5. List of Factor Distances

   5.1. Socio-Economic Group Characteristics Graphs..... 67

   5.1. National Characteristics Graphs..... 79

   5.2. Comparative Factor Distances for whole sample.....179

1. Diagramatic and Theoretical Summary of Factor Analysis

1.1 Definitions and Notation

In order to define and understand the theory of Factorial Analysis, it is essential to define a few basic definitions and notations used. This section describes briefly some basic notations and definitions which will be used in the later sections. Consider any two dimensional data arrays, where x_{ij} is any element of row (case) i and column (variable) j: the following definitions will be used:

Definition 1.1

$$\text{Average} : \left(\sum_{i=1}^{n} x_{ij} \right) / n \qquad (1.1)$$

where x_{ij} : value for case i, on variable j

n : no. of cases

Notation 1.1

$\bar{X}_j$: mean of variable j

where x_{ij} : value for case i, on variable j

n : no. of cases

Definition 1.2

$$\text{Variance} : \sum_{i=1}^{n} \left(x_{ij} - \bar{X}_j \right)^2 / n \qquad (1.2)$$

Notation 1.2

s_j^2 : variance of variable X_j

Definition 1.3

Standard deviation : $\left(\sum_{i=1}^{n} \left(x_{ij} - \bar{X}_j \right)^2 / n \right)^{1/2}$ (1.3)

Notation 1.3

s_j : standard deviation of variable X_j

Definition 1.4

Standard score : $\left(x_{ij} - \bar{X}_j \right) / s_j$ (1.4)

Notation 1.4

z_{ij} : standard score for case x_{ij}

Definition 1.5

Standardized variable : transformed variables into standardized scores.

Notation 1.5

Z_j : standardized variable X_j

Definition 1.6

Covariance : $\left(\sum_{i=1}^{n} \left(x_{ij} - \bar{X}_j \right) \left(x_{ik} - \bar{X}_k \right)\right) / n$ (1.5)

Notation 1.6

c_{jk} : covariance between variables j and k

Definition 1.7

Correlation coefficient:

$$r = c_{jk} / \left(s_j \cdot s_k \right)$$

$$= \left(\sum_{i=1}^{n} (x_{ij} - \bar{X}_k)(x_{ik} - \bar{X}_k)\right) / \left(\left(\sum_{i=1}^{n} (x_{ij} - \bar{X}_j)^2 \left(\sum_{i=1}^{n} (x_{ik} - \bar{X}_k)^2\right)^{1/2}\right.\right.$$

(1.6)

for standardized variables z_{ij} and z_{ik}:

$$r_{jk} = \left(\sum_{i=1}^{n} z_{ij} \cdot z_{jk} \right) / n \qquad (1.7)$$

Notation 1.7

r_{jk} : coefficient of correlation between variables j and k

r_{jk}^2 = coefficient of determination between variable j and k

Definition 1.8

Linear Regression : the straight line fitted to the plot of X_j (vertical axis) on X_i (horizontal axis) for which the sum of squared vertical deviations of values x_{ij} from the line are a minimum.

Definition 1.9

Linear regression equation :

$$X_k = a + b\, X_j \qquad (1.8)$$

where a : constant representing intercept to X_k

b : constant representing the slope of the best fitted line.

Definition 1.10

Linear Multiple Regression equation:

$$X_j = a_k + b_1 X_1 + b_2 X_2 + \ldots\ldots + b_m X_m \qquad (1.9)$$

where a_k : constant representing intercept to X_k

$b_1 \ldots\ldots b_m$: constant representing slope to $X_1 \ldots X_m$

Definition 1.11

Partial correlation for two variables :

$$r_{12.3} = (r_{12} - r_{13}\, r_{23}) \,/\, ((1 - r_{13}^2)(1 - r_{23}^2))^{1/2} \qquad (1.10)$$

where r_{kl} : coefficient of correlation between k and l

$r_{kl.m}$: partial coefficient between k and l holding m constant.

1.2. Vector and Matrix concepts

Notation 2.1

A_{m*n} : data matrix of order n * m

x_{ij} : an element of matrix A contained in row i and column j

n : no. of rows in A

m : no. column in A

Vector definition

Any column or row of a matrix is defined as a vector. The numbers in the row or column are the vector elements of the vector.

Definition 2.1

Row vector:

$$X_i = x_{i1} , x_{i2} , x_{i3} , ... , x_{im} \qquad (2.1)$$

Column vector:

$$X_j = \begin{vmatrix} x_{1j} \\ x_{2j} \\ . \\ . \\ . \\ . \\ x_{nj} \end{vmatrix}$$

Geometric representation:

Euclidean vector space of n dimensions is defined as a collection of all n-component vectors for which the operations of vector addition and multiplication by a scalar is permissible. A vector can be represented geometrically as a line segment length and direction in Euclidean space. The coordinates for allocating

a vector in space are given by the vector's elements. Thus for any matrix A_{2*3} :

$$A_{2*3} = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \end{vmatrix}$$

It can be represented as figure (6.1) (page 9)

Vector space definition

A Vector Space is defined by all the elements in a matrix and includes all the column and row vectors of the matrix. If the space consists of column vectors, the matrix rows are a coordinate system for this space.

Definition 2.4

The inner Product of two vectors is the sum of the products of their corresponding elements. If X_j and X_k are the two vectors, their inner product is defined as:

$$\text{Inner Product} = x_{1J}\, x_{1K} + x_{2J}\, x_{2k} + \ldots\ldots + x_{nj}\, x_{nk} \qquad (2.4)$$

Notation 2.4

(X_j , X_k) = inner product of vector X_j and X_k

Definition 2.5

$$\text{vector length} = (X_j , X_k) \qquad (2.5)$$

Notation 2.5

X_j = length of vector X

Definition 2.6

Distance between any two vectors:

$$X_j - X_k = ((x_{1j}-x_{1k})^2 + (x_{2j}-x_{2k})^2 + \ldots\ldots + (x_{nj}-x_{nk})^2)^{1/2} \qquad (2.7)$$

Notation 2.7

d_{jk} = distance between any two vectors X_j and X_k

Definition 2.8

Cosine of any angle between two vectors is the ratio of their inner product to the product of their length. Thus for any two vectors X_j and X_k, whose angle is v_{jk}

$$\cos(v_{jk}) = \frac{(X_j, X_k)}{X_j \; X_k} \qquad (2.8)$$

Definition 2.9

Referring to figure 6.2, (page 10) x_1 and x_2 are the basis of vector A whose coordinate is (a_1,a_2). Any rotation (w) will change the coordinate of A from (a_1,a_2) to (b_1,b_2).

By simple trigonometry rotation can be represented as:

$$b_1 = a_1 \cos(w) + a_2 \sin(w)$$
$$b_2 = -a_1 \sin(w) + a_2 \cos(w)$$

In matrix form it can be written as;

$$\begin{vmatrix} b_1 \\ b_2 \end{vmatrix} = \begin{vmatrix} \cos(w) & \sin(w) \\ -\sin(w) & \cos(w) \end{vmatrix} * \begin{vmatrix} a_1 \\ a_2 \end{vmatrix} \qquad (2.9)$$

figure 6.1
Vectors in Two Dimensions

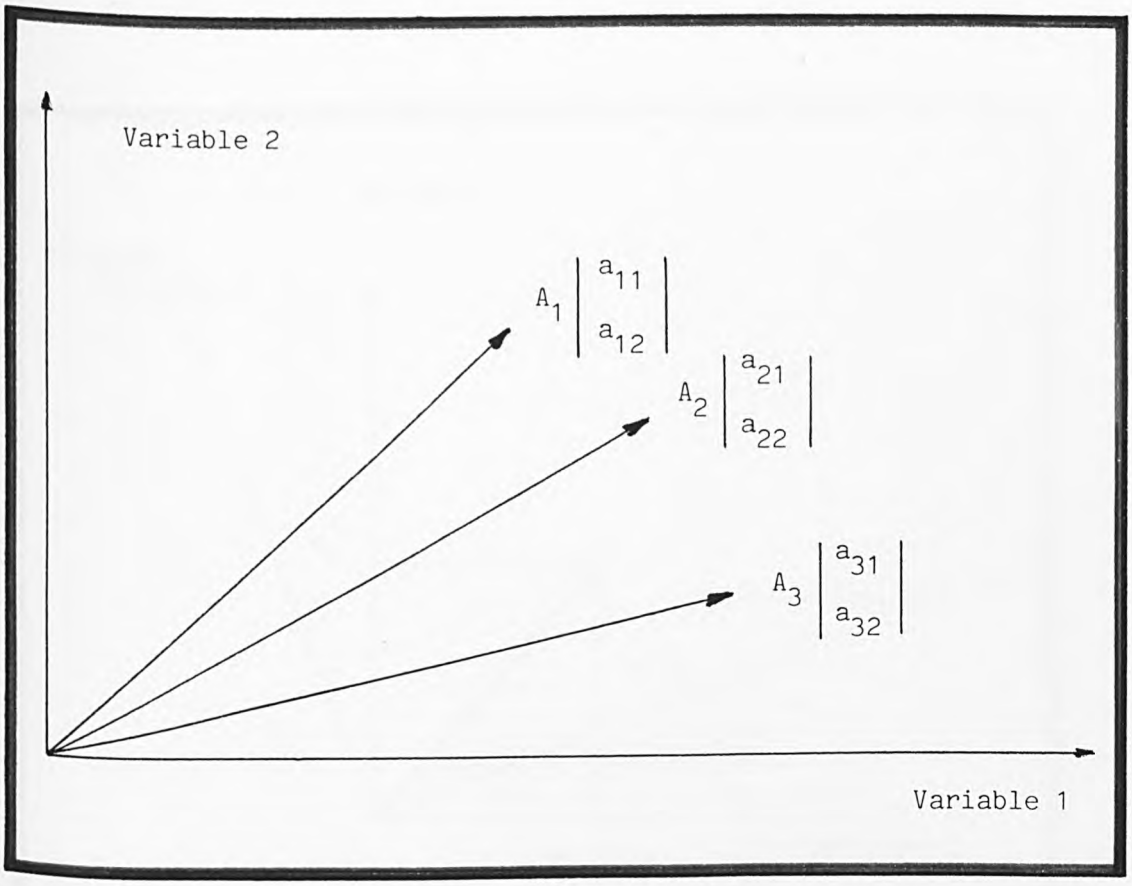
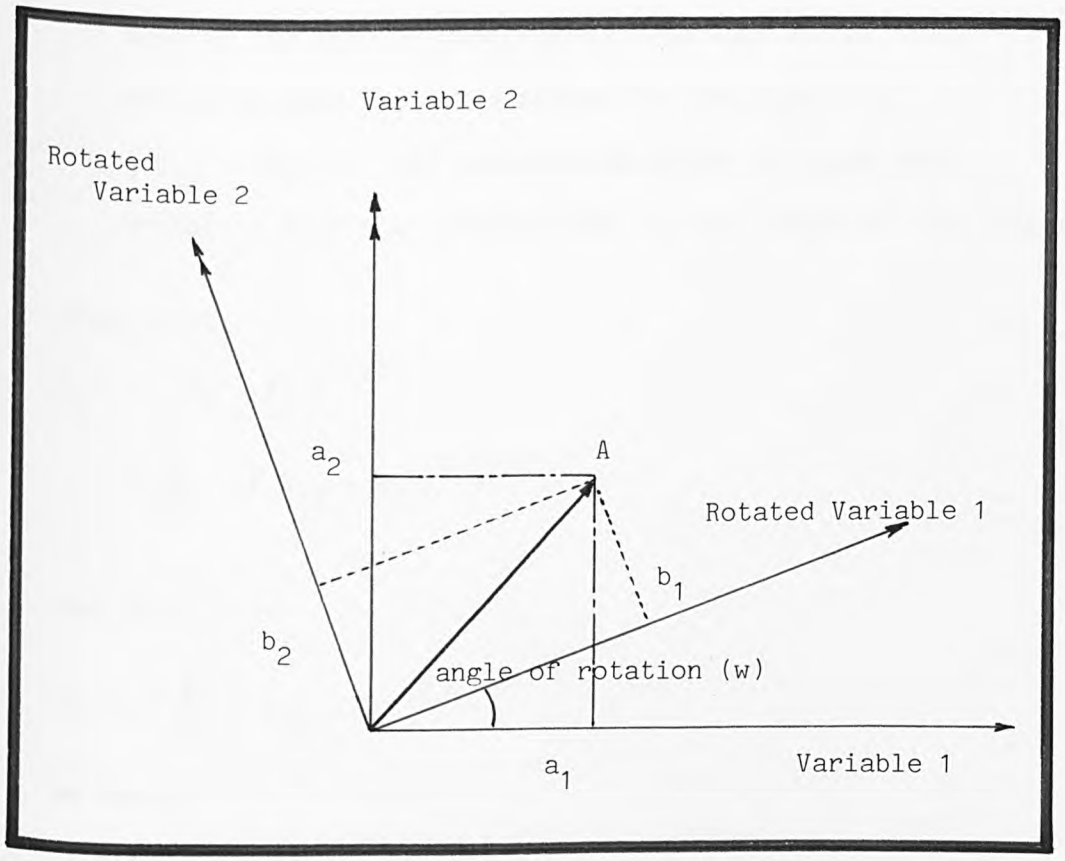


figure 6.2
Two Dimensional Vector Rotation



1.3. Vectors and matrix applications in statistics

Definition 3.1

The standard deviation of the data for a variable X_j has a simple relationship to the length of the vector. Let the mean of the data be substracted from each value. The resulting mean deviation scores for any case i is $(x_{ij} - \bar{X}_j)$. The standard deviation of these mean deviation scores is proportional to the length of the vector.

From (2.5),

$$X_j = (X_j , X_j)^{1/2}$$

$$= \sum_{i=1}^{n} ((x_{ij} - \bar{X}_j)^2)^{1/2}$$

And from (1.3),

$$s_j = (\sum_{i=1}^{n} (x_{ij} - \bar{X}_j)^2)^{1/2} / n^{1/2}$$

we have;

$$X_j = n^{1/2} s_j = (\sum_{1=1}^{n} (x_{ij} - \bar{X}_j)^2)^{1/2} \qquad (3.1)$$

For standardized data,

$$s_j = 1$$

therefore,

$$X_j = n^{1/2} \qquad (3.2)$$

Similarly combining definition (2.4) and (1.6), we have covariance redefined as,

$$c_{jk} = (X_j , X_k) / n \qquad (3.3)$$

Defining transformed variable into standardized scores as Z_j and Z_k, the inner product is

$$(Z_j , Z_k) = \sum_{i=1}^{n} (z_{ij} \cdot z_{ik})$$

$$= n\, r_{jk}$$

Therefore the correlation coefficient

$$r_{jk} = (Z_j , Z_k) / n \qquad (3.4)$$

From (1.6), (2.4), and (2.8), we have,

$$\cos v_{jk} = (X_j , X_k) / X_j X_k$$

$$= c_{jk}\ n / (s_j\, n^{1/2}).(s_k\, n^{1/2})$$

$$= c_{jk} / (s_j\ s_k)$$

$$= r_{jk} \qquad (3.5)$$

Thus the strength of relationship of any two variables (correlation) can also be represented geometrically as the cosine angle between two vectors (figure 6.6, page 21).

Definition 3.2

Covariance matrix: let the data matrix A_{n*m} consist of mean-deviation obtained by subtracting the mean for each variable from the values for each case (equation 3.1). The covariance is obtained by left multiplying the mean-deviation of data matrix by itself and by the reciprocal of the number of cases. Thus,

$$C_{m*m} = (1/n)\ A'_{m*n} \cdot A_{n*m} \qquad (3.6)$$

Notation 3.2

Covariance matrix:

$$C_{m*m} = \begin{vmatrix} c_{11} & c_{12} & \cdots & c_{1m} \\ c_{21} & c_{22} & & c_{2m} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ c_{m1} & c_{m2} & & c_{m*m} \end{vmatrix}$$

Notation 3.3

Correlation matrix:

$$R_{m*m} = \begin{vmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & & r_{2m} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ r_{m1} & r_{m2} & & r_{mm} \end{vmatrix}$$

Definition 3.3

Correlation matrix: can be obtained from the covariance matrix by left multiplying and right multiplying C_{m*m} by a diagonal matrix, consisting of the reciprocal square roots of the variance for the variables (Rummel, 4). Thus,

$$R_{m*m} = V_{m*m}^{-1/2} \cdot C_{m*m} \cdot V_{m*m}^{-1/2} \qquad (3.7)$$

where

$$V_{m*m} = \begin{vmatrix} v_1^2 & 0 & \cdots & 0 \\ 0 & v_2^2 & \cdots & 0 \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ 0 & 0 & \cdots & v_m^2 \end{vmatrix}$$

v_j^2 = variance for each variable X_j

If the data are in standardized scores, the correlation matrix equals the left multiplication of the standardized matrix by the transpose of itself times the reciprocal of the number of cases. If R_{m*m} is the standardized data matrix, then,

$$R_{m*m} = (1/n)\ Z'_{m*n}\ Z_{n*m} \qquad (3.8)$$

Definition 3.6

Orthogonal matrix: Any matrix that when left multiplied by its transpose equals to a diagonal matrix. For any matrix B_{p*q} when $B'_{q*p} \cdot B_{p*q} = D_{q*q}$ (diagonal matrix), then B_{p*q} is orthogonal.

Definition 3.7

Orthonormal matrix: Any matrix that when left multiplied by its transpose equals an identity matrix. An orthonormal matrix is a special case of an orthogonal matrix. For any matrix B_{p*q} when $B'_{q*p} \cdot B_{p*q} = I_{q*q}$ (identity matrix), then B_{p*q} is orthonormal.

Definition 3.4

Eigenvalue and Eigen vector: for any square matrix B_{p*p} it is possible to make a transformation such that

$$B_{p*p} \cdot E_j = L_j \; E_j \tag{3.9}$$

where $E_j < 0$, $E_j > 0$

E_j = Eigen vector

L_j = Eigenvalue

In the matrix form we can represent the above equation as:

$$B_{p*p} \; E_{p*p} = L_{p*p} \; E_{p*p} \tag{3.10}$$

An important characteristic of the above equation is that when B_{p*p} is symmetric (as in the case of correlation or covariance matrix), its Eigen values are real, and the associated Eigen vectors are orthogonal. These Eigen vectors form an orthogonal basis of the vector space defined by B_{p*p}.

1.4. Graphical Approach to Factor Analysis

The basic of Factor Analysis are the application of vector and statistical theories. This method therefore has the advantage of powerful and widely researched statistics background concept. The application of vector concept is useful in the sense that it can be geometrically represented which can be visualised to allow further physical modelling and theories. It is a suitable socio techno economic analytical tool because the statistics allow for fluctuation in any statistical measurement. In the world of socio techno economics nearly all data available are in the form of statistic formats. Therefore it can be argued that proper modelling should not only used the 'accounting type' mathematics but the use of statistical interpretations are equally essential.

The relationship of any two variables can be best explained by the set theory (fig. 6.3, page 19). The shaded area represents the strength of relationship between two variables. The larger the proportion of the shaded area, the higher is the correlation. With more variables, this shaded area can be thought similar to the multiple correlation coefficient. This area can become progressively smaller in size as more and more variables are used (figure 6.4, page 19). As we increase the number of variables used, there are more such common areas identifiable as 'cluster of common variables'. These clusters are in fact the components of variables which share common characteristics. The application of the above method in three

dimension (three cases), is represented in figure 6.5 (page 20). In practice we analyse much larger variables, in which case they can only be represented analytically. The variables in our three cases example can be represented geometrically as three coordinate points. These variables have magnitudes equal to the distance between the coordinate points and the origin. The relationship between variable 1 and variable 2 can be represented by the direction (ie. relative angle) of the vectors (figure 6.6, page 21). The size of the angle represents the strength of relationship. The smaller is the angle the higher is the correlation between the two vectors.

If all variables are represented in imaginary vector space in the manner as shown in figure 6.5 (page 20), we end up with a collection of vectors. For ten variables it can be represented as figure 6.7 (page 22). Suppose the data come from cross national sources. These vectors are exactly similar to these variables. In this imaginary vector space we can resolve these vectors to obtain some dimensional reductions. The reduced vectors are representative of the overall characteristics (described previously by ten variables). The requirement of this 'resolving' method is that the dimensions must be independant one to another. As we can see, characteristics that are highly inter-related to one another will cluster together; characteristics that are unrelated will be at right angle to each other. By inspecting this configuration analytically, the distinct cluster of vectors can be identified. These cluster index the dimensions of the relationship in the data. Each

cluster can further be identified with a factor component (or dimension). Thus for our example (figure 6.8, page 22), we can graphically reduce the ten variables into two independant vectors components. Graphically it can be seen that these two vectors account for the large portion of the variance of the ten variables data.

Factor Analysis is used as an analytical technique. Therefore these cluster of 'components' can still be defined even when the number of cases exceeds our pictorial limit. Each factor delineated by factor analysis define a distinct cluster of vectors.

The projections of each vector point on the factor axes (defined by cluster) are called 'factor loadings'. Figure 6.9 (page 23) shows an example of two dimensional factor loadings.

By rotation, the 'axis' can be searched such that they represent maximum characteristic of the original variables. The amount of the contribution of these vectors can be measured by the total variance of the factor axes. On these new axis, each case' characteristics can be mapped. These axes represent similar collective indicators shown by the original variables. The exact amount of representativeness is given by the total variance explained.

figure 6.3
Correlation between Two Variables

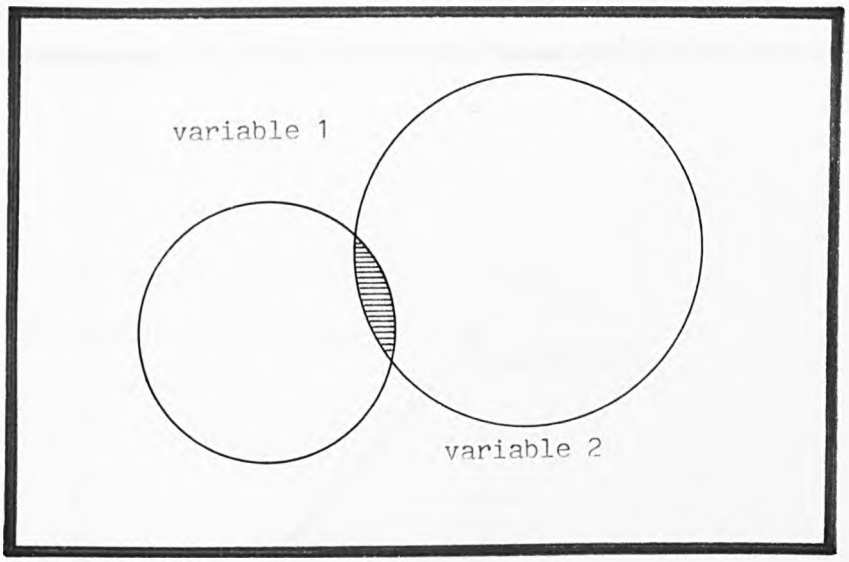


figure 6.4
Correlation between Three Variables

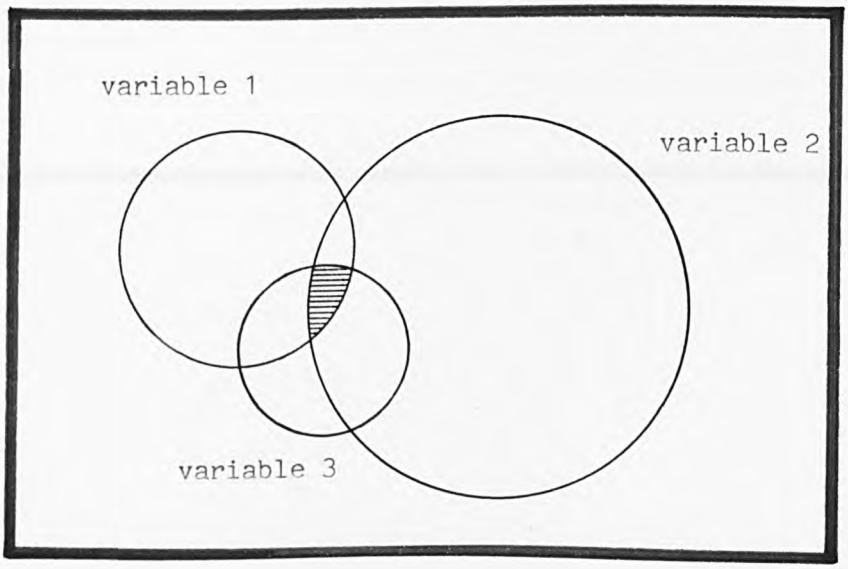


figure 6.5
Variables Reprentation in Euclidean Space

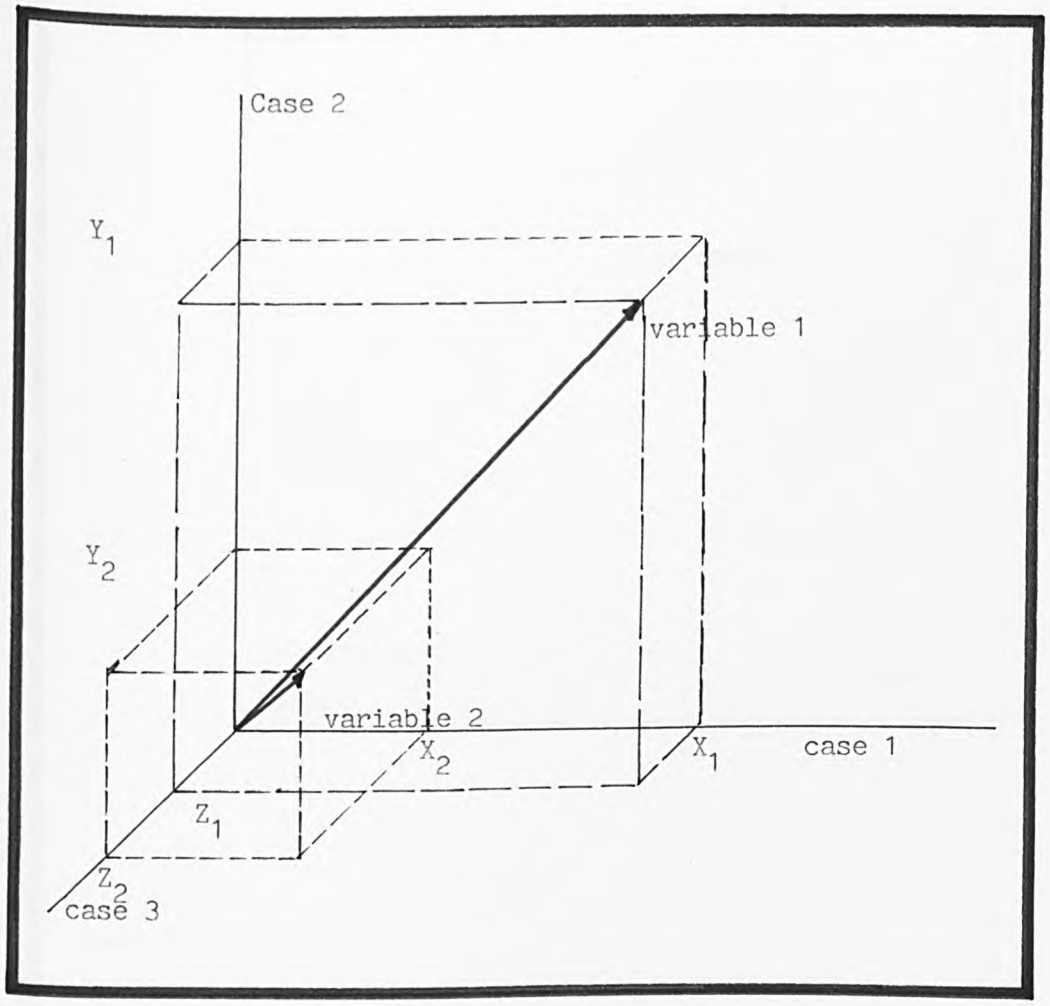


figure 6.6
Vector Angle Representation in Euclidean Space

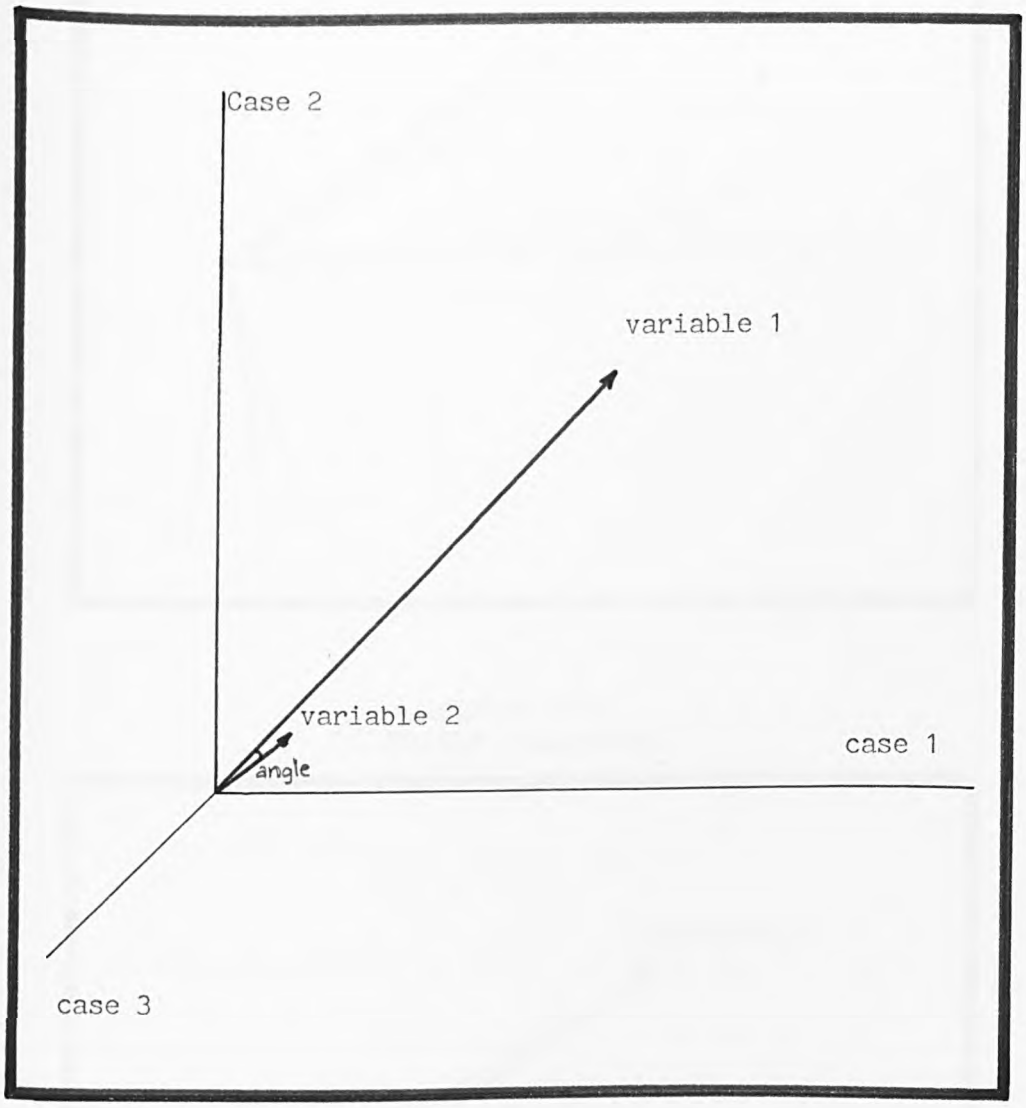


figure 6.7
Possible Clustering among ten Variables

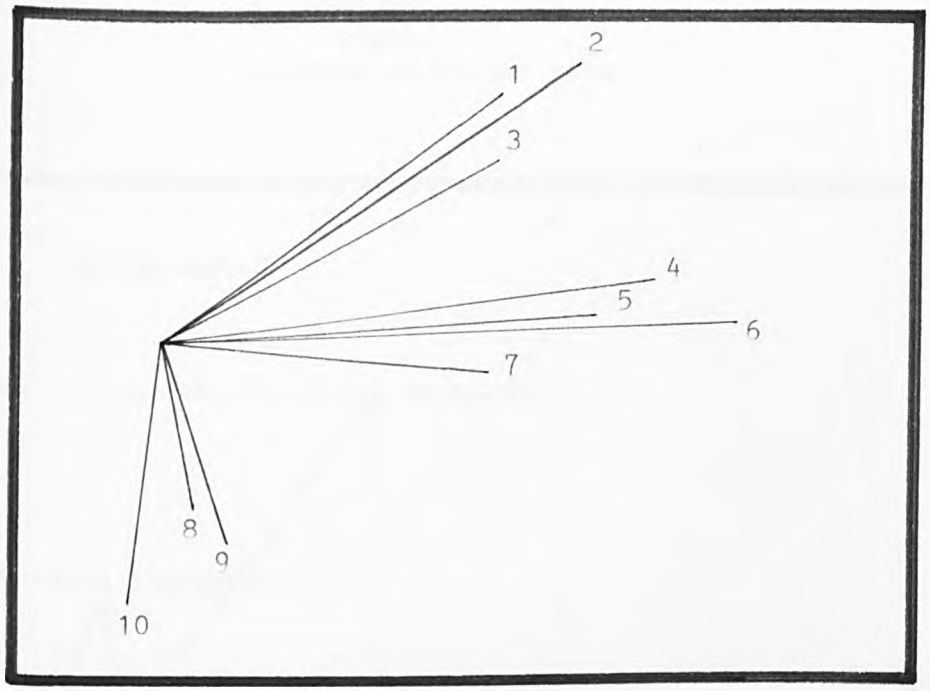


figure 6.8
Factor Dimensions

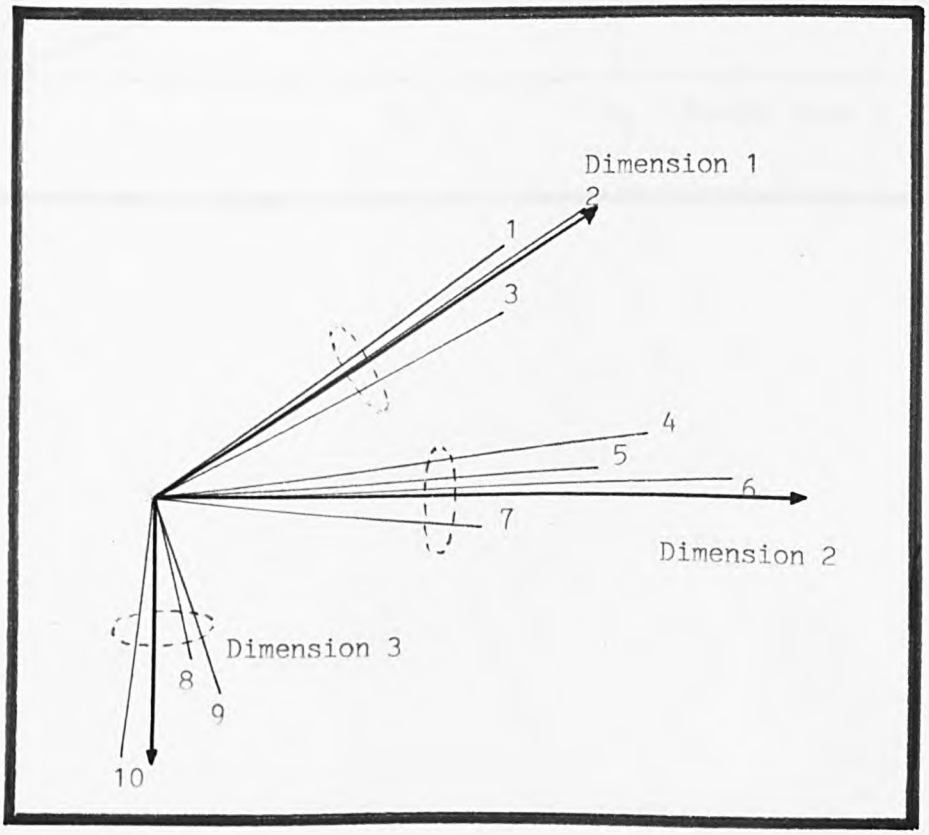
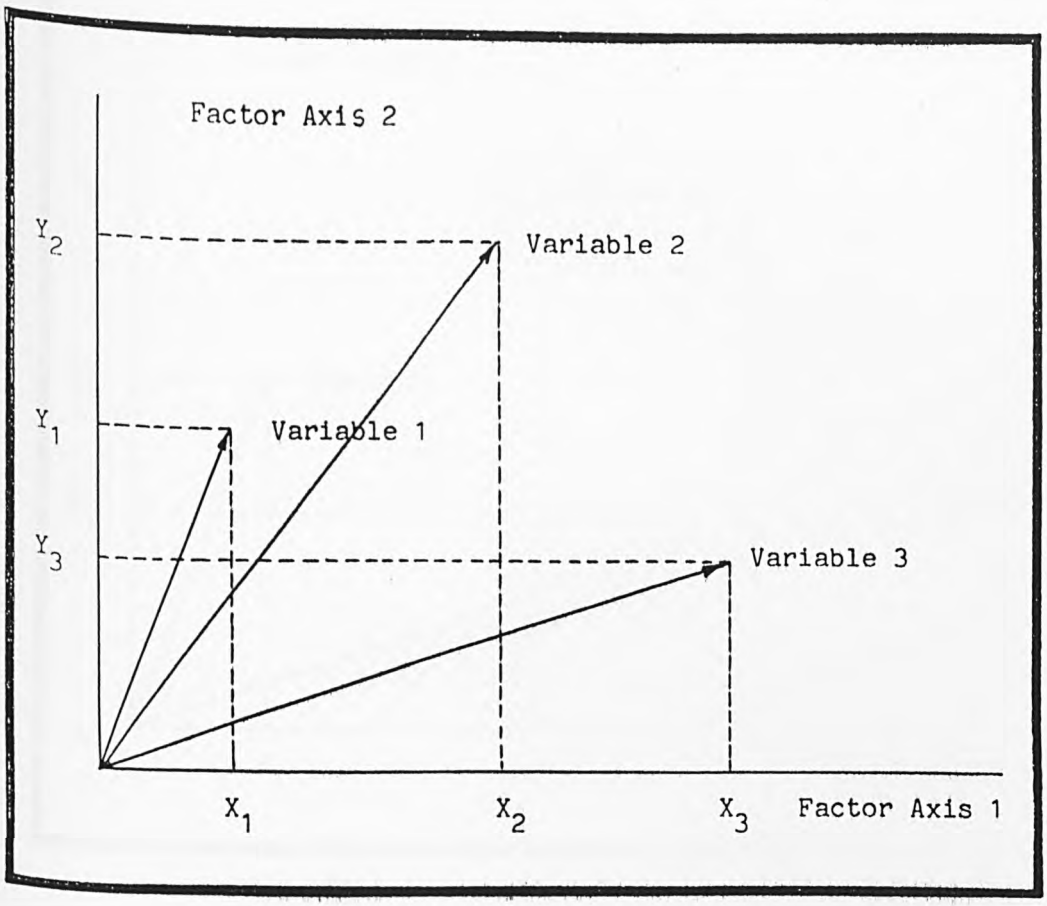


figure 6.9
Loadings on Factor Axis



1.5. Principle Factor Analysis Methodology

The basic model used in Factor Analysis is the Principal Factor method. The model is given by:

$$
\begin{aligned}
X_1 &= a_{11} S_1 + a_{12} S_2 + a_{13} S_3 + \ldots + a_{1p} S_p \\
X_2 &= a_{21} S_2 + a_{22} S_2 + a_{23} S_3 + \ldots + a_{2p} S_p \\
&\vdots \\
X_m &= a_{m1} S_1 + a_{m2} S_2 + a_{m3} S_3 + \ldots + a_{mp} S_p
\end{aligned}
\qquad (4.1)
$$

where S_i = factor dimension of data

p = dimensionality of data

a_{jn} = constants

X_j = data vector

The variables described by the vectors on the left hand side of the above equation are known. Geometrically they define a vector space. It is important to clarify at this stage that the term S_i on the right hand side are function of variables rather than pure variables. The unknown variables in each function S_i in the above equation are related in unknown ways although the functions themselves are linear. To be more specific, consider the equality of X_i in the above equation :

let

$$S_1 = f_1 \ (W_1 , W_2 , W_3 , \ldots , W_t) \qquad (4.2)$$

where $W_1 , W_2 , \ldots , W_t$ = unknown variables related to S

Substituting into equation (4.1):

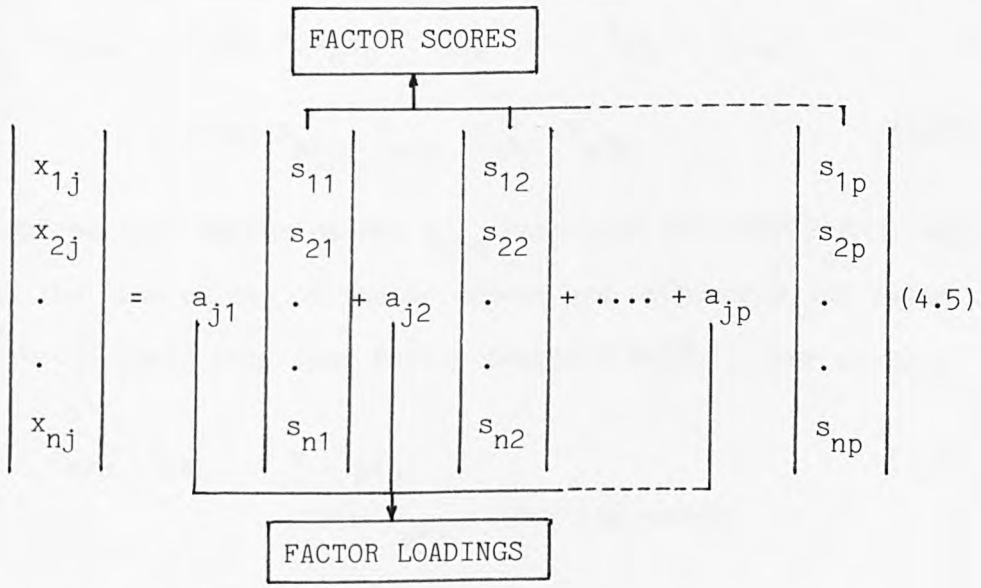
$$X_1 = a_{11} f_1 (W_1 , W_2 , \ldots , W_t) + a_{12} f_1 (W_1 , W_2 , \ldots , W_t)$$

$$+ \ldots\ldots\ldots + a_{13} f_1 (W_1 , W_2 , \ldots , W_t) \qquad (4.3)$$

Thus the Principal Factor Analysis defines the hypothetical unknown S_i functions related to variance components of variables. The constants a_{ij} are defined as 'loadings'. They represent the strength of relationship between that specific function to X_j. Thus the general form of equation (4.1) may be rewritten as:

$$X_j = a_{j1} S_1 + a_{j2} S_2 + a_{j3} S_3 + \ldots\ldots + a_{jp} S_p \qquad (4.4)$$

The purpose of Principal Factor Analysis therefore is to determine (a) the value of the loadings, (b) the relative scores which represent comparative indices. They can be obtained from:



normally, for cross sectional analysis, we can standardize the data, therefore the above equation becomes:

$$Z_{n*m} = S_{n*p} \; F'_{p*m} \qquad (4.6)$$

where Z_{n*m} = standardized X_{n*m}

S_{n*p} = factor score matrix

F_{p*m} = factor loading matrix

Recalling the basic matrix / statistics definition (3.8), we have

$$R_{m*m} = (1/n) \; Z'_{m*n} \; Z_{n*m} \qquad (4.7)$$

where R_{m*m} = correlation of m variables

Z_{n*m} = standardized data matrix

Z_{m*n} = inverse of standardized data matrix

m = number of variables

n = number of cases

Substituting equation (4.6) into (4.7), we have

$$R_{m*m} = (1/n) \; (S_{n*p} \cdot F'_{p*m}) \; (S_{n*p} \cdot F'_{p*m})$$

$$= (1/n) \; F_{m*p} \; S'_{p*n} \; S_{n*p} \; F'_{p*m} \qquad (4.8)$$

Assuming that factor scores S_{p*n} have been standardized by column and that the column of factor scores are orthogonal (to agree with the basic Principal Factor Analysis model), then we have

$$S'_{p*n} \; S_{n*p} = n \; I_{p*p} \qquad (4.9)$$

where I_{p*p} = identity matrix

the equation (4.8) can therefore be simplified into:

$$R_{m*m} = (1/n) \; F_{m*p} \; (n) \; I_{p*p} \; F'_{p*m}$$

$$R_{m*m} = F_{m*p} \; F'_{p*m} \qquad (4.10)$$

From (3.10), we see that for any symmetric matrix and Eigenvalues there may be an infinite number of associated Eigen vector matrices. There is at least one such matrix of associated Eigen vectors that is orthogonal (Hadley 8, pp. 241). The equation (4.10) is known as the fundamental derivation in Principal Factor model. It indicates that the factor loading F_{m*p} in the equation (5.4) can be determined by factoring variable's correlation matrix.

The problem of finding F_{m*p} is solved by determining Eigenvalues and Eigen vectors of the correlation matrix. Since R_{m*m} are symmetric, its Eigenvalues are therefore real numbers. The characteristic equation is given by:

$$R_{m*m} - L\, I_{m*m} = 0 \qquad (4.11)$$

where L = constant

R_{m*m} = correlation matrix

From earlier definition (3.13) and (4.11), combining with equation (4.10), we have,

$$R_{m*m} = L_{m*m} \; E_{m*m} \; E'_{m*m} \qquad (4.12)$$

$$= (E_{m*m} \; L_{m*m}^{1/2}) \; (L_{m*m}^{1/2} \; E'_{m*m})$$

$$= F_{m*p} \; F'_{p*m}$$

Therefore the value of factor score matrix S_{n*p} in the equation (4.6) can be obtained. In practice, we proceed with factoring R_{m*m} such that the residual variance in the correlation is small

or attributable only to random error. This measure is given by summing the factor variance for each factor. The variance for a factor itself is given by:

$$V_l = \left(\sum_{j=1}^{m} a_{jl}^2 \right) * 100 / m \quad \text{(percent)} \qquad (4.13)$$

where a_{jl} = factor loadings

m = number of variables

The commulative proportion of total variance is given by:

$$V = \sum_{l=1}^{p} V_l \qquad (4.14)$$

Apart from their geometric interpretation, the constant a_{jl} in matrix S_{n*p} have a useful descriptive interpretation. For orthogonal factors, these weights are the correlation of the variables with the factor scores. Thus for variable X_j on orthogonal factor S_l, a_{jl} is the product moment correlation between X_j and S_l ;

$$a_{jl} = r_{X_j S_l} \qquad (4.15)$$

Therefore the squared loadings for orthogonal factors measure the proportion of variance in the variables. This figure commonly known as Communality, it can be calculated from:

$$h_j^2 = a_{j1}^2 + a_{j2}^2 + a_{j3}^2 + \ldots\ldots + a_{jp}^2 \qquad (4.16)$$

It is customary in applied factor analysis to alter initial factor solution to a solution with more desirable properties.

In most cases the original unaltered solution is 'substansively uninteresting' (Rummel 4, pp. 372). The alteration involves a transformation consisting of rotation of the factor axes around the origin in a specific manner. There are a number of rotation methods available such as maximax, varimax, quartimax, covarimin, quartimin, and oblique (Harman, 5). However, only varimax which is accepted as the best rotation criteria is used (Harman, 5, pp. 311). The rotation itself can be represented as matrix transformation:

$$F^{*}_{m*p} = F_{m*p} \; T_{p*p} \qquad (4.17)$$

where F^{*}_{m*p} = rotated factor loading matrix

F_{m*p} = unrotated factor loading matrix

T_{p*p} = linear transformation for p factor

The rotation in this project is carried out using the varimax (Variance Maximum) criteria (Harman (5), and BMDP (6), pp. 670) to minimize:

$$G = \sum_{i=1}^{m} \left(\sum_{k=1}^{p} a_{ki}^{2} \; a_{kj}^{2} - (1/p)\left(\sum_{k=1}^{p} a_{ki}^{2}\right)\left(\sum_{k=1}^{p} a_{kj}^{2}\right)\right) \qquad (4.18)$$

where a_{ki} = factor loading for variable X_k on factor S_i

p = number of variables.

m = number of factors

2. Variables sources and definition.

1. Country names.

2. POPULA : Midyear estimate of Population.
   Measure total midyear populaton estimate.
   Unit : Thousand (000).
   Sources : United Nation Statistical Yearbook (UNSY) 1978, table 18, pp. 68-75, UNSY 1966, table 17, pp. 78-86.

3. YOUNPO : Young Population (0-14 years).
   Measure the number of young population age 0-14 years as percentage of total population.
   Unit : Percent.
   Sources : United Nation Demographic Yearbook (UNDY) 1975, table 7, pp. 188-223, UNDY 1968, table 7, pp. 190-277, World Tables (WT) 1980, pp. 436-441.

4. ADULPO : Adult Population (15-64 years).
   Measure the number of adult, working age population age between 15-64 years as percentage of total population.
   Unit : Percent.
   Sources : United Nation Demographic Yearbook (UNDY) 1975, table 7, pp. 188-223, UNDY 1968, table 7, pp. 190-277, World Tables (WT) 1980, pp. 436-441.

5. ELDEPO : Elder Population (65 years and over).
   Measure the older population aged 65 years and over as percentage of total population.
   Unit : Percent.
   Sources : United Nation Demographic Yearbook (UNDY) 1975, table 7, pp. 188-223, UNDY 1968, table 7, pp. 190-277, World Tables (WT) 1980, pp. 436-441.

6. POPDEN : Population Density.
   Measure the number of population per square kilometer of total land.
   Unit : No. of people per square land.
   Sources : UNSY 1978, table 18, pp. 68-75, UNSY 1966, table 17, pp. 78-86, WT 1980, pp. 436-441.

7. URBAPO : Urban Population.
   Measure the number of inhibitants of cities and towns as percentage of total population.
   Unit : Percent.
   Sources : WT 1980, pp. 436-441, UNDY 1975, pp. 167-180.

8. BIRTRT : Crude Birth Rate.
   Measure the number of live births in a year per thousand of midyear population.
   Unit : No. of birth per thousand.
   Sources : UNSY 1978, table 19, pp. 80-85, UNSY 1972,

table 18, pp. 93-96, UNSY 1967, table 19, pp. 97-99, WT 1980, pp. 442-447.

9. MORTAL : Crude Death Rate.
Measure the number of deaths in a year per thousand of midyear population.
Unit : No. of death per thousand.
Sources : UNSY 1978, table 19, pp. 80-85, UNSY 1972, table 19, pp. 89-94, UNSY 1967, table 19, pp. 97-99, WT 1980, pp. 442-447.

10. LIFEXP : Life Expectancy at Birth.
Measure the average number of years of life to a newborn child if subject to the mortality risks prevailing for a cross section of the population at the time of birth.
Unit : Years.
Sources : UNSY 1978, table 19, pp. 80-85, UNSY 1972, table 19, pp. 89-94, UNSY 1967, table 19, pp. 97-99, WT 1980, pp. 442-447.

11. PHYSIC : Population per Physician.
Measure the number of population devided by the number of practicing physicians qualified from medical school at university level.
Unit : Years.
Sources : UNSY 1978, table 207, pp. 893-897, UNSY 1973, table 197, pp. 719-723, UNSY 1968, table 206, pp. 701-705, UNSY 1964, table 184, pp. 648-651, WT 1980, pp. 442-447.

12. NURSES : Population per Nursing persons.
Measure the number of population devided by the number of practicing female and male nurses, practical nurses, and assistant nurses.
Unit : No. of persons.
Sources : UNSY 1978, table 207, pp. 893-897, UNSY 1973, table 197, pp. 719-723, UNSY 1968, table 206, pp. 701-705, UNSY 1964, table 184, pp. 648-651, WT 1980, pp. 442-447.

13. HOSPIT : Population per hospital bed
Measure the number of population devided by the number of hospital beds made available by public and private general, specialized hospital and rehabilitation centres. Hospitals included are establishments permanently staffed by at least one physician, except in rural areas where health and medical centres are staffed by a medical assistant, nurses, or a midwife, but not a physician, and that offer in patient accomodation and a limited range of medical facilities. Establishments providing principally custodical or preventive care are not included.
Unit : No. of hospital beds.

Sources : UNSY 1978, table 207, pp. 893-897, UNSY 1973, table 197, pp. 719-723, UNSY 1968, table 206, pp. 701-705, UNSY 1964, table 184, pp. 648-651, WT 1980, pp. 442-447.

14. CALORY : Calorie supply per capita.
Computed from the energy equivalent of per capita net food supplies available in the country per day and expressed as a percentage of the estimated requirement. Available supplies comprise domestic production, imports less exports, and changes in stocks. Net supplies exclude animal feed, seeds, quantities used in food processing and losses in distribution. The FAO has estimated the requirement on the basis of physiological needs for normal activity and health, taking into consideration environmental temperature, body weight, age and sex distributions of the population in the various countries, and allowing the waste at household level.
Unit : Percent.
Sources : WT 1980, pp. 448-453.

15. INMOR : Infant Mortality rate.
Measure the annual death rate per thousand children in the 1-4 age group.
Unit : Thousand of life birth.
Sources : UNSY 1978, table 19, pp. 80-85, UNSY 1972, table 18, pp. 93-96, UNSY 1967, table 19, pp. 97-99, WT 1980, pp. 442-447.

16. PRIMA : Total primary school enrollment ratio.
Measure the enrollment of all ages in primary schools as a percentage of the population of primary school age, which normally cover all children aged 6-11 years. For countries with universal education, the enrollment ratio may exceed 100 percent because some pupils are below or above the official school age.
Unit : Constant.
Sources : UNESCO Statistical Yearbook 1980, table 3.2, pp. 153-216, UNESCO 1973, table 3.2, pp. 143-160, UNESCO 1966, table 2.7, pp. 90-108, WT 1980, pp. 454-459.

17. SECOND : Secondary school enrollment ratio (total).
Measure the enrollment of all ages in secondary schools as a percentage of the population of school age. Secondary school require at least four years of approved primary instruction, and typically it provides general or vocational instruction for those in the 12-17 age group.
Unit : Constant.
Sources : UNESCO 1980, table 3.2, pp. 153-216, UNESCO 1973, table 3.3, pp.161-168, UNESCO 1966,

table 2.8, pp. 109-145.

18. PRIRAT : Primary Student Teacher Ratio.
Measure the total number of students enrolled in primary schools devided by the total number of teachers employed by those schools.
Unit : Constant.
Sources : UNESCO 1980, table 3.4, pp. 233-260, UNESCO 1973, table 3.2, pp. 143-160, UNESCO 1966, table 2.8, pp. 90-108.

19. LITER : Adult Literacy Rate.
Measure the number of adults with the ability to both read and write expressed as a percentage of the total adult population aged 15 or over.
Unit : Percent.
Sources : UNESCO 1980, table 1.3, pp. 44-55, UNESCO 1973, table 1.4, pp. 35-51, UNESCO 1965, table 3, pp. 32-35.

20. LABOUR : Total Labour Force.
Measured in thousands, include all economically active persons, including those in the armed forces and unemployed, but excluding housewives, students, and other inactive groups.
Unit : Thousand (000).
Sources : International Labour Statistic (ILO) 1980, table 1, pp. 15-31, ILO 1977, table 1, pp. 9-43, ILO 1974, table 1, pp. 9-45, ILO 1972, table 1, pp. 9-51, WT 1980, pp. 460-465.

21. PWOLAB : Women in Labour Force.
Measure the number of female in labour force as a percentage of labour force.
Unit : Percent.
Sources : International Labour Statistic (ILO) 1980, table 1, pp. 15-31, ILO 1977, table 1, pp. 9-43, ILO 1974, table 1, pp. 9-45, ILO 1972, table 1, pp. 9-51, WT 1980, pp. 460-465.

22. PAGLAB : Agriculture Labour Force.
Measure the number of labour force in agriculture activities, including farming, forestry, hunting and fishing, as percentage of total labour force.
Unit : Percent.
Sources : ILO 1980, table 2a, pp. 32-79, ILO 1977, table 2a, pp. 52-167, ILO 1974, table 2a, pp. 46-141, ILO 1972, table 2a, pp. 44-149, WT 1980, pp. 460-465.

23. PINLAB : Industry Labour Force.
Measure the number of labour force for industry as a percentage of total labour force. Industrial activity includes mining and quarring, manufacturing, construction, and public utilities

(electricities, gas, water and sanatary services).
Unit : Percent.
Sources : ILO 1980, table 2a, pp. 32-79, ILO 1977, table 2a, pp. 52-167, ILO 1974, table 2a, pp. 46-141, ILO 1972, table 2a, pp. 44-149, WT 1980, pp. 460-465.

24. RADIO : Number of Radio per thousand population.
Measure the number of all types of receivers for radio broadcasts to general public (including speakers connected to general redistribution system, but excluding unlisenced receivers in countries and years when registration of radio sets in effect) per thousand population.
Unit : Radios per thousand population.
Sources : UNSY 1978, table 215, pp. 950-954, UNSY 1974, pp. 863-867, UNSY 1970, pp. 802-806.

25. CARS : Number of passenger cars per thousands population.
Measure the motor cars seating less than eight persons (including taxis, station wagons, but excluding ambulances, hearses, and military vehicles) per thousand population.
Unit : Cars per thousand population.
Sources : UNSY 1978, table 158, pp. 545-551, UNSY 1974, table 153, pp. 435-441, UNSY 1970, table 148, pp. 422-428.

26. INVGDP : Investment per Gross Domestic Product.
Measure the outlay for addition of reproducible capital goods to the fixed assets of private and public enterprises, private non profit institutions, and general government (reduced by their net sales of used or scrapped capital goods) and the value of the net increase or decrease of the inventories. This category includes all new items produced domestically or purchased from abroad, as well as all imported secondhand goods. It also covers all new dwellings (including those acquired by owner-occupants), expenditures on the improvement of durable goods and nonreproducible tangible assets (such as land, mineral deposits, plantations, orchards, wineyards and the like), and addition to lifestock herds. Dealers' margin and other transfer cost arising from sales or purchases of land and other of nonreproducible tangible assets and of used equipment included. Government outlays for construction and durable goods for military purposes are excluded. The definition of GDP is on described later (var. no. 50).
Unit : Percent.
Sources : WT 1980, table 3, pp.384-389.

27. GOVCON : Government Consumption.
Measure all current expenditure for purchase of

goods and services by government bodies: that is, central, regional, and local governments; seperately operated social security funds; and international authorities that exercise tax or governmental expenditure functions within the national territory. It includes of public non financial enterprises and public financial institutions. The current expenditure of general government covers outlays for compensation of employees, purchase of goods, and services from other sector of the economy, military equipment, and other purchase from abroad. Capital expenditure for national defense is trated as consumption, whereas all expenditure on capital formation is included in gross domestic inverstment.
Unit : Million own currency.
Sources : WT 1980, table 3, pp.384-389.

28. EXPGDP : Exports of Goods as percent of GDP.
Measure the value of goods and services sold to the rest of the world.
Unit : Percent.
Sources : WT 1980, table 3, pp.384-389.

29. IMPGDP : Imports of Goods as percent of GDP.
Measure the value of goods and services purchased from the rest of the world. Included in the goods and services are merchandise, transport, travel, insurance and other non factor services. Generally the value of military equipment transferred between government are excluded.
Unit : Percent.
Sources : WT 1980, table 3, pp.384-389.

30. GDPAGR : Gross Domestic Product from Agriculture origin.
Measure the GDP obtained from corresponding International Standard Industrial Classification (ISIC) division 0, this includes agriculture, forestry, hunting and fishing.
Unit : Percent.
Sources : WT 1980, table 4, pp. 390-395.

31. GDPMAN : Gross Domestic Product from Manufacturing.
Measure the GDP obtained from corresponding International Standard Industrial Classification (ISIC) division 2 and 3.
Unit : Percent.
Sources : WT 1980, table 4, pp. 390-395.

32. GDPOTH : Gross Domestic Product from Other Industry.
Measure the GDP obtained from corresponding International Standard Industrial Classification (ISIC) division 1, 4, 6, 8, 9, 11.
Unit : Percent.
Sources : WT 1980, table 4, pp. 390-395.

33. GDPSER : Gross Domestic Product from Services.
Measure the GDP obtained from corresponding International Standard Industrial Classification (ISIC) division 5.
Unit : Percent.
Sources : WT 1980, table 4, pp. 390-395.

34. XFOOD : Export of Food and Beverages.
Measure the amount of export included in Standard International Trade Classification (SITC) division (0) food, (1) beverages and tobacco, (22) oilseeds, oil nuts, and oil kernels, and (4) animals and vegetable oils and fats.
Unit : Percent of total export.
Sources : WT 1980, table 5, pp. 396-401.

35. XAGRI : Export of Nonfood Agriculture Goods.
Measure the amount of export included in Standard International Trade Classification (SITC) division (2) crude materials, inedible, except fuels (excluding (22) oilseeds, oil nuts, oil kernel, (27) crude fertilizers and crude minerals, and (28) metalliferous ores and metal scrap).
Unit : Percent of total export.
Sources : WT 1980, table 5, pp. 396-401.

36. XFUEL : Export of Fuels, Mineral and Metal.
Measure the amount of export included in Standard International Trade Classification (SITC) division (3) mineral fuels, lubricants, and related materials, (27) crude fertilizers and crude minerals, (28) metalliferrous ores and metal scrap, and (68) nonferrous metals.
Unit : Percent of total export.
Sources : WT 1980, table 5, pp. 396-401.

37. XMACHI : Export of Machinery and Equipment.
Measure the amount of export including in Standard International Trade Classification (SITC) division (7) machinery and transport equipment.
Unit : Percent of total export.
Sources : WT 1980, table 5, pp. 396-401.

38. XOTHER : Export of Other Manufacturing Goods.
Measure the amount of export included in SITC division (5) chemicals, (6) manufactured goods, classified chiefly by materials (excluding (68) nonferrous metals), (8) miscellaneous manufactured articles, and (9) commodities and transactions not classified according to kind.
Unit : Percent of total export.
Sources : WT 1980, table 5, pp. 396-401.

39. IFOOD : Import of Food and Beverages.
Measure the amount of import included in SITC

division (0) food, (1) beverages and tobacco, (22) oilseeds, oil nuts, and oil kernels, and (4) animals and vegetable oils and fats.
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

40. INFUEL : Import of Nonfuel minerals and Metals.
Measure the amount of import included in SITC division (27) crude fertilizers and crude minerals, (28) metaliferrous ores and metal scrap, and (68) nonferrous metal.
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

41. IMACHI : Import of Machinery and Equipment.
Measure the amount of import included in SITC division (7) machinery and transport equipment.
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

42. IFUEL : Import of Fuels.
Measure the amount of import included in SITC division (3) mineral fuels, lubricants, and related materials.
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

43. IOTHER : Import of Other Manufactured Goods.
Measure the amount of import included in SITC division (5) chemicals, (6) manufactured goods, classified chiefly by material (excluding (68) nonferrous metals), (8) miscellaneous manufactured articles, and (9) commodities and transactions not classified according to kind.
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

44. IAGRI : Import of Nonfood Agriculture.
Measure the amount of import included in SITC division (2) crude materials, inedible, except fuels (excluding (22) oilseeds, oil nuts, oil kernels, (27) crude fertelizers, crude minerals, and (28) metalliferrous ores and metal scrap).
Unit : Percent of total import.
Sources : WT 1980, table 6, pp. 402-407.

45. SAVERT : Average National Saving Rate.
Expressed a percentage of GNP at current market price.
Unit : Percent.
Sources : WT 1980, table 9, pp. 420-425.

46. SECTEC : Secondary School Student Teacher Ratio.
Measure the total number of students enrolled in secondary schoo<£p45&945d by the total number of

teachers employed in those schools.
Unit : Constant.
Sources : UNESCO 1980, table 3.7, pp. 308-382, UNESCO 1973, table 3.2, pp. 143-160, UNESCO 1966, table 2.8, pp. 308-382.

47. VOCATE : Vocational Enrollment.
Measure the enrollment in vocational institutions as a percentage of secondary school enrollment. Vocational institutions include technical, industrial, or other programs that operate independantly or as departments of secondary institutions.
Unit : Constant.
Sources : UNESCO 1980, table 3.7, pp. 308-382, UNESCO 1973, table 3.2, pp. 143-160, UNESCO 1966, table 2.8, pp. 308-382.

48. LOINCO : percentage of lowest income received.
Measure the income received by the poorest 20 percent of households as percentage of total income of all households.
Units : percent.
Sources : WT 1980, pp. 460-465.

49. HIINCO : percentage of highest income received.
Measure the income received by the richest 5 percent of households as percentage of total income of all households.
Units : percent.
Sources : WT 1980, pp. 460-465.

50. GNPTOT : Gross Domestic Product (GDP).
Measure the total final output of a country's economy, that is all goods and services rendered within its territory by residents and non residents, without regards to its allocation among domestic and foreign claims. Its value is calculated before deductions are made for depreciation and other capital consumption allowance.
Unit : Million US$.
Sources : World Bank Atlas (WBA) 1978, WT 1980, WBA 1976, WBA 1973, International Monetary Fund Yearbook (IMF) 1980, UNSY 1966, UNSY 1962.

51. GNPUS : GNP per Capita in US$.
Measure the estimated GNP per capita by World Bank, where some adjustment have been made to ensure cross sectional comparability. The figures indicate the value in US$.
Unit : US$.
Sources : World Bank Atlas (WBA) 1978, WT 1980, WBA 1976, WBA 1973, International Monetary Fund Yearbook (IMF) 1980, UNSY 1966, UNSY 1962.

52. ENECAP : Energy consumed percapita
Measure the amount of energy consumed percapita in term of kg. of coal equivalent.
Unit : kg. of coal equivalent
Sources : United Nation Energy Supplies (UNES) 1973-1978 (1978), UNES 1950-1974 (1975).

53. TRACTR : Tractors in use.
Measure the actual total number of tractors in use.
Unit : no. of tractors.
Sources : UNSY 1980, table 25, pp. 100-103, UNSY 1968, table 27, pp. 112-115.

54. NEWS : Newspaper consumption per capita.
Measure the number of newspaper circulation percapita.
Unit : kg. per habitant.
Sources : UNSY 1978, table 173, pp. 625-654, UNSY 1970, table 179, pp. 542-543.

55. THIEDU : Third level education.
Measure the number of of third level enrollment per 100 000 inhibitants.
Units : persons per 100 000 inhibitants.
Sources : UNESCO 1980, table 3.10, pp. 423-431, UNESCO 1973, table 4.1, pp. 273-283, UNESCO 1966, table 2.14, pp. 244-250.

56. TELEPO : Number of telephones.
Measure the number of telephones per 100 inhibitants.
Units : number of telephones per 100 inhibitants.
Sources : UNSY 1978, table 167, pp. 627-630, UNSY 1974, table 163, pp. 533-536, UNSY 1970, table 159, pp. 500-503.

57. EDUEXP : Educational expenditure.
Measure the amount of educational expenditure in term of total GNP at current market cost.
Units : percent.
Sources : UNESCO 1980, table 4.1, pp. 659-683, UNESCO 1973, table 5.1, pp. 405-406, UNESCO 1966, table 2.16, pp. 255-284.

58. AREA : Total land area.
Measure the total land area of the country.
Units : square kilometers.
Sources : UNSY 1978, table 18, pp. 68-75.

Appendix 3: Description of Data Distribution, Extreme Values and Data Transformation (1960)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
2.	PUPULA1	log(x)	28847	80867	23.4	74.0	China (639422), India (434850)	3.967	0.571	2.77	1.55
3.	YOUNPO1		38.49	7.818	-3.38	-1.59		38.49	7.818	-3.38	-1.59
4.	ADULPO1		56.65	5.10	2.50	-2.19		56.65	5.10	2.50	-2.19
5.	ELDEPO1		4.82	3.09	4.89	0.29		4.82	3.09	4.89	0.29
6.	POPDEN1	ln(x)+10	115.94	405.8	26.35	85.40	Hongkong (3100), Singapore (2667)	3.84	1.109	4.82	3.79
7.	URBAPO1		36.23	24.63	2.17	-1.48		36.23	24.63	2.17	-1.48
8.	BIRTRT1		38.25	12.69	-2.73	-2.54		38.25	12.69	-2.37	-2.54
9.	MORTAL1		17.20	7.40	0.71	-2.98		17.2	7.40	0.71	-2.98
10.	LIFEXP1		52.57	12.95	0.67	-3.12		52.57	12.95	0.67	-3.12
11.	PHYSIC1	log(x)	15127	24724	10.52	15.88	Rwanda (144000)	3.66	0.69	1.43	-2.37
12.	NURSES1	log(x)	6470	14896	21.97	63.35	Bangladesh (104549), Nepal (99164)	3.37	0.60	0.42	-0.84
13.	HOSPIT1	log(x)	945.34	1543	17.04	42.81		2.66	0.51	1.23	-1.31
14.	CALORY1		100.19	16.79	1.64	-1.91		100.19	16.67	1.64	-1.91
15.	INMORT1		124.42	75.51	0.26	-2.38		124.42	75.51	0.26	-2.38
16.	PRIMA1		72.20	35.67	-1.31	-2.13		72.20	35.67	-1.31	-2.13
17.	SECOND1		22.18	22.43	4.11	-0.18		22.18	22.43	4.11	-0.18
18.	PRIRAT1	sq(x)	36.55	12.05	6.56	9.79	Mozambique (95)	5.97	0.93	3.52	3.94
19.	LITER1		50.65	35.34	0.18	-3.19		50.65	35.34	0.18	-3.19
20.	LABOUR1	log(x)	12534	39117	25.20	85.76	China (324491), India (188670)	3.55	0.58	3.04	1.79
21.	PWOLAB1		28.14	12.86	-0.64	-2.00		28.14	12.86	-0.64	-2.0
22.	PAGLAB1		55.94	28.05	-1.43	-2.30		55.94	28.05	-1.43	-2.30
23.	PINLAB1		19.36	14.34	2.56	-1.65		19.36	14.34	2.56	-1.65
24.	RADIO1	log(x)*100	100.42	136.64	11.45	25.50	USA (941)	3.53	0.75	-1.38	-2.02
25.	CARS1	ln(x)+1	27.13	56.38	13.61	25.29	USA (344)	2.13	1.44	3.04	-0.86
26.	INVGDP1		17.40	6.99	2.34	1.01	Algeria (41.9)	17.40	6.99	2.34	1.01
27.	GOVCON1	sq(x)	11.36	4.60	5.90	10.81	Papua N. Guinea (35)	3.30	0.66	1.43	3.50
28.	EXPGDP1	ln(x)	23.36	19.89	16.04	46.44	Singapore (163.1)	2.91	0.69	-1.17	2.61

Description of Data Distribution, Extreme Values and Data Transformation (1960)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
29.	IMPGDP1	ln(x)	24.55	19.65	21.02	72.01	Singapore (177.1) Hongkong (97.2)	3.30	0.55	0.73	3.97
30.	GDPAGR1		29.64	18.57	2.31	-1.14		18.45	13.91	5.03	2.47
31.	GDPMAN1	sq(x)	18.45	13.91	5.03	2.47		3.99	1.58	1.32	-0.34
32.	GDPOTH1	ln(x)*10	10.98	10.61	14.28	28.10		4.47	0.64	1.93	4.22
33.	GDPSER1		40.88	13.34	-2.28	0.55		40.88	13.34	-2.28	0.55
34.	XFOOD1		41.45	29.36	0.99	-2.63		41.45	29.36	0.99	-2.36
35.	XAGRI1	ln(x)+10	18.46	18.87	5.63	3.08		3.16	0.59	1.72	-1.91
36.	XFUEL1	ln(x)+1	16.07	25.03	9.38	8.64		2.04	1.25	1.10	-1.46
37.	XMACHI1	ln(x)+1	6.63	11.53	7.37	4.44		1.11	1.26	3.78	-1.42
38.	XOTHER1	ln(x)+1	17.58	19.39	4.48	0.27		2.26	1.23	-0.14	-2.65
39.	IFOOD1	ln(x)+10	18.42	10.40	12.79	34.51	Yemen (87)	3.29	0.29	3.49	4.45
40.	INFUEL1	sq(x)	4.32	4.44	6.97	4.38		1.85	0.94	3.58	0.41
41.	IMACHI1		25.82	8.72	1.37	1.60		25.82	8.72	1.37	1.60
42.	IFUEL1		8.21	4.01	1.91	0.79		8.21	4.01	1.91	0.79
43.	IOTHER1		34.78	12.34	0.60	0.63		34.78	12.34	0.6	0.63
44.	IAGRI1	sq(x)	5.81	5.70	6.36	4.22		2.15	1.09	2.85	-0.44
45.	SAVERT1	sq(x+9)-3	15.09	9.28	2.10	0.83		1.81	0.96	-0.6	0.49
46.	SECTEC1		18.83	6.39	3.73	1.65		18.83	6.39	3.73	1.60
47.	VOCATE1	sq(sq(x))	22.87	19.40	5.18	2.27		2.02	0.50	-1.18	-0.48
48.	LOINCO1		5.12	1.26	-2.6	-0.08		5.12	1.26	-2.6	-0.08
49.	HIINCO1		26.0	6.68	0.46	-1.64		26.0	6.68	0.46	-1.64
50.	GNPTOT1	log(x)	32387	113135	30.47	127.7	USA (1048935)	0.561	0.091	0.02	-1.50
51.	GNPUS1	log(x)	1163	1546	7.86	6.23		2.74	0.52	1.49	-1.92
52.	ENECAP1	log(x)	1069	1777	10.97	17.6	Kuwait (10396)	2.41	0.83	-0.64	-1.78
53.	TRACTR1	log(x)	122693	512060	31.21	131.38	USA (4751600)	3.61	1.43	-1.45	-1.03
54.	NEWS1	ln(x)+1	4.31	7.58	9.76	10.72		1.03	1.02	3.84	-0.52
55.	THIEDU1	sq(x)	272.0	323.5	8.32	13.15	USA (1984)	13.46	9.57	2.08	-0.77
56.	TELEPO1	log(x)+10	1480	7833	37.25	174.19	USA (77422)	2.11	0.86	2.85	-0.53
57.	EDUEXP1	log(x)	3.35	1.59	1.19	-1.22		3.35	1.59	1.19	-1.22
58.	AREA1		1216.7	2912.7	19.68	56.65	USSR (22402)	2.50	0.75	-2.17	3.17

Appendix 3: Description of Data Distribution, Extreme values, and Data Transformation (1965)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
2.	PUPULA2	log(x)	28847	80867	23.59	74.40	China (705973), India (487324)	4.01	0.56	3.12	1.45
3.	YOUNPO2		38.49	7.81	-3.24	-1.98		38.47	8.18	-3.24	-1.98
4.	ADULPO2		56.66	5.10	-0.91	7.94		56.39	6.29	-0.91	7.94
5.	ELDEPO2		4.82	3.09	4.79	-0.04		5.08	3.38	4.79	-0.04
6.	POPDEN2	ln(x)+10	115.9	405.8	26.40	85.34	Hongkong (3477), Singapore (3055)	3.91	1.12	4.70	3.80
7.	URBAPO2		36.23	24.64	1.69	-1.80		38.82	24.96	1.69	-1.80
8.	BIRTRT2		38.25	12.69	-2.23	-2.86		36.65	12.86	-2.23	-2.86
9.	MORTAL2		17.20	7.40	1.47	-2.17	Niger (34)	15.77	6.75	1.47	-2.17
10.	LIFEXP2		52.57	12.95	0.28	-3.18		54.42	12.64	0.28	-3.18
11.	PHYSIC2	log(x)	15127	24724	9.27	10.11		3.61	0.67	1.44	-2.37
12.	NURSES2	log(x)	6470	14896	21.83	62.75	Bangladesh (86779), Nepal (82310)	3.29	0.61	0.50	-1.00
13.	HOSPIT2	log(x)	9445	1543	16.45	39.34	Bangladesh (9451), Nepal (7408)	2.64	0.49	.21	-1.27
14.	CALORY2		100.1	16.79	1.33	-2.24		102.5	16.73	1.33	-2.24
15.	INMORT2		124.4	75.51	0.13	-2.43		105.2	64.11	0.13	-2.43
16.	PRIMA2		72.21	35.67	-2.25	-1.83		76.27	32.65	-2.25	-1.83
17.	SECOND2		22.18	22.43	3.17	-1.23		26.89	24.51	3.17	-1.23
18.	PRIRAT2	sq(x)	36.56	12.05	4.35	4.03	Mozambique (82)	5.90	0.92	2.19	1.02
19.	LITER2		50.65	35.34	-0.09	-3.20		53.15	34.61	-0.09	-3.20
20.	LABOUR2	log(x)	12534	39117	25.33	86.46	China (352631), India (206890)	3.59	0.58	3.28	1.81
21.	PWOLAB2		28.14	12.86	-1.14	-1.79		28.91	12.54	-1.14	-1.79
22.	PAGLAB2		55.94	28.05	-1.01	-2.51		52.85	28.39	-1.01	-2.51
23.	PINLAB2		19.36	14.34	2.56	-1.30		20.66	14.70	2.56	-1.30
24.	RADIO2	log(x)*100	100.4	136.6	13.12	33.02	USA (1153)	3.69	0.65	-0.95	-2.23
25.	CARS2	ln(x)+1	27.13	56.38	11.06	16.24	USA (386)	2.43	1.51	2.39	-1.46
26.	INVGDP2		17.40	6.99	-0.08	-1.90		18.61	6.75	-0.08	-1.90
27.	GOVCON2	sq(x)	11.36	4.60	3.95	5.18	Papua N Guinea (327)	3.45	0.64	0.81	1.57

Description of Data Distribution, Extreme values, and Data Transformation (1965)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
28.	EXPGDP2	ln(x)	23.36	19.89	11.11	22.46	Singapore (123.5) Hongkong (79.6)	2.94	0.65	-0.98	2.20
29.	IMPGDP2	ln(x)	24.55	19.65	14.88	40.75	Singapore (135.5) Hongkong (91.5)	3.07	0.54	-0.77	3.02
30.	GDPAGR2		29.64	18.57	2.25	-1.13		27.31	17.51	2.25	-1.13
31.	GDPMAN2	sq(x)	18.46	13.91	5.66	3.80		4.14	1.47	2.10	0.13
32.	GDPOTH2	ln(x)*10	10.99	10.61	14.85	32.28	Kuwait (69.4)	2.33	0.53	3.43	4.25
33.	GDPSER2		40.88	13.34	-2.84	0.34		42.16	12.39	-2.84	0.34
34.	XFOOD2		41.45	29.36	1.06	-2.67		38.89	28.59	1.06	-2.67
35.	XAGRI2	ln(x)+10	18.46	18.87	6.25	4.34	Chad (80.1), Bangladesh (80)	3.11	0.57	2.12	-1.53
36.	XFUEL2	ln(x)+1	16.07	25.03	8.62	6.83		2.18	1.22	0.95	-1.40
37.	XMACHI2	ln(x)+1	6.63	11.53	7.03	3.76		1.19	1.27	3.52	-1.65
38.	XOTHER2	ln(x)+1	17.58	19.39	3.73	-0.85	Hongkong (80.7)	2.41	1.23	-0.64	-2.50
39.	IFOOD2	ln(x)+10	18.42	10.40	10.32	22.96	Yemen (75)	3.29	0.29	2.60	3.49
40.	INFUEL2	sq(x)	4.32	4.44	5.77	3.68	Japan (17.3)	1.74	0.80	2.75	-0.76
41.	IMACHI2		25.82	8.72	-0.34	-0.51		26.90	8.53	-0.34	-0.51
42.	IFUEL2		8.21	4.01	4.19	3.25		7.32	4.23	4.19	3.25
43.	IOTHER2		34.78	12.34	-0.04	0.44	Afghanistan (43.2)	37.27	10.67	-0.04	0.44
44.	IAGRI2	sq(x)	5.81	5.70	5.62	4.10		2.10	0.96	1.52	-0.69
45.	SAVERT2	sq(x+9)-3	15.09	9.28	2.39	1.43	Kuwait (49.7)	1.89	0.94	0.00	-0.12
46.	SECTEC2		18.84	6.39	2.71	1.39		18.83	5.44	2.17	1.39
47.	VOCATE2	sq(sq(x))	22.87	19.40	5.47	2.83		1.99	0.48	-0.22	-1.21
48.	LOINCO2		5.13	1.26	-1.65	-0.08		4.98	1.23	-1.65	-0.08
49.	HIINCO2		26.00	6.68	0.39	-1.51		25.12	6.62	0.39	-1.51
50.	GNPTOT2	log(x)	32387	113135	29.58	121.7	USA (1319720)	0.57	0.09	-0.22	-1.48
51.	GNPUS2	log(x)	1163	1546	7.69	5.77		2.80	0.55	1.19	-2.07
52.	ENECAP2	log(x)	1069	1777	7.80	6.90	USA (9175)	2.51	0.81	-0.40	-2.11
53.	TRACTR2	log(x)	122693	512060	27.97	106.9	USA (4684831)	3.74	1.39	-1.49	-1.00
54.	NEWS2	ln(x)+1	4.31	7.58	8.75	7.95		1.13	1.08	3.19	-1.31
55.	THIEDU2	sq(x)	272.0	323.5	8.01	10.13	USA (2840)	16.78	11.73	2.49	-0.54

Description of Data Distribution, Extreme values, and Data Transformation (1965)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
56.	TELEPO2	log(x)+10	1480	78.33	36.24	167.23	USA (93695)	2.22	0.89	2.54	-0.81
57.	EDUEXP2	log(x)	3.35	1.59	0.27	-1.45		3.54	1.50	0.27	-1.45
58.	AREA2		1216	2912	19.68	56.65	USSR (22402)	2.50	0.75	-2.12	3.17

Appendix 3: Description of Data Distribution, Extreme values, and Data Transformation (1970)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
2.	PUPULA3	log(x)	34908	98164	23.67	74.52	China (771840), India (547596)	4.06	0.55	3.33	1.39
3.	YOUNPO3		38.44	8.73	-3.03	-2.24		38.44	8.73	-3.03	-2.24
4.	ADULPO3		55.70	7.59	-12.64	43.55		55.70	7.59	2.34	-2.00
5.	ELDEPO3		5.34	3.71	4.61	-0.33		5.34	3.71	4.61	-0.33
6.	POPDEN3	ln(x)+10	143.5	519.4	26.43	85.27	Hongkong (3900), Singapore (3500)	3.99	1.13	4.71	3.99
7.	URBAPO3		41.72	25.30	1.21	-2.09		41.72	25.30	1.21	-2.09
8.	BIRTRT3		35.45	13.30	-1.76	-3.10		35.45	13.30	-1.76	-3.10
9.	MORTAL3		14.66	6.49	3.63	2.72	Niger (42)	14.66	6.49	3.63	2.72
10.	LIFEXP3		56.65	12.13	-0.09	-3.19		56.65	12.13	-0.09	-3.19
11.	PHYSIC3	log(x)	11210	17916	9.61	11.24		3.56	0.66	1.48	-2.31
12.	NURSES3	log(x)	4603	10368	21.25	60.05	Bangladesh (72030), Nepal (68320)	3.21	0.62	0.57	-1.14
13.	HOSPIT3	log(x)	799.8	1224	15.71	35.40	Bangladesh (8120), Nepal (6750), Afghanistan (5240)	2.61	0.49	1.14	-1.26
14.	CALORY3		104.5	17.50	0.53	-2.32		104.5	17.50	0.53	-2.32
15.	INMORT3		89.16	54.48	0.01	-2.49		89.16	54.48	0.01	-2.49
16.	PRIMA3		79.81	31.30	-2.66	-1.47		79.81	31.30	-2.66	-1.47
17.	SECOND3		33.57	27.61	2.61	-1.78		33.57	27.61	2.61	-1.78
18.	PRIRAT3	sq(x)	34.67	11.61	2.82	0.55		5.80	0.97	1.20	-0.73
19.	LITER3		56.42	33.64	-0.36	-3.16		56.42	33.64	-0.36	-3.16
20.	LABOUR3	log(x)	14784	46091	25.43	87.02	China (383212), India (226870)	3.64	0.57	3.47	1.93
21.	PWOLAB3		29.68	12.32	-1.63	-1.59		29.68	12.32	-1.63	-1.59
22.	PAGLAB3		49.75	28.89	-0.62	-2.69		49.75	28.89	-0.62	-2.69
23.	PINLAB3		21.36	14.10	1.85	-1.91		21.36	14.10	1.85	-1.91
24.	RADIO3	log(x)*100	148.2	191.5	13.95	35.94	USA (1412)	3.84	0.58	-1.03	-1.85
25.	CARS3	ln(x)+1	53.89	89.23	8.28	7.31	USA (433)	2.76	1.60	1.87	-2.09
26.	INVGDP3		22.76	21.86	32.70	146.4		22.76	21.86	32.70	146.4

Description of Data Distribution, Extreme values, and Data Transformation (1970)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
27.	GOVCON3	sq(x)	13.54	5.21	4.72	4.78		3.61	0.68	1.60	1.98
28.	EXPGDP3	ln(x)	24.06	16.88	10.49	19.92	Singapore (113.2), Hongkong (99.7)	2.98	0.65	-1.67	2.15
29.	IMPGDP3	ln(x)	26.26	17.09	13.74	35.57	Singapore (135.5), Hongkong (99.8)	3.11	0.55	-0.45	1.98
30.	GDPAGR3		24.25	16.86	2.71	-0.73		24.25	16.86	2.71	-0.73
31.	GDPMAN3	sq(x)	19.93	12.38	5.13	2.93		4.26	1.31	2.15	-0.03
32.	GDPOTH3	ln(x)*10	11.79	9.75	13.31	26.36		2.38	0.54	2.86	3.08
33.	GDPSER3		44.16	11.62	-2.33	-0.44		44.16	11.62	-2.33	-0.44
34.	XFOOD3		35.88	27.09	1.46	-2.50		35.88	27.09	1.46	-2.50
35.	XAGRI3	ln(x)+10	14.11	15.49	7.17	6.82	Sudan (739 Chad (722)	3.02	0.54	2.69	-1.14
36.	XFUEL3	ln(x)+1	19.04	26.65	8.08	5.63		2.27	1.23	0.44	-1.49
37.	XMACHI3	ln(x)+1	9.01	13.41	6.00	1.64		1.44	1.30	2.31	-2.39
38.	XOTHER3	ln(x)+1	21.71	20.62	3.34	-0.95	Hongkong (81.6)	2.56	1.19	-1.40	-2.22
39.	IFOOD3	ln(x)+10	16.44	9.08	8.66	14.20	Yemen (62.4), Bangladesh (48), Srilanka (47)	3.22	0.29	2.94	2.14
40.	INFUEL3	sq(x)	3.75	3.58	7.22	8.22	Japan (20.9)	1.75	0.83	3.28	0.19
41.	IMACHI3		29.83	8.22	0	0.26		29.83	8.22	0	0.26
42.	IFUEL3		6.67	3.81	2.65	1.54	Japan (20.7)	6.67	3.81	2.65	1.54
43.	IOTHER3		38.74	8.37	0.58	0.35		38.74	8.37	0.58	0.35
44.	IAGRI3	sq(x)	4.45	3.22	4.95	3.49		1.97	0.75	1.21	-0.60
45.	SAVERT3	sq(x+9)-3	17.07	9.31	2.27	0.75		2.02	0.91	0.16	-0.27
46.	SECTEC3		19.45	5.89	2.04	0.74		19.45	5.89	2.04	0.74
47.	VOCATE3	sq(sq(x))	19.95	19.16	5.93	3.51		1.92	0.51	0.45	-1.74
48.	LOINCO3		5.13	1.43	0.53	-0.44		5.13	1.43	0.53	-0.44
49.	HIINCO3		24.51	6.87	0.30	-1.36		24.51	6.87	0.30	-1.36
50.	GNPTOT3	log(x)	55219	175319	26.78	102.3	USA (1544829)	0.58	0.09	-0.33	-1.57
51.	GNPUS3	log(x)	1686	2221	7.17	4.58		2.87	0.57	0.98	-2.28
52.	ENECAP3	log(x)	1623	2327	7.27	5.75		2.64	0.81	-0.47	-2.25

Description of Data Distribution, Extreme values, and Data Transformation (1970)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
53.	TRACTR3	log(x)	162444	573819	24.58	80.63	USA (4619000), USSR (2977000)	3.88	1.35	-1.54	-0.90
54.	NEWS3	ln(x)+1	6.22	10.10	8.27	6.80		1.23	1.15	2.80	-1.68
55.	THIEDU3	sq(x)	630.5	700.5	7.76	11.30	USA (4148), Canada (2999)	21.13	13.62	1.93	-0.78
56.	TELEPO3	log(x)+10	2660	12387	35.15	159.63	USA (120220)	2.38	0.91	2.07	-1.03
57.	EDUEXP3	log(x)	3.85	1.61	1.25	-0.29		3.85	1.61	1.25	-0.29
58.	AREA3		1216	2912	19.68	56.65	USSR (22402)	2.50	0.75	-2.12	3.17

Appendix 3: Description of Data Distribution, Extreme values, and Data Transformation (1977)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
2.	PUPULA4	log(x)	39449	110567	23.79	74.81	China (865677), India (631726)	4.12	0.54	23.79	74.81
3.	YOUNPO4		37.39	9.50	-2.38	-2.75		37.39	9.50	-2.38	-2.75
4.	ADULPO4		56.99	5.82	1.68	2.85		56.99	5.82	1.68	-2.85
5.	ELDEPO4		5.67	4.11	4.31	-0.82		5.67	4.11	4.31	-0.82
6.	POPDEN4	ln(x)+10	161.39	585.84	26.62	86.78	Hongkong (4500), Singapore (3833)	4.09	1.13	26.62	86.78
7.	URBAPO4		44.77	25.52	0.8	-2.29		44.77	25.52	0.80	-2.29
8.	BIRTRT4		33.27	14.02	-1.19	-3.16		33.27	14.02	-1.19	-3.16
9.	MORTAL4		12.97	4.95	1.77	-1.96		12.97	4.95	1.77	-1.96
10.	LIFEXP4		59.47	11.56	-0.35	-3.09		59.47	11.56	-0.35	-3.09
11.	PHYSIC4	log(x)	9442	15002	9.92	13.66	Ethiopia (84850), Upper Volta (61798)	3.48	0.67	9.92	13.66
12.	NURSES4	log(x)	3808	8585	18.39	43.62	Bangladesh (53700), Nepal (52770)	3.10	0.62	18.39	43.62
13.	HOSPIT4	log(x)	700.3	988.6	15.27	33.94	Bangladesh (6630), Afghanistan (5210)	2.59	0.46	15.27	33.94
14.	CALORY4		106.9	19.06	0.93	-2.42		106.98	19.06	0.93	-2.42
15.	INMORT4		72.09	45.55	0.04	-2.56	Afghanistan (185)	72.09	45.55	0.04	-2.56
16.	PRIMA4		84.10	28.80	-3.12	0.95		84.10	28.80	-3.12	-0.95
17.	SECOND4		41.03	31.46	2.64	-0.98	USA (140)	41.03	31.46	2.64	-0.98
18.	PRIRAT4	sq(x)	33.65	12.78	3.13	0.82		5.70	1.08	3.13	0.82
19.	LITER4		61.36	31.85	-1.05	2.96		61.36	31.85	-1.05	-2.96
20.	LABOUR4	log(x)	16590	51365	25.13	84.58	China (422514), India (261000)	3.69	0.56	25.13	84.58
21.	PWOLAB4		30.31	12.00	-2.03	-1.33		30.31	12.00	-2.03	-1.33
22.	PAGLAB4		45.16	28.92	-0.04	-2.77		45.16	28.92	-0.04	-2.77
23.	PINLAB4		23.28	14.09	1.69	-1.65		23.28	14.09	1.69	-1.65
24.	RADIO4	log(x)*100	202.8	261.1	13.57	32.89	USA (1882)	3.99	0.56	13.57	32.89
25.	CARS4	ln(x)+1	72.05	113.7	7.24	4.41	USA (499)	2.99	1.68	7.24	4.41
26.	INVGDP4		22.79	7.69	0.81	1.52		22.79	7.69	0.81	1.52

Description of Data Distribution, Extreme values, and Data Transformation (1977)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
27.	GOVCON4	sq(x)	14.77	6.55	6.98	11.77	Somalia (48)	3.75	0.80	6.98	11.77
28.	EXPGDP4	ln(x)	28.76	20.07	11.2	25.14	Singapore (149.6)	3.16	0.63	11.20	25.14
29.	IMPGDP4	ln(x)	32.09	19.65	12.28	32.42	Singapore (158.4)	3.32	0.55	12.28	32.42
30.	GDPAGR4		22.55	16.37	2.85	-0.36		22.55	16.37	2.85	-0.36
31.	GDPMAN4	sq(x)	20.14	12.14	5.3	3.2		4.30	1.27	5.30	3.20
32.	GDPOTH4	ln(x)*10	13.51	12.33	12.77	22.81		2.46	0.59	12.77	22.81
33.	GDPSER4		43.99	12.27	-1.26	-0.98		43.99	12.27	-1.26	-0.98
34.	XFOOD4		33.22	27.03	2.03	-2.16		33.22	27.03	2.03	-2.16
35.	XAGRI4	ln(x)+10	10.38	12.77	9.17	10.92		2.88	0.47	9.17	10.92
36.	XFUEL4	ln(x)+1	21.71	29.52	6.65	2.69		2.31	1.32	6.65	2.69
37.	XMACHI4	ln(x)+1	10.24	14.33	5.48	1.32		1.54	1.34	5.48	1.32
38.	XOTHER4	ln(x)+1	23.17	20.22	2.66	-1.34		2.64	1.22	2.66	-1.34
39.	IFOOD4	ln(x)+10	14.22	6.96	6.33	7.83		3.15	0.26	6.33	7.83
40.	INFUEL4	sq(x)	2.75	2.02	4.84	2.32		1.55	0.58	4.84	2.32
41.	IMACHI4		31.11	9.28	0.11	-0.39		31.11	9.28	0.11	-0.39
42.	IFUEL4		13.68	8.49	2.82	1.48		13.68	8.49	2.82	1.48
43.	IOTHER4		34.24	7.29	-0.14	-0.46		34.24	7.29	-0.14	-0.46
44.	IAGRI4	sq(x)	3.45	2.54	5.12	3.78		1.73	0.67	5.12	3.78
45.	SAVERT4	sq(x+9)-3	18.28	9.69	3.59	6.44	Chad (-4.5), Saudi Arabia (68.1)	2.13	0.94	3.59	6.44
46.	SECTEC4		19.82	6.05	1.39	-0.28		19.82	6.05	1.39	-0.28
47.	VOCATE4	sq(sq(x))	19.51	19.18	6.42	4.25		1.91	0.51	6.42	4.25
48.	LOINCO4		5.71	1.53	-0.9	-0.47		5.71	1.53	-0.90	-0.47
49.	HIINCO4		19.98	5.29	0.29	-0.86		19.98	5.29	0.29	-0.86
50.	GNPTOT4	log(x)	73363	220185	24.86	88.76	USA (4370000)	0.60	0.09	24.85	88.76
51.	GNPUS4	log(x)	2180	2821	6.6	3.58		2.95	0.61	6.60	3.58
52.	ENECAP4	log(x)	1870	2517	6.52	4.42		2.72	0.81	6.62	4.42
53.	TRACTR4	log(x)	186449	545664	22.45	71.81		4.07	1.30	22.45	71.81
54.	NEWS4	ln(x)+1	6.27	10.35	8.66	8.37		1.23	1.15	8.66	8.37
55.	THIEDU4	sq(x)	966.9	927.5	5.38	5.79		26.94	15.59	5.38	5.79
56.	TELEPO4	log(x)+10	4141	17207	32.39	139.6	USA (162072)	2.58	0.94	32.39	139.6

Description of Data Distribution, Extreme values, and Data Transformation (1977)

No. (1)	Variable (2)	Tranf. (3)	UNTRANSFORMED Mean (4)	Std dev. (5)	Skew. (6)	Kurt. (7)	Extreme values (8)	TRANSFORMED Mean (9)	Std dev. (10)	Skew (11)	Kurt (12)
57.	EDUEXP4	log(x)	4.916	2.015	1.31	-1.19		4.19	2.01	1.31	-1.19
58.	AREA4		1216.7	2912.7	19.68	56.65	USSR (22402)	2.50	0.75	19.68	56.65

Appendix 4: Unrotated Factor Loadings (1960)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
2	POPULA1	.311	.830	.152	.291	-.185	.038	.9625
3	YOUNGP1	-.836	-.110	.227	.094	-.213	-.263	.9385
4	ADULPO1	.767	.128	-.237	-.069	.248	.225	.8294
5	ELDEPO1	.837	.060	-.152	-.138	.128	.263	.8544
6	POPDEN1	.351	.073	-.689	.359	-.068	-.350	.8596
7	URBAPO1	.795	-.263	.019	.008	-.206	-.148	.7698
8	BIRTRT1	-.921	-.108	.224	.121	-.123	-.134	.9644
9	MORTAL1	-.885	.059	.037	.042	.145	.271	.8990
10	LIFEXP1	.965	-.055	-.088	-.084	-.086	-.106	.9085
11	PHYSIC1	-.917	.041	-.107	.041	.83	.238	.9191
12	NURSES1	-.845	.203	-.060	.057	-.156	-.063	.7941
13	HOSPIT1	-.817	.281	-.084	.202	-.191	-.108	.8428
14	CALORY1	.840	.072	-.194	-.222	-.004	.148	.8216
15	INMORT1	-.861	.113	.191	.056	.015	.031	.7977
16	PRIMA1	.867	-.038	-.003	-.067	-.077	-.210	.8170
17	SECOND1	.888	.059	-.082	.003	-.069	.109	.8210
18	PRIRAT1	-.586	.074	-.090	-.092	-.121	.069	.3857
19	LITER1	.923	.044	-.059	-.185	-.034	-.166	.9255
20	LABOUR1	.333	.829	.104	.254	-.062	.065	.9214
21	PWOLAB1	.011	.295	-.314	-.155	.483	.170	.5380
22	PAGLAB1	-.862	.229	.048	-.032	.171	.013	.8707
23	PINLAB1	.923	-.137	-.035	.015	0	-.027	.8862
24	RADIO1	.884	-.175	.101	-.126	-.054	-.122	.8561
25	CARS1	.796	-.350	.140	-.116	-.132	.199	.8506
26	INVGDP1	.715	-.034	.265	-.012	.137	.091	.6291
27	GOVCON1	-.009	-.324	.017	-.031	-.116	.408	.2896
28	EXPGDP1	.186	-.612	-.022	.223	.314	-.007	.7300
29	IMPGDP1	.089	-.629	-.245	.182	.289	.026	.7590
30	GDPAGR1	-.800	.359	-.206	-.183	.127	.087	.8691
31	GDPMAN1	.833	.258	-.002	.035	.118	-.239	.8335
32	GDPOTH1	.252	-.351	.410	.409	.200	.125	.6143
33	GDPSER1	.228	-.444	-.035	-.180	-.570	.001	.6224
34	XFOOD1	-.538	.008	-.151	-.444	-.008	-.021	.5130
35	XAGRI1	-.303	.182	-.142	-.308	-.354	.060	.4046
36	XFUEL1	.174	-.120	.482	.503	.076	-.003	.5385
37	XMACHI1	.807	.171	-.259	.131	.203	.193	.8446
38	XOTHER1	.647	.185	-.371	.120	.067	-.008	.6163
39	IFOOD1	-.213	-.280	-.179	.457	-.231	.229	.5438
40	INFUEL1	.615	.412	-.174	.086	.231	-.067	.6456
41	IMACHI1	.159	.188	.526	-.036	.150	-.315	.5958
42	IFUEL1	.354	.158	-.274	-.190	-.119	.003	.2791
43	IOTHER1	-.431	-.222	.003	-.393	-.049	.194	.5024
44	IAGRI1	.646	.283	-.315	.303	-.055	-.182	.7332
45	SAVERT1	.586	-.096	.465	.115	.008	.062	.5942
46	SECTEC1	-.131	.017	-.309	.298	-.261	.241	.3708
47	VOCATE1	.487	.135	.128	-.193	.484	-.127	.5668
48	LOINCO1	-.202	.111	-.261	.011	.010	.181	.1554
49	HIINCO1	-.433	-.091	.331	-.018	.281	-.288	.4707
50	GNPTOT1	.825	.343	.255	.198	-.179	.055	.9421
51	GNPUS1	.898	-.277	.150	-.051	-.052	.104	.9346

Appendix 4: Unrotated Factor Loadings (1960)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
52	ENECAP1	.932	-.131	.212	.052	.014	-.048	.9421
53	TRACTR1	.751	.333	.311	-.120	-.081	.143	.8160
54	NEWS1	.895	-.104	-.039	-.203	-.178	.098	.8950
55	THIEDU1	.861	.109	.007	-.088	-.201	-.123	.8195
56	TELEPO1	.906	.260	.133	.054	-.158	.123	.9497
57	EDUEXP1	.543	-.194	.049	.167	.085	.226	.4926
58	AREA1	-.061	.513	.693	-.079	-.089	.346	.8942
Eigen values:		26.000	4.704	3.517	2.342	2.100	1.675	
Percent of Total Variance		45.61	8.25	7.62	4.11	3.68	2.94	70.76

Appendix 4: Unrotated Factor Loadings (1965)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
2	POPULA2	.297	.820	.312	.255	.037	-.004	.9455
3	YOUNGP2	-.857	-.134	.256	.096	-.189	-.188	.9229
4	ADULPO2	.763	.136	-.226	-.023	.206	.126	.7291
5	ELDEPO2	.846	.066	-.179	-.136	.128	.193	.8425
6	POPDEN2	.345	.160	-.601	.386	-.068	-.391	.8225
7	URBAPO2	.796	-.238	.039	.036	-.271	-.009	.7771
8	BIRTRT2	-.936	-.119	.323	.090	-.075	-.078	.9647
9	MORTAL2	-.858	.057	-.007	-.022	.189	.256	.8697
10	LIFEXP2	.962	-.043	-.068	-.046	-.130	-.112	.9686
11	PHYSIC2	-.920	.049	-.103	.012	.117	.185	.9095
12	NURSES2	-.861	.215	-.041	.097	-.121	-.052	.8168
13	HOSPIT2	-.829	.300	-.023	.227	-.112	-.125	.8735
14	CALORY2	.865	.080	-.182	-.220	.024	.096	.8504
15	INMORT2	-.877	.073	.193	.025	.037	.032	.8200
16	PRIMA2	.856	-.037	.055	-.056	-.116	-.244	.8316
17	SECOND2	.913	.069	-.074	.005	-.050	.087	.8576
18	PRIRAT2	-.677	.086	-.055	-.055	-.199	.021	.4992
19	LITER2	.921	.044	-.030	-.175	-.076	-.171	.9214
20	LABOUR2	.320	.819	.263	.195	.146	.013	.9168
21	PWOLAB2	.073	.237	-.277	-.251	.539	.057	.4993
22	PAGLAB2	-.880	.227	.055	-.062	.207	.015	.8775
23	PINLAB2	.916	-.091	-.060	.048	.022	-.089	.8671
24	RADIO2	.893	-.151	.081	-.163	-.154	-.077	.8869
25	CARS2	.846	-.303	.079	-.107	-.150	.196	.8991
26	INVGDP2	.686	-.153	.105	.034	.151	.141	.6951
27	GOVCON2	-.011	-.322	-.032	-.003	-.025	.463	.3198
28	EXPGDP2	.257	-.631	-.115	.194	.417	-.064	.7466
29	IMPGDP2	.067	-.585	-.398	.183	.413	.024	.7857
30	GDPAGR2	-.814	.340	-.169	-.203	.159	.023	.8812
31	GDPMAN2	.807	.246	-.018	-.019	.157	-.276	.8147
32	GDPOTH2	.280	-.472	.379	.485	.157	.115	.7448
33	GDPSER2	.227	-.348	-.008	-.091	-.575	.178	.5538
34	XFOOD2	-.515	.038	-.119	-.514	-.170	-.063	.5808
35	XAGRI2	-.329	.189	-.122	-.216	-.244	.179	.3688
36	XFUEL2	.120	-.198	.521	.470	.153	-.078	.5756
37	XMACHI2	.825	.190	-.249	.066	.229	.110	.8586
38	XOTHER2	.618	.180	-.341	.110	.096	-.036	.5710
39	IFOOD2	-.153	.053	-.308	.567	-.167	.214	.6632
40	INFUEL2	.791	.417	-.061	-.043	.115	-.012	.8236
41	IMACHI2	.044	-.178	.630	-.241	.135	-.225	.6395
42	IFUEL2	.363	.185	-.250	-.209	-.096	.064	.3030
43	IOTHER2	-.444	-.265	-.098	-.342	.110	.098	.5031
44	IAGRI2	.615	.298	-.233	.260	-.103	-.124	.6148
45	SAVERT2	.689	-.199	.354	.211	.029	.024	.7017
46	SECTEC2	-.240	.060	-.181	.336	-.145	.181	.3403
47	VOCATE2	.560	.088	.031	-.287	.385	-.247	.6397
48	LOINCO2	-.017	.253	-.359	.211	-.018	.206	.3433
49	HIINCO2	-.454	-.167	.293	-.129	.145	-.406	.6011
50	GNPTOT2	.826	.326	.333	.205	.058	.018	.9487
51	GNPUS2	.907	-.251	.121	-.033	-.089	-.088	.9242

Appendix 4: Unrotated Factor Loadings (1965)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
52	ENECAP2	.947	-.151	.181	.045	.014	-.030	.9549
53	TRACTR2	.737	.322	.350	-.145	-.009	.173	.8207
54	NEWS2	.907	-.078	-.055	-.164	-.182	.096	.9066
55	THIEDU2	.865	.081	.046	-.071	-.174	-.005	.8034
56	TELEPO2	.911	.282	.172	.043	-.079	.112	.9597
57	EDUEXP2	.512	-.261	.149	.004	.327	.279	.5375
58	AREA2	.069	.430	.726	-.127	.080	.361	.8716
Eigen values:		26.769	4.597	3.623	2.479	2.137	1.664	
Percent of total variance		46.96	8.06	6.36	4.35	2.97	2.27	74.67

Appendix 4: Unrotated Factor Loadings (1970)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
2	POPULA3	.227	.738	.499	.189	-.005	.071	.9185
3	YOUNGP3	-.862	-.176	.230	.167	-.109	-.274	.9464
4	ADULPO3	.803	.208	-.252	-.143	.124	.251	.8505
5	ELDEPO3	.850	.091	-.180	-.179	.052	.239	.8685
6	POPDEN3	.341	.259	-.526	.502	.120	-.286	.8086
7	URBAPO3	.791	-.249	.020	.054	-.214	-.135	.7770
8	BIRTRT3	-.940	-.139	.191	.084	-.032	-.051	.9522
9	MORTAL3	-.800	.083	-.047	-.140	.062	.361	.8238
10	LIFEXP3	.955	-.035	-.063	.017	-.069	-.178	.9545
11	PHYSIC3	-.921	.048	-.098	-.039	.033	.207	.9087
12	NURSES3	-.866	.221	-.010	.121	-.069	-.105	.8296
13	HOSPIT3	-.828	.301	.031	.259	-.048	-.122	.8625
14	CALORY3	.857	.079	-.145	-.187	.044	-.015	.8112
15	INMORT3	-.884	.033	.216	-.026	.007	.031	.8374
16	PRIMA3	.798	-.066	.084	.043	-.003	-.343	.7949
17	SECOND3	.911	.066	-.058	.020	-.087	.044	.8477
18	PRIRAT3	-.699	.073	-.019	.009	-.111	-.151	.5745
19	LITER3	.923	.031	.003	-.124	.026	-.244	.9276
20	LABOUR3	.291	.760	.440	.123	.168	.054	.9093
21	PWOLAB3	.124	.233	-.233	-.285	.498	.142	.5287
22	PAGLAB3	-.895	.192	.089	-.057	.171	.052	.8966
23	PINLAB3	.925	-.082	-.085	.066	.019	-.006	.9109
24	RADIO3	.862	-.136	.044	-.145	-.132	-.161	.8309
25	CARS3	.883	-.257	-.003	-.135	-.166	.098	.9159
26	INVGDP3	.253	-.012	-.075	.222	.074	-.151	.2858
27	GOVCON3	-.018	-.342	-.037	-.057	-.345	.357	.4925
28	EXPGDP3	.293	-.623	-.214	.221	.398	.123	.7842
29	IMPGDP3	.141	-.532	-.450	.158	.349	.153	.7357
30	GDPAGR3	-.805	.367	-.128	-.170	.120	.029	.8470
31	GDPMAN3	.798	.230	-.037	-.015	.276	-.173	.8060
32	GDPOTH3	.253	-.489	.443	.407	.089	.294	.7749
33	GDPSER3	.317	-.329	-.084	-.144	-.542	-.161	.5753
34	XFOOD3	-.553	.002	-.119	-.487	-.029	-.284	.6434
35	XAGRI3	-.390	.252	-.159	-.234	-.321	-.021	.4275
36	XFUEL3	.132	-.284	.559	.399	.133	.093	.5994
37	XMACHI3	.805	.204	-.168	-.049	.140	.201	.7845
38	XOTHER3	.578	.229	-.320	.046	.075	-.040	.5369
39	IFOOD3	-.301	.105	-.319	.413	-.233	.290	.5941
40	INFUEL3	.760	.398	-.033	.010	.063	.019	.7409
41	IMACHI3	.121	-.291	.618	-.186	.157	-.186	.7078
42	IFUEL3	.313	.261	-.249	-.138	-.162	.095	.2867
43	IOTHER3	-.397	-.326	-.044	-.263	.179	-.129	.3845
44	IAGRI3	.548	.410	-.163	.327	-.018	-.107	.6135
45	SAVERT3	.660	-.248	.290	.245	.031	.013	.6526
46	SECTEC3	-.324	.048	.020	.209	-.162	-.076	.2582
47	VOCATE3	.624	.087	-.024	-.237	.379	-.086	.6095
48	LOINCO3	.129	.462	-.311	.262	-.209	.172	.5246
49	HIINCO3	-.460	-.245	.203	-.042	.334	-.368	.6064
50	GNPTOT3	.829	.258	.407	.167	-.022	-.001	.9476
51	GNPUS3	.920	-.245	.064	-.030	-.095	.045	.9292

Appendix 4: Unrotated Factor Loadings (1970)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
52	ENECAP3	.949	-.197	.155	.068	-.001	-.008	.9687
53	TRACTR3	.723	.270	.416	-.205	-.068	.098	.8253
54	NEWS3	.908	-.066	-.092	-.129	-.171	-.045	.8850
55	THIEDU3	.887	.057	.101	-.024	-.124	-.100	.8283
56	TELEPO3	.915	.232	.226	.025	-.100	.023	.9521
57	EDUEXP3	.504	-.359	.180	-.091	.021	.348	.5883
58	AREA3	-.078	.291	.782	-.278	-.063	.262	.8587
Eigen values:		26.383	4.721	3.909	2.282	1.973	1.805	
Percent of total variance		46.28	8.28	6.86	4.01	3.46	3.17	74.27

Appendix 4: Unrotated Factor Loadings (1977)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
2	POPULA4	.242	-.460	.763	.239	.125	-.096	.9424
3	YOUNGP4	-.871	.240	.179	.116	-.273	.039	.9431
4	ADULPO4	.838	-.282	-.154	-.058	.202	-.009	.8492
5	ELDEPO4	.839	-.155	-.159	-.185	.271	-.032	.8747
6	POPDEN4	.329	-.398	-.363	.628	-.191	-.090	.8901
7	URBAPO4	.787	.225	-.063	-.092	-.246	-.065	.7589
8	BIRTRT4	-.936	.231	.112	.040	-.040	.018	.9463
9	MORTAL4	-.769	-.031	-.062	-.152	.437	-.135	.8387
10	LIFEXP4	.933	-.037	-.087	.012	-.220	.079	.9344
11	PHYSIC4	-.928	-.081	-.079	-.034	.150	-.108	.9278
12	NURSES4	-.865	-.199	.088	.131	-.112	-.095	.8383
13	HOSPIT4	-.835	-.175	.162	.234	-.107	-.118	.8368
14	CALORY4	.861	-.114	-.067	-.065	.064	.070	.7752
15	INMORT4	-.891	.053	.207	-.002	-.029	.009	.8432
16	PRIMA4	.771	.066	.116	.113	-.291	.141	.7748
17	SECOND4	.883	-.085	.042	-.026	.003	-.113	.8039
18	PRIRAT4	-.722	-.117	-.012	.079	:.119	.021	.6310
19	LITER4	.907	-.082	-.005	-.070	-.149	.178	.8943
20	LABOUR4	.277	-.528	.693	.213	.218	-.063	.9508
21	PWOLAB4	.119	-.378	-.208	-.110	.412	.231	.5101
22	PAGLAB4	-.871	-.130	.180	.096	.118	.099	.8693
23	PINLAB4	.909	.036	-.101	.116	.037	.025	.8755
24	RADIO4	.834	.214	.020	-.122	-.145	.026	.7808
25	CARS4	.886	.159	-.075	-.221	-.022	-.054	.8815
26	INVGDP4	.341	.372	.108	.338	.112	-.040	.5823
27	GOVCON4	.032	.389	-.063	-.257	.176	-.420	.4660
28	EXPGDP4	.339	.481	-.427	.356	.250	.145	.7770
29	IMPGDP4	.185	.391	-.553	.383	.343	.031	.8849
30	GDPAGR4	-.815	-.396	.006	-.102	.054	.114	.8812
31	GDPMAN4	.754	-.302	.003	.200	.133	.393	.9368
32	GDPOTH4	.173	.727	.247	.305	.141	-.158	.7883
33	GDPSER4	.372	.092	-.251	-.345	-.328	-.329	.5931
34	XFOOD4	-.573	-.240	-.130	-.344	-.165	.312	.6557
35	XAGRI4	-.354	-.196	-.133	-.290	-.001	-.118	.3172
36	XFUEL4	.112	.525	.427	.256	.018	-.048	.5530
37	XMACHI4	.873	-.252	-.111	.045	.173	-.004	.8695
38	XOTHER4	.612	-.385	-.217	.125	-.074	-.006	.6017
39	IFOOD4	-.273	-.128	-.203	.311	.153	-.332	.6057
40	INFUEL4	.700	-.373	.142	.102	.061	.095	.6803
41	IMACHI4	-.038	.652	.370	-.122	.047	.266	.7184
42	IFUEL4	.190	-.574	-.010	-.191	-.208	-.180	.5146
43	IOTHER4	-.183	.285	-.177	-.116	.136	.217	.3686
44	IAGRI4	.491	-.437	.008	.393	-.054	-.144	.6206
45	SAVERT4	.484	.427	.238	.311	-.118	-.032	.6062
46	SECTEC4	-.369	-.031	.032	.194	-.225	-.140	.4428
47	VOCATE4	.516	-.168	.007	-.013	.217	.435	.5774
48	LOINCO4	-.163	-.380	-.201	.107	.212	-.255	.4224
49	HIINCO4	-.515	.230	.188	.107	-.096	.382	.5671
50	GNPTOT4	.831	-.065	.487	.129	.012	-.090	.9761
51	GNPUS4	.921	.283	-.029	-.076	-.040	-.045	.9605

Appendix 4: Unrotated Factor Loadings (1977)

No.	Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Communality
52	ENECAP4	.945	.235	.090	.004	-.031	.017	.9591
53	TRACTR4	.718	-.150	.501	-.188	.074	-.019	.8500
54	NEWS4	.909	.034	-.132	-.185	-.037	-.127	.9189
55	THIEDU4	.888	.052	.127	-.086	-.186	.008	.8553
56	TELEPO4	.914	-.127	.303	-.018	-.021	-.109	.9587
57	EDUEXP4	.467	.405	.022	-.227	.373	-.254	.6806
58	AREA4	-.089	.013	.811	-.353	.251	-.032	.8755
Eigen values		25.708	5.252	4.045	2.543	1.904	1.655	
Percent of total variance		45.10	7.30	9.21	4.46	3.34	2.90	72.11

Appendix 4: Rotated Factor Loadings (1960)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
LIFEXP1	10	.952					
NEWS1	54	.941					
BIRTRT1	8	-.917					-.312
GNPUS1	51	.906		.302			
LITER1	19	.904					
PINLAB1	23	.900					
PAGLAB1	22	-.877					
RADIO1	24	.872					
CALORY1	14	.872					
SECOND1	17	.865					
ENECAP1	52	.864		.327			
PHYSIC1	11	-.862					
INMORT1	15	-.862					
ELDEPO1	5						.326
MORTAL1	9	-.848			-.290		
CARS1	25	.847					
TELEPO1	56	.842	.447				
YOUNGP1	3	-.840					-.439
HOSPIT1	13	-.834					
THIEDU1	55	.834					
PRIMA1	16	.829					
NURSES1	12	-.823					
URBAPO1	7	.796					-.268
ADULPO1	4	.760					.459
GDPAGR1	30	-.754		-.439			.281
XMACHI1	37	.751					.408
GDPMAN1	31	.723	.270		.368	.253	
GNPTOT1	50	.708	.594	.256			
TRACTR1	53	.693	.488				
INVGDP1	26	.651		.268			
XOTHER1	38	.599			.357		
PRIRAT1	18	-.521		-.274			
SAVERT1	45	.510		.486			
INFUEL1	40	.507	.336		.350		.381
POPULA1	2		.921				
LABOUR1	20		.882				
AREA1	58		.678		-.527	.255	
GDPOTH1	32			.746			
XFUEL1	36			.660			
XAGRI1	35			-.538			
POPDEN1	6	.296			.787	-.338	
IAGRI1	44	.548	.254		.564		
IMACHI1	41					.732	
IFOOD1	39			.273		-.604	
SECTEC1	46					-.533	
PWOLAB1	21			-.284			.630
GDPSER1	33	.366					-.595

Appendix 4: Rotated Factor Loadings (1960) (continued)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
IMPGDP1	29		-.359				.757
EXPGDP1	28		-.264	.289			
IFUEL1	42	.401		-.265			
GOVCON1	27				-.401	-.281	
IOTHER1	43	-.294		-.369	-.439		
LOINCO1	48						
HIINCO1	49	-.493				.403	
XFOOD1	34	-.411	-.278	-.459			
VOCATE1	47	.411				.457	.399
Eigen values:		23.967	4.119	3.456	2.821	2.613	2.539

Note: blank indicates loading equal or less than 0.25

Appendix 4: Rotated factor loadings (1965)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
LIFEXP2	10	.967					
NEWS2	54	.942					
BIRTRT2	8	-.937					
LITER2	19	.929					
RADIO2	24	.911					
ENECAP2	52	.906		.339			
GNPUS2	51	.904					
SECOND2	17	.902					
PHYSIC2	11	-.901					
PINLAB2	23	.894					
PAGLAB2	22	-.891					
CALORY2	14	.890					
INMORT2	15	-.887					
CARS2	25	.872			-.268		
THIEDU2	55	.865					
TELEPO2	56	.862	.433				
MORTAL2	9	-.852			-.290		
YOUNGP2	3	-.852					-.366
NURSES2	12	-.851					
ELDEPO2	5	.851					.275
PRIMA2	16	.848					
HOSPIT2	13	-.848					
URBAPO2	7	.809					-.277
XMACHI2	37	.788					.387
GDPAGR2	30	-.785		-.430			.255
GDPMAN2	31	.755			.333		.274
INFUEL2	40	.749	.361				.312
ADULPO2	4	.744					.353
GNPTOT2	50	.733	.534	.318			
TRACTR2	53	.695	.534				
INVGDP2	26	.650		.281		-.320	
PRIRAT2	18	-.639		-.256			
SAVERT2	45	.616		.512			
XOTHER2	38	.600					
IAGRI2	44	.578			.349	.261	
VOCATE2	47	.533					.446
POPULA2	2		.853		.266		
LABOUR2	20		.815				.305
AREA2	58		.764		-.390	-.307	
IMPGDP2	29		-.744				.260
EXPGDP2	28		-.620	.281			
GDPOTH2	32			.477			
XFUEL2	36			.789			
XFOOD2	34	-.402		.727			
PWOLAB2	21			-.583			.668
GDPSER2	33	.322					-.593
IFOOD2	39					.742	

Appendix 4: Rotated factor loadings (1965) (continued)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
IMACHI2	41					-.699	
POPDEN2	6	.330			.655	.340	
HIINCO2	49	-.470					
LOINCO2	48						
GOVCON2	27				-.495		
SECTEC2	46						
IOTHER2	43	-.369	-.353	-.254		-.350	
XAGRI2	35	-.258		-.428			
EDUEXP2	57	.470		.353	-.353		
IFUEL2	42	.411		-.298			
Eigen values		25.659	4.353	3.669	2.089	2.151	2.857

Note: blank indicates loading equal or less than 0.25

Appendix 4: Rotated Factor Loadings (1970)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
LIFEXP3	10	.936			.266		
NEWS3	54	.924					
GNPUS3	51	.921					
CARS3	25	.919					
LITER3	19	.917					
PINLAB3	23	.916					
BIRTRT3	8	-.910					
PAGLAB3	22	-.909					
ENECAP3	52	.902		.337			
PHYSIC3	11	-.898					
RADIO3	24	.892					
SECOND3	17	.873					
HOSPIT3	13	-.861					
NURSES3	12	-.858					
INMORT3	15	-.856			-.274		
THIEDU3	55	.856					
ELDEPO3	5	.852					.300
YOUNPO3	3	-.847					-.396
TELEPO3	56	.846	.444				
CALORY3	14	.843					
URBAPO3	7	.817					-.261
GDPAGR3	30	-.783		-.404			
ADULPO3	4	.779					.409
XMACHI3	37	.765					.349
PRIMA3	16	.755			.381		
MORTAL3	9	-.753			-.429		
GDPMAN3	31	.753					.256
GNPTOT3	50	.718	.559	.301			
INFUEL3	40	.695	.374				
PRIRAT3	18	-.689					
TRACTR3	53	.678	556				
VOCATE3	47	.618					.376
SAVERT3	45	.568		.494			
XOTHER3	38	.523			.380		.251
POPULA3	2		.907				
LABOUR3	20		.882				
AREA3	58		.711		-.352	.375	
IMPGDP3	29		-.669	.255	.265		.345
EXPGDP3	28		-.583	.478			.284
GDPOTH3	32			.837			
XFUEL3	36			.726			
XFOOD3	34	-.406		-.521	-.259	.273	
XAGRI3	35	-.333		-.507			
IMACHI3	41			.277		.764	
IFOOD3	39	-.300				-.683	
POPDEN3	6	.268			.591	-.484	
PWOLAB3	21						.683

Appendix 4: Rotated Factor Loadings (1970) (continued)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
GOVCON3	27						
SECTEC3	46	-.373			.263		
INVGDP3	26				.494		
IFUEL3	42	.325		-.297			
IOTHER3	43	-.311	-.375			.304	
GDPSER3	33	.401					-.452
LOINCO3	48				.367	-.484	
HIINCO3	49	-.412				.370	
EDUEXP3	57	.461		.349			
IAGRI3	44	.458	.292		.398	-.356	
Eigen values		25.549	4.676	3.558	2.554	2.794	2.369

Note: blank indicates loading equal or less than 0.25

Appendix 4: Rotated Factor Loadings (1977)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Deta	Factor 5 Epsilon	Factor 6 Zeta
BIRTRT4	8	-.923					
LIFEXP4	10	.922					
GNPUS4	51	.922		.303			
NEWS4	54	.920					
CARS4	25	.918					
ENECAP4	52	.907		.315			
PHYSIC4	11	-.902					
LITER4	19	.898					
PAGLAB4	22	-.894					
PINLAB4	23	.887					
YOUNPO4	3	-.885					-.258
INMORT4	15	-.882					
HOSPIT4	13	-.871					
ELDEPO4	5	.868					
NURSES4	12	-.868					
THIEDU4	55	.867					
CALORY4	14	.852					
SECOND4	17	.850					
TELEPO4	56	.849	.457				
XMACHI4	37	.844					
ADULPO4	4	.836					
RADIO4	24	.828					
URBAPO4	7	.801					
GDPAGR4	30	-.772		-.389			
PRIRAT4	18	-.737					
GNPTOT4	50	.726	.576	.317			
MORTAL4	9	-.718				.295	.347
GDPMAN4	31	.707	.252				
PRIMA4	16	.706				-.322	-.251
TRACTR4	53	.663	.579		-.253		
INFUEL4	40	.637	.421				
XOTHER4	38	.596		-.255	.335		
VOCATE4	47	.521					
HIINCO4	49	-.507			-.310		
POPULA4	2		.948				
LABOUR4	20		.936				
GDPOTH4	32			.809			
XFUEL4	36			.702			
SAVERT4	45	.383		.611			
IFUEL4	42		.287	-.569			
IMACHI4	41			.531	-.476	-.438	
POPDEN4	6	.253			.872		
AREA4	58		.632		-.644		
IAGRI4	44	.388	.386		.502		
GOVCON4	27						
EDUEXP4	57	.446					
IMPGDP4	29		-.439				

Appendix 4: Rotated Factor Loadings (1977) (continued)

Variables	No.	Factor 1 Alpha	Factor 2 Beta	Factor 3 Gamma	Factor 4 Delta	Factor 5 Epsilon	Factor 6 Zeta
INVGDP4	26			.380			
PWOLAB4	21			-.346			.577
IFOOD4	39	-.284				.673	
IOTHER4	43		-.367				.340
LOINCO4	48				.417		.327
XAGRI4	35	-.293		-.429			
EXPGDP4	28	.299	-.431	.436			.281
SECTEC4	46	-.440			.266	-.349	
XFOOD4	34	-.467		-.480			
GDPSER4	33	.426					-.382
Eigen values		24.300	4.578	4.243	2.962	1.457	1.840

Note: blank indicates loading equal or less than 0.25

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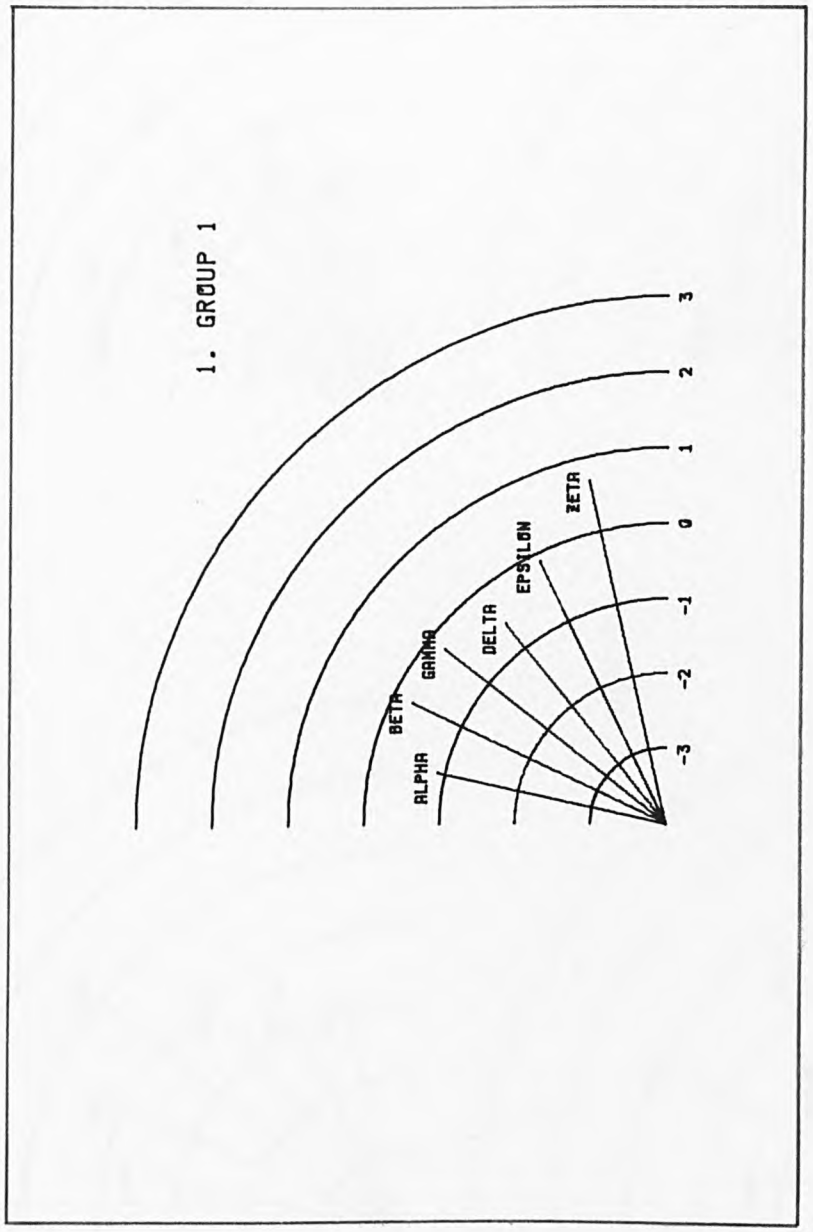

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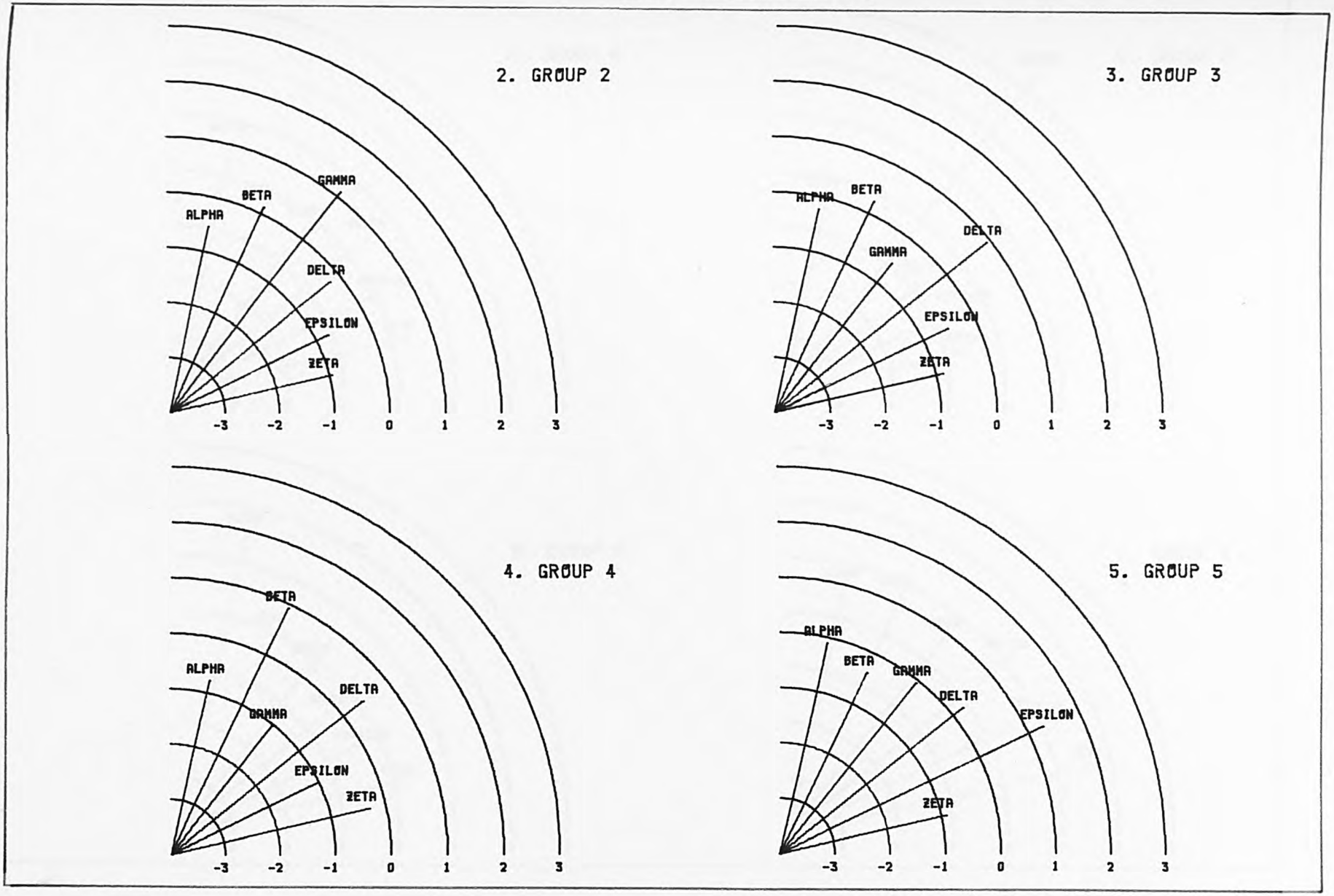

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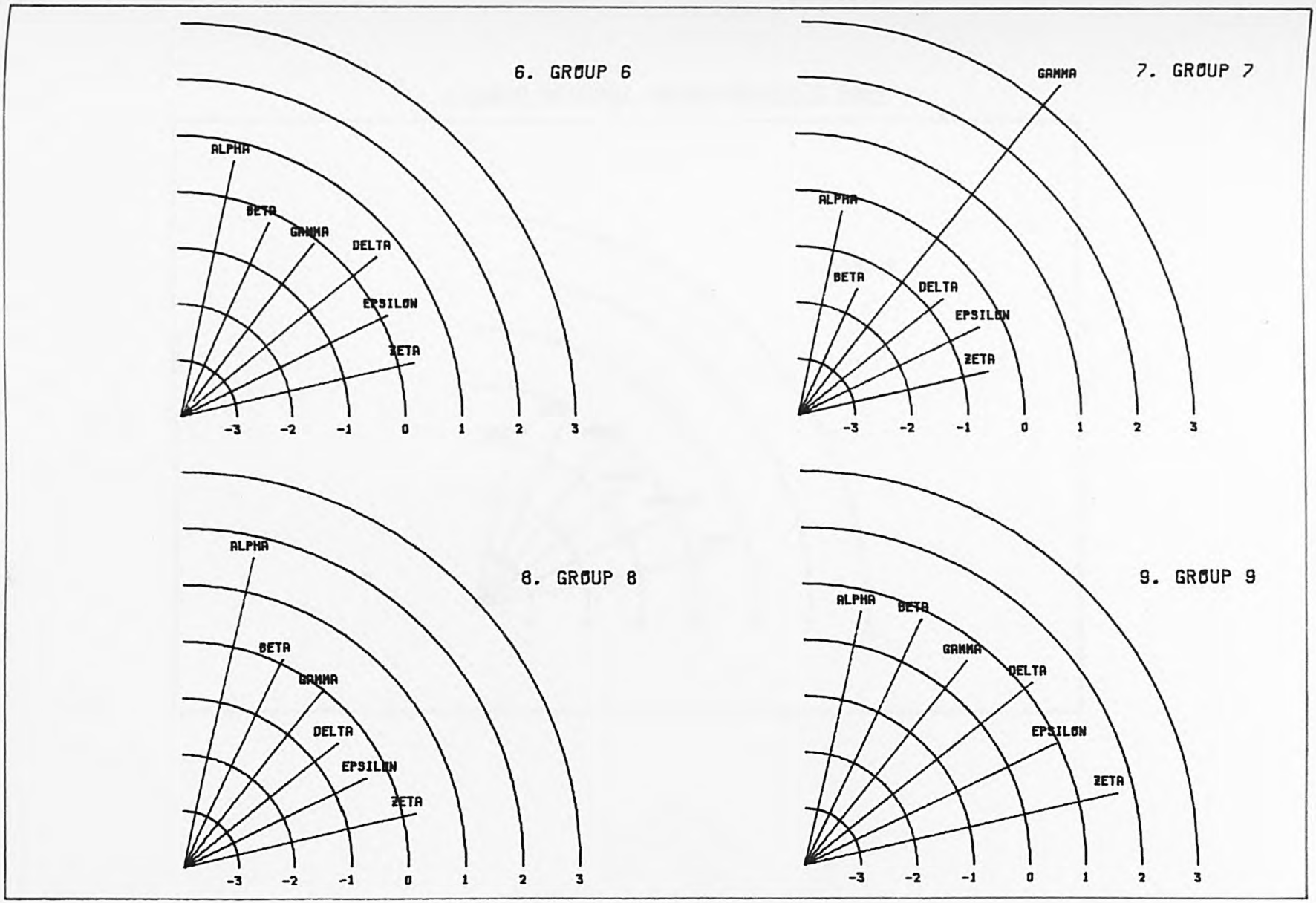
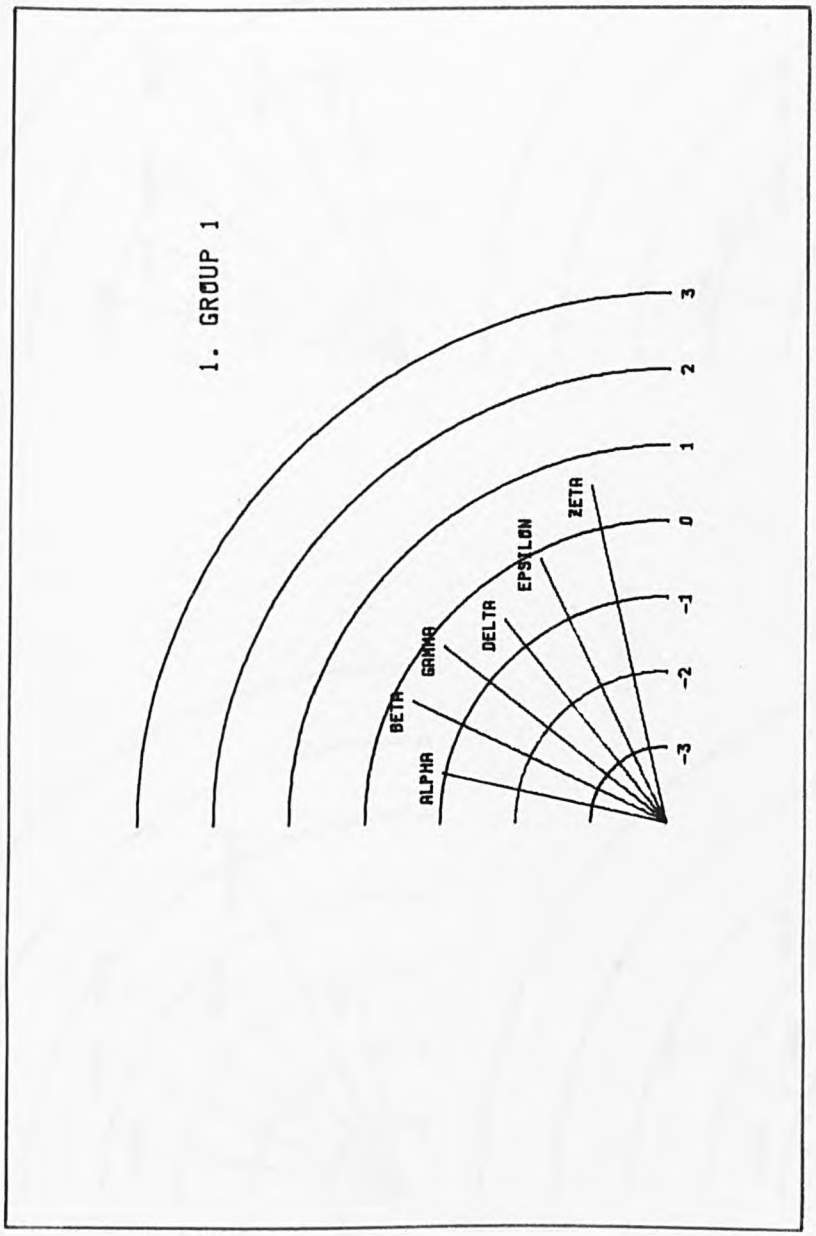
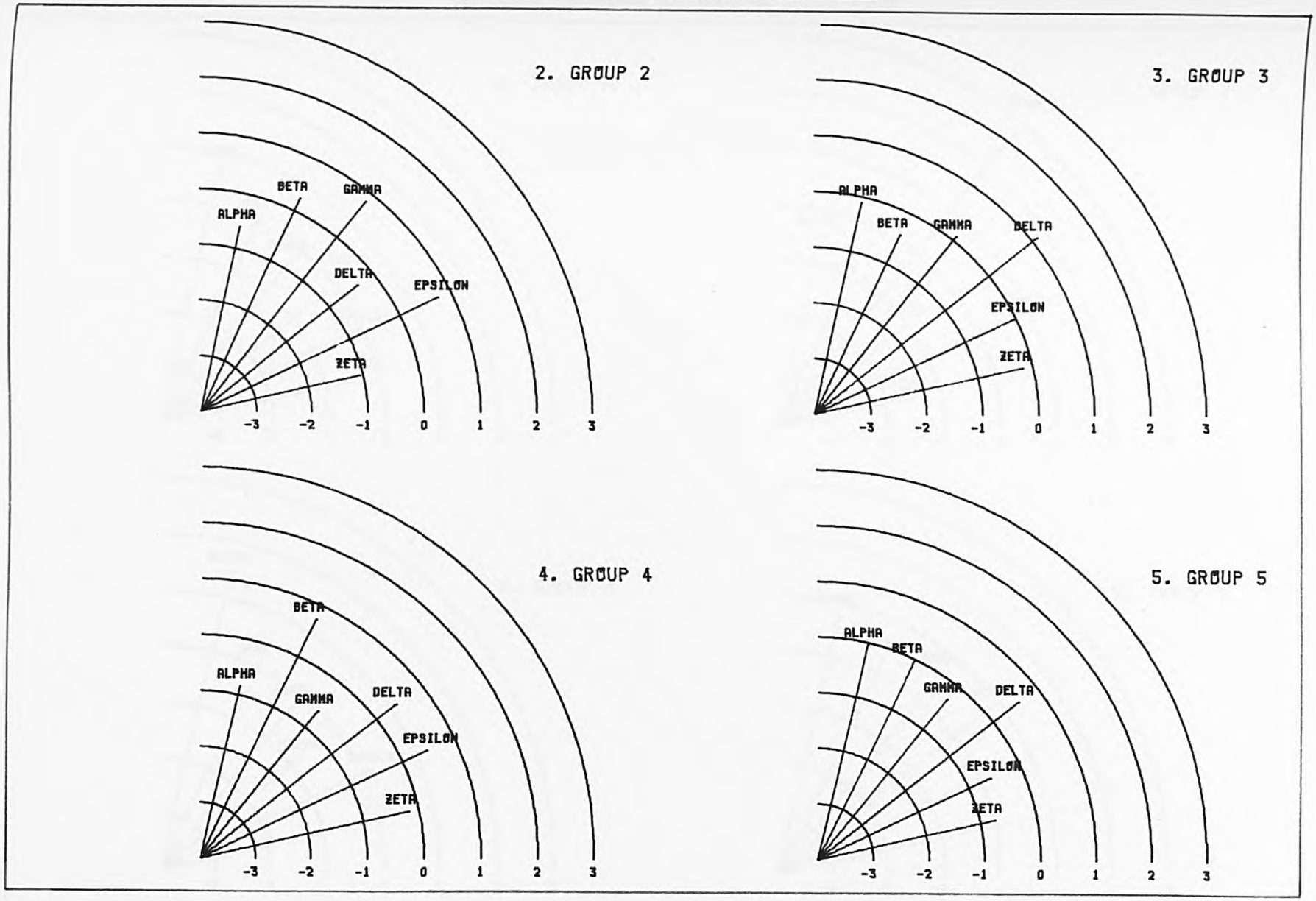


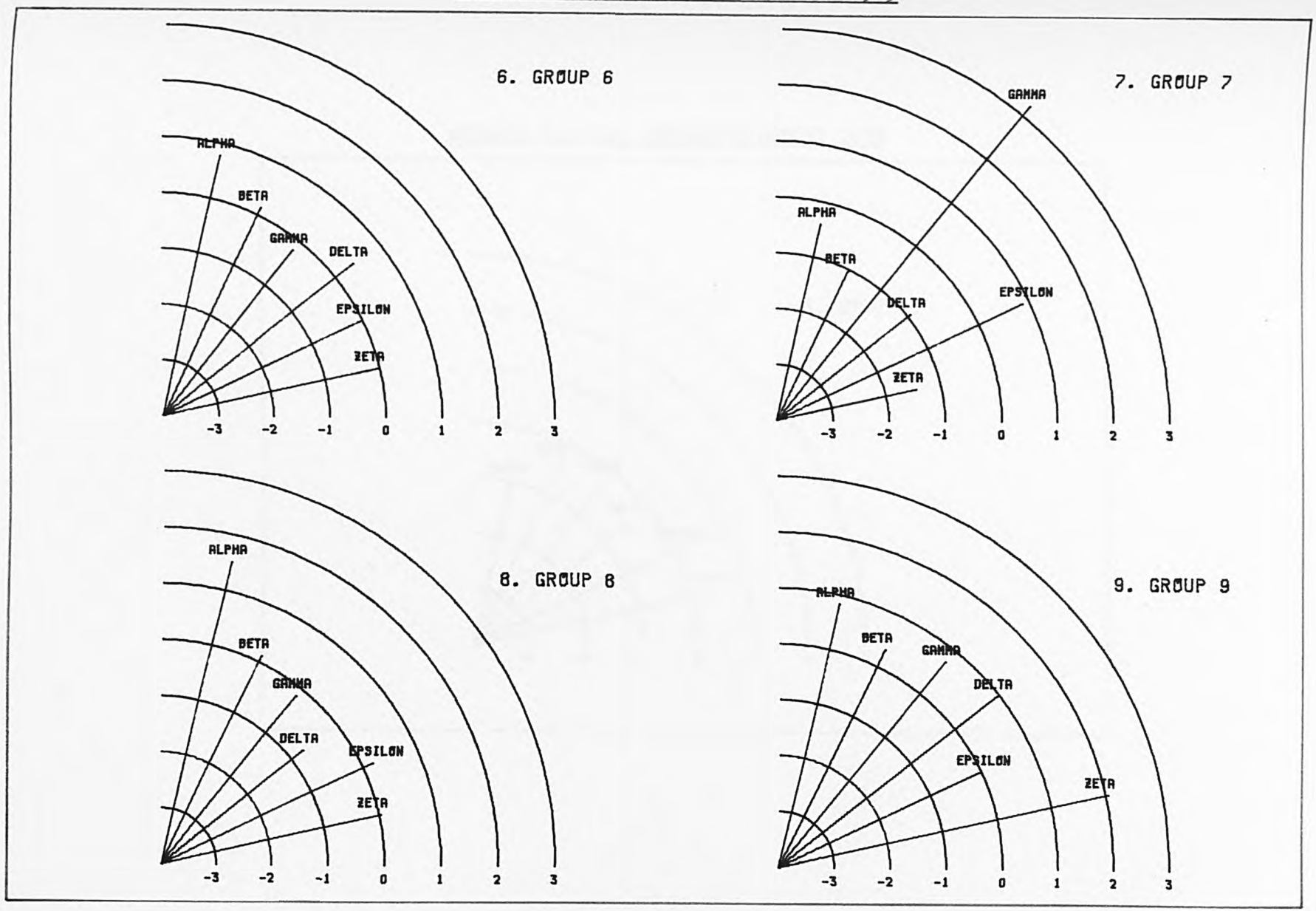
AVERAGE NATIONAL CHARACTERISTICS 1965



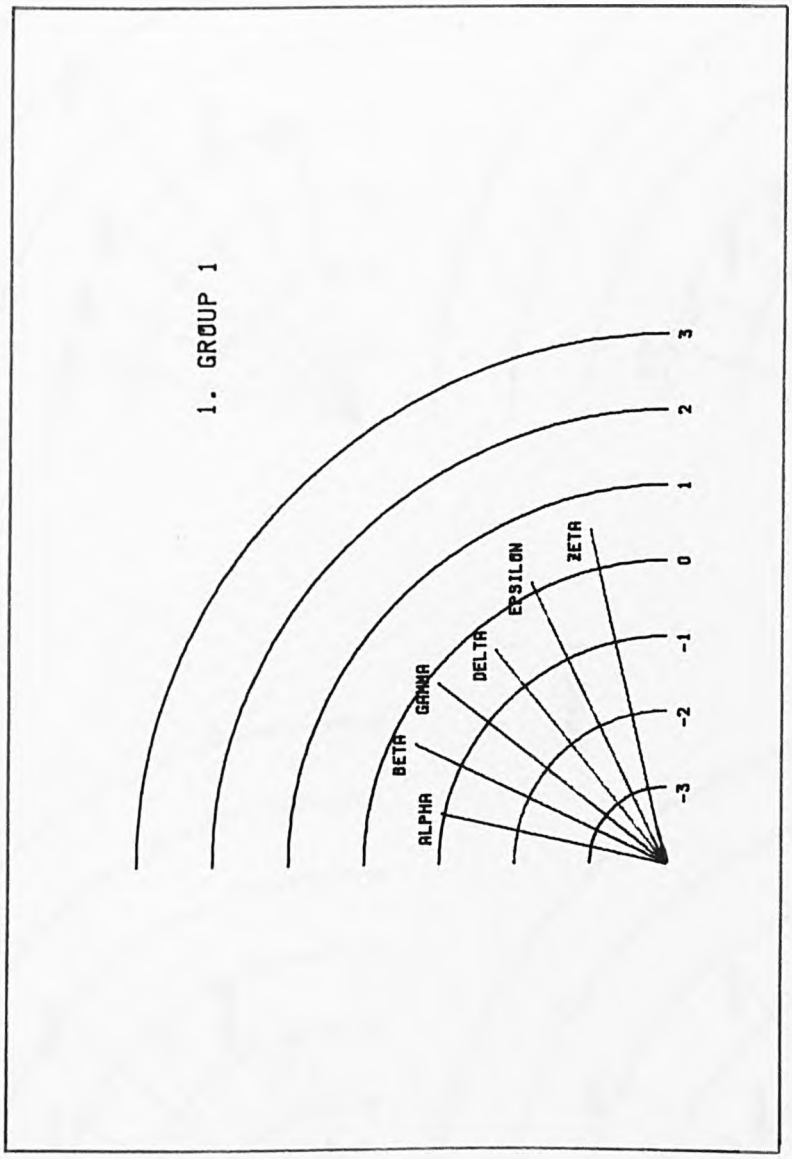
AVERAGE NATIONAL CHARACTERISTICS 1965



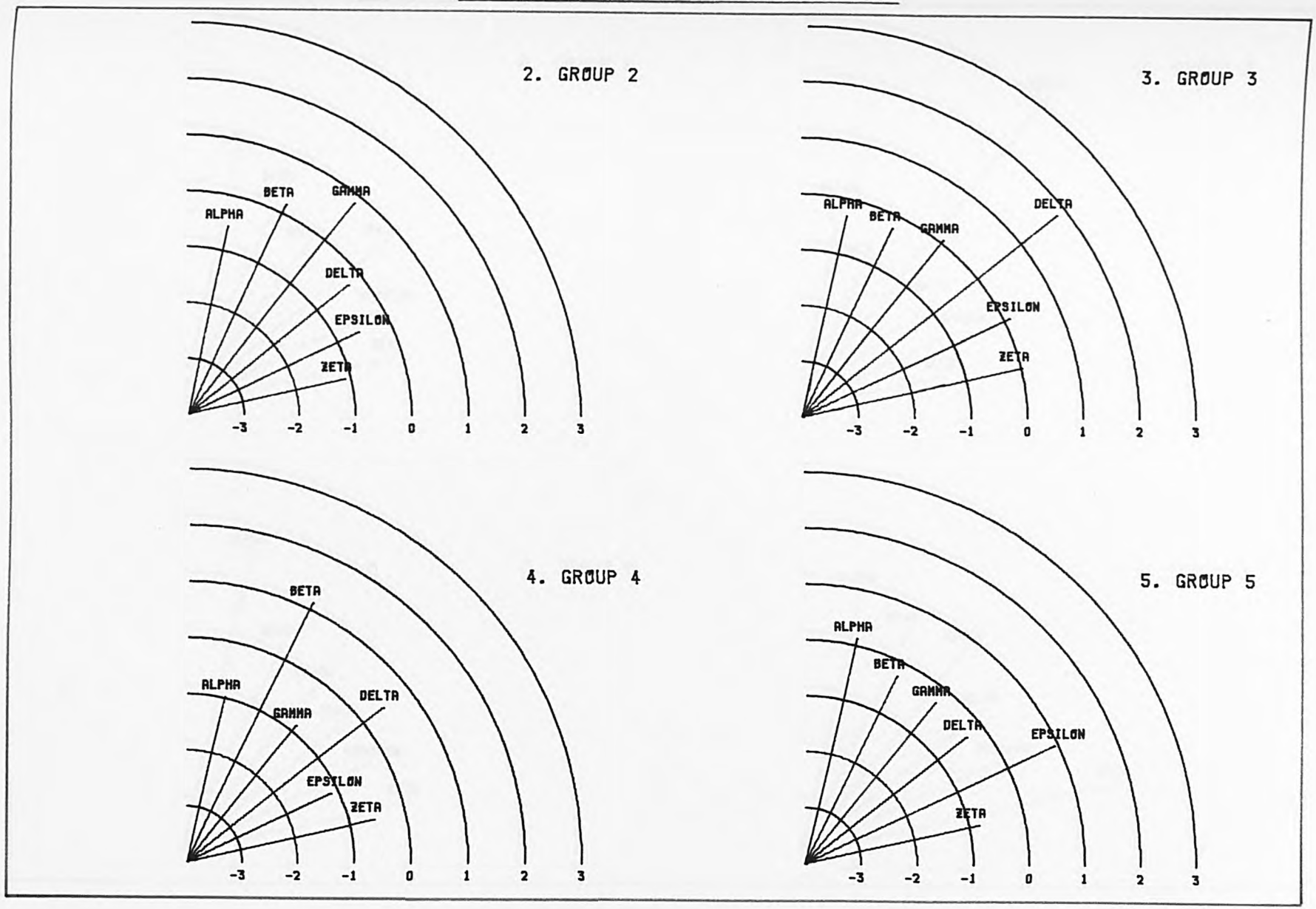
AVERAGE NATIONAL CHARACTERISTICS 1965



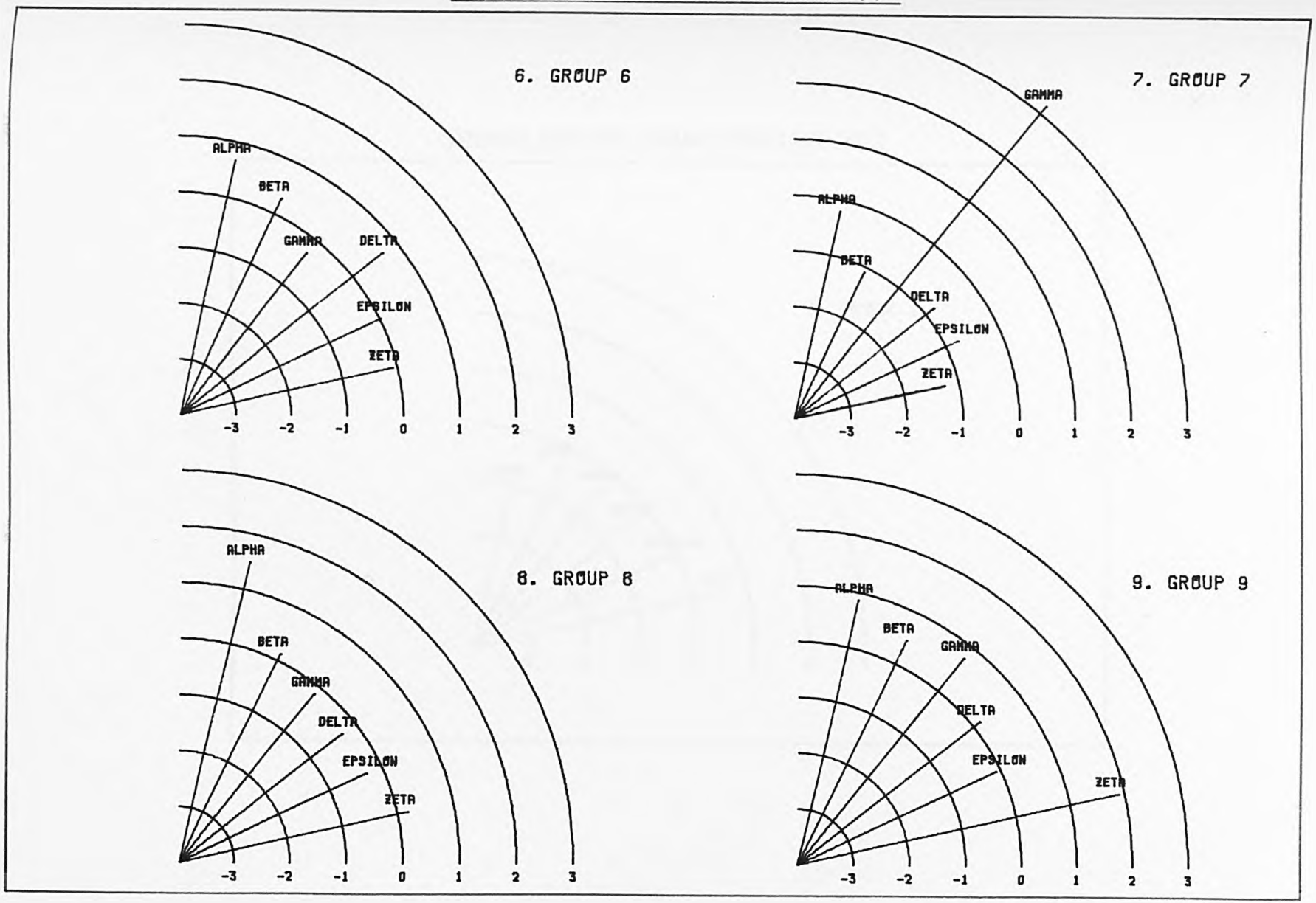
AVERAGE NATIONAL CHARACTERISTICS 1970



AVERAGE NATIONAL CHARACTERISTICS 1970



AVERAGE NATIONAL CHARACTERISTICS 1970



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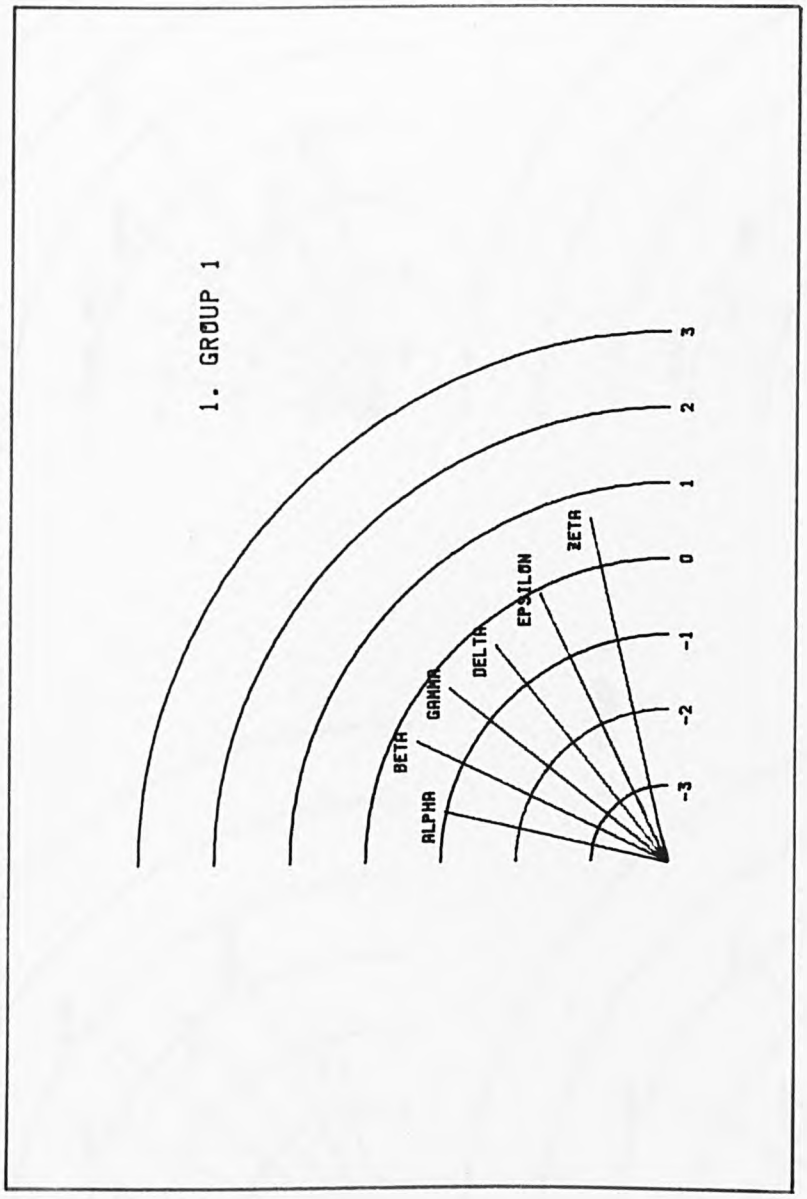
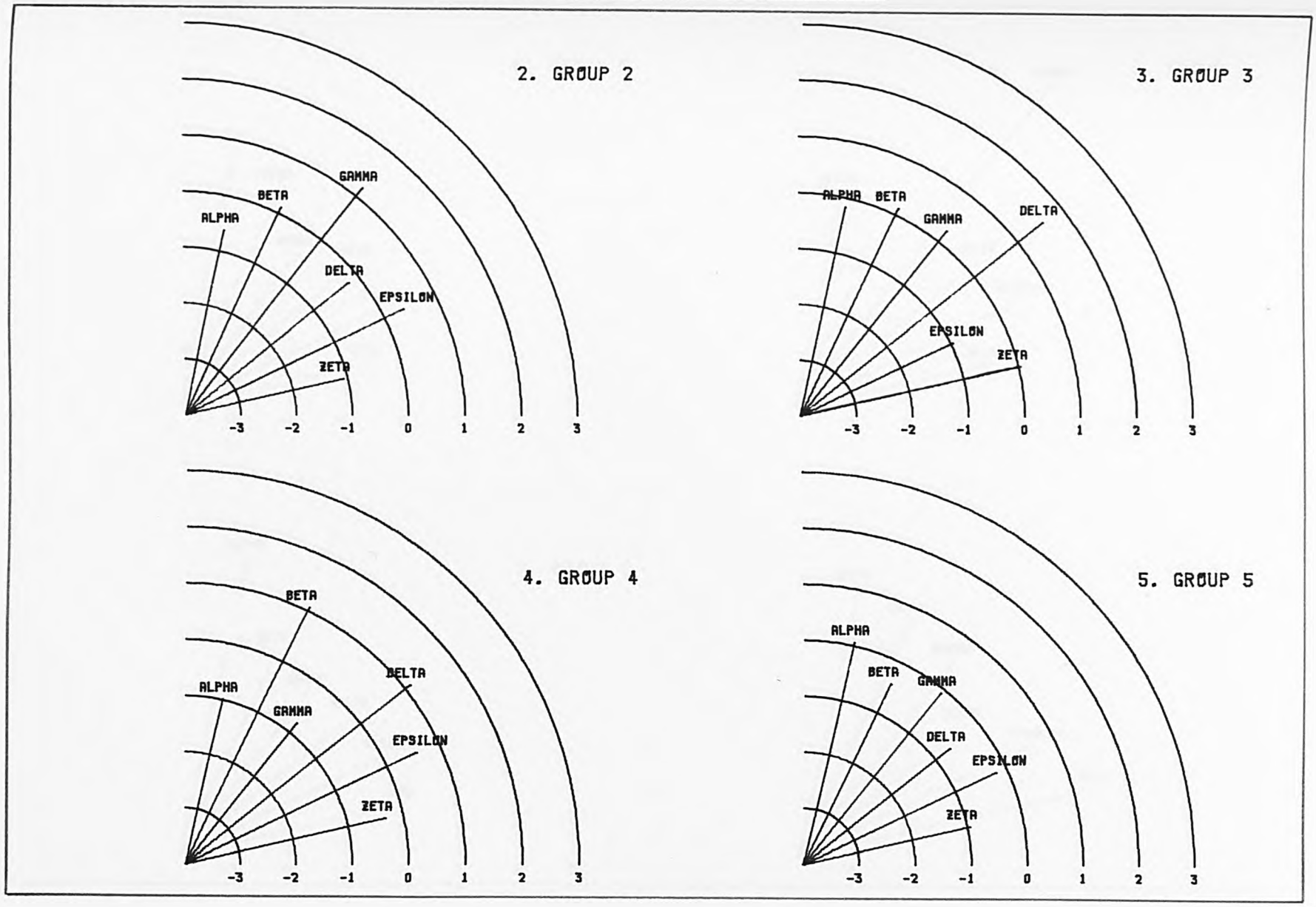
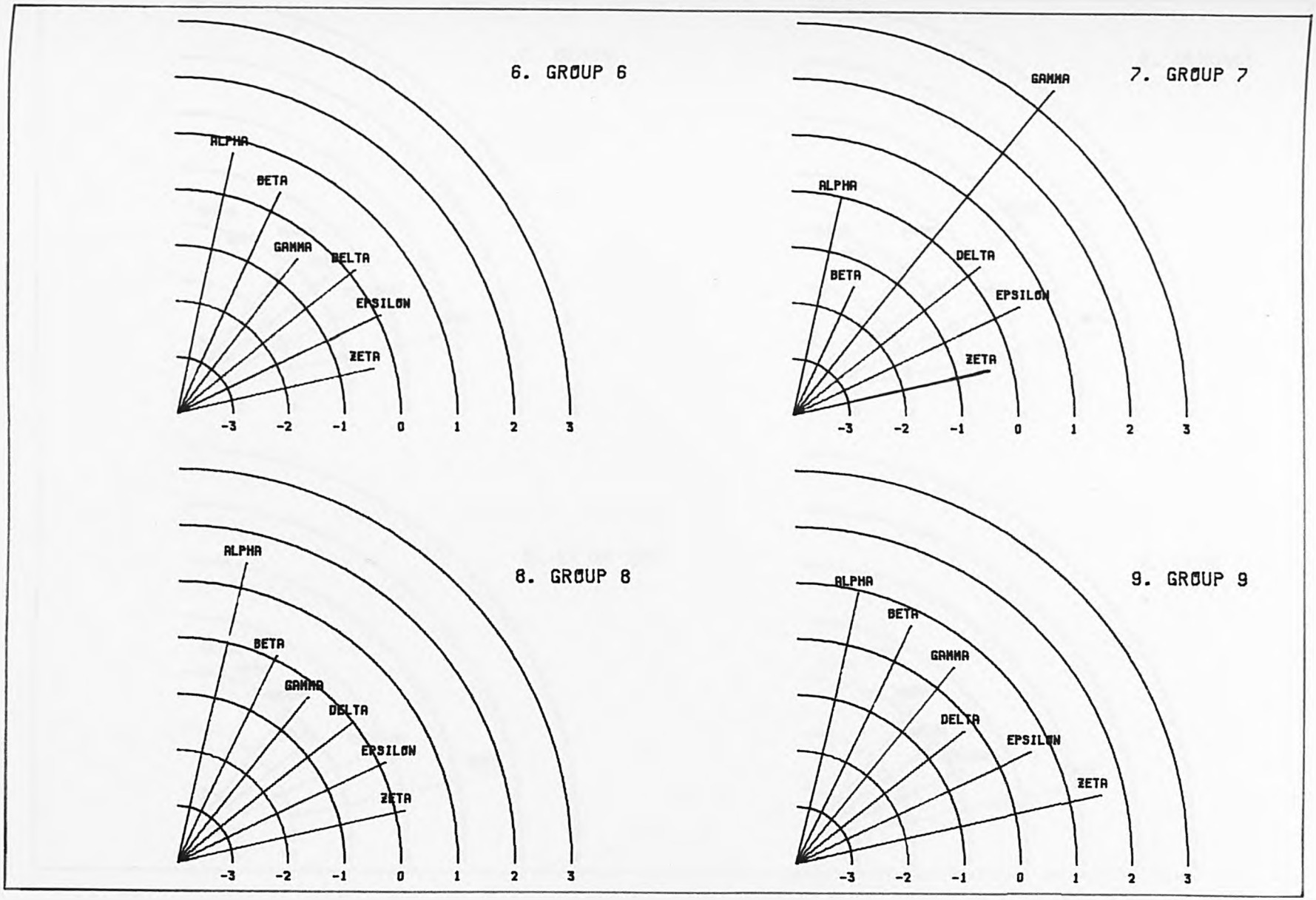


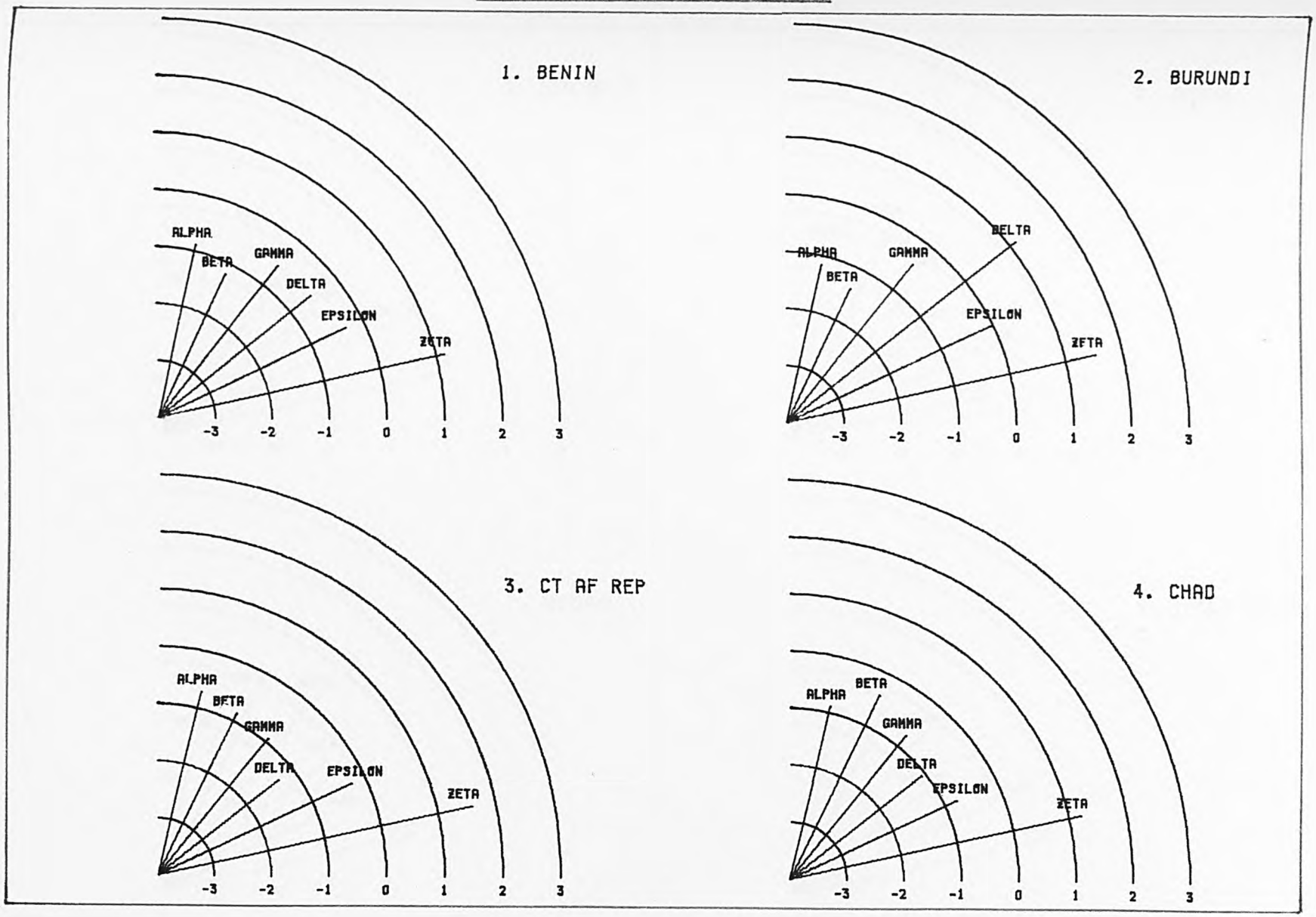
AVERAGE NATIONAL CHARACTERISTICS 1977



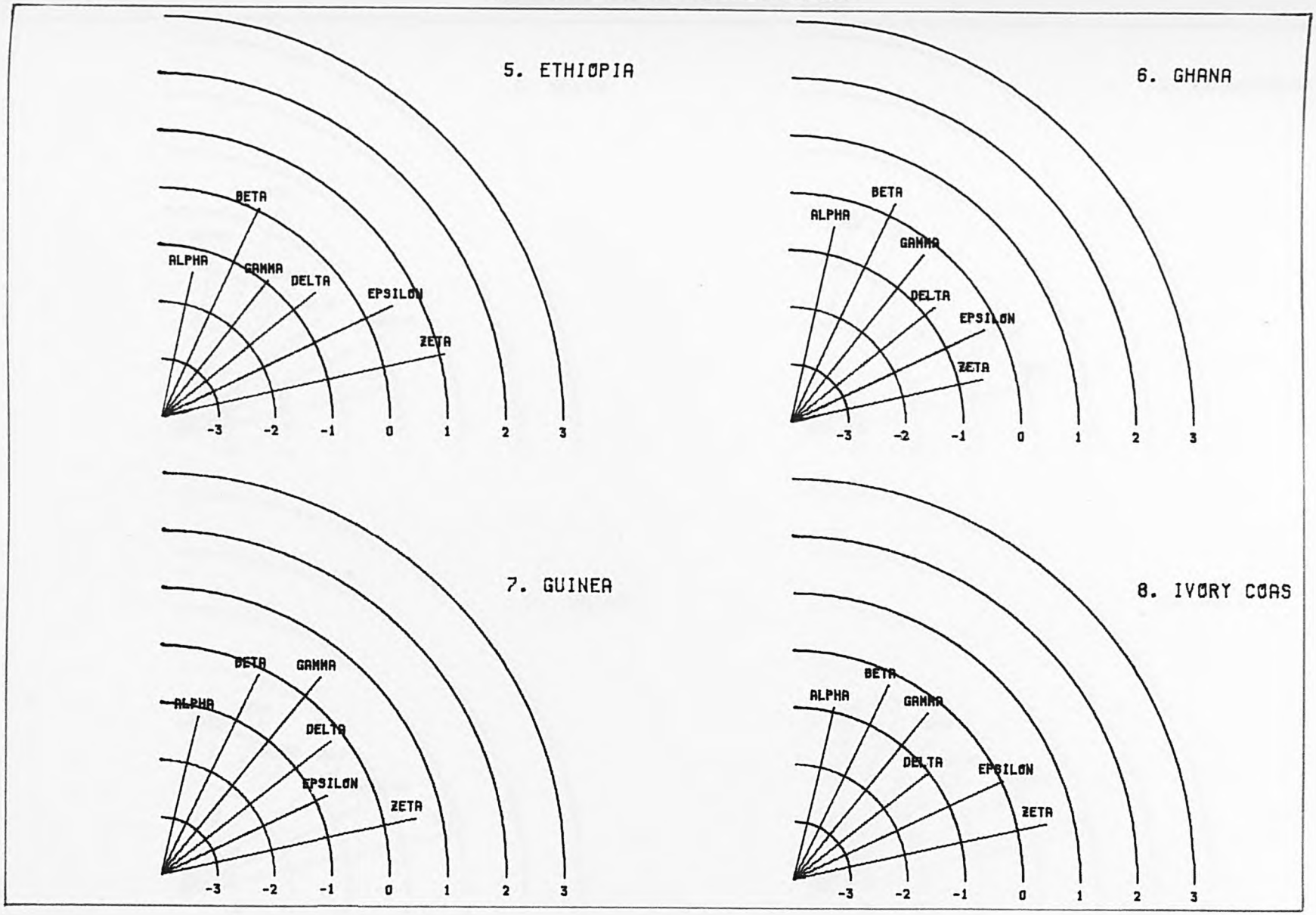
AVERAGE NATIONAL CHARACTERISTICS 1977



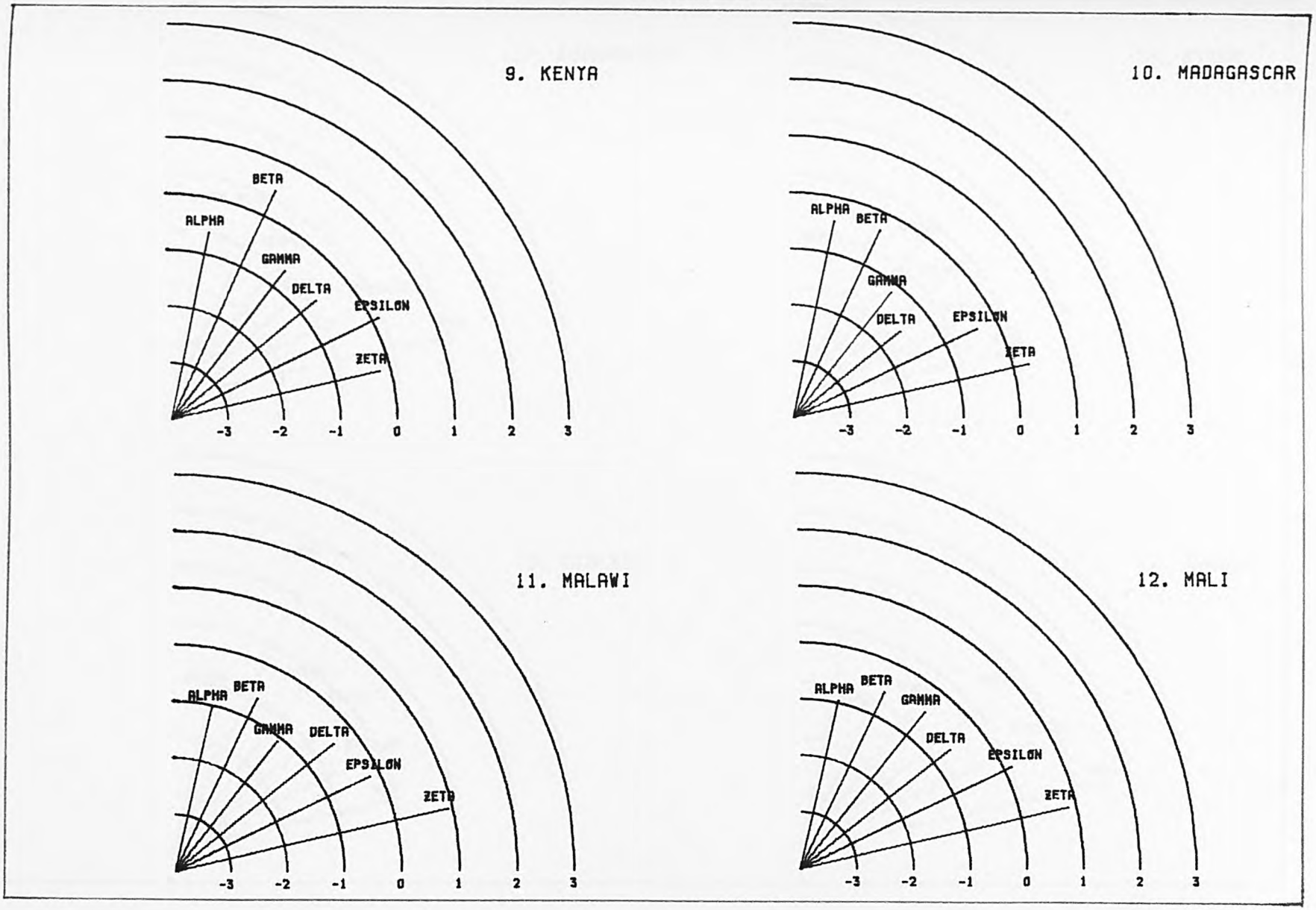
NATIONAL CHARACTERISTICS 1960



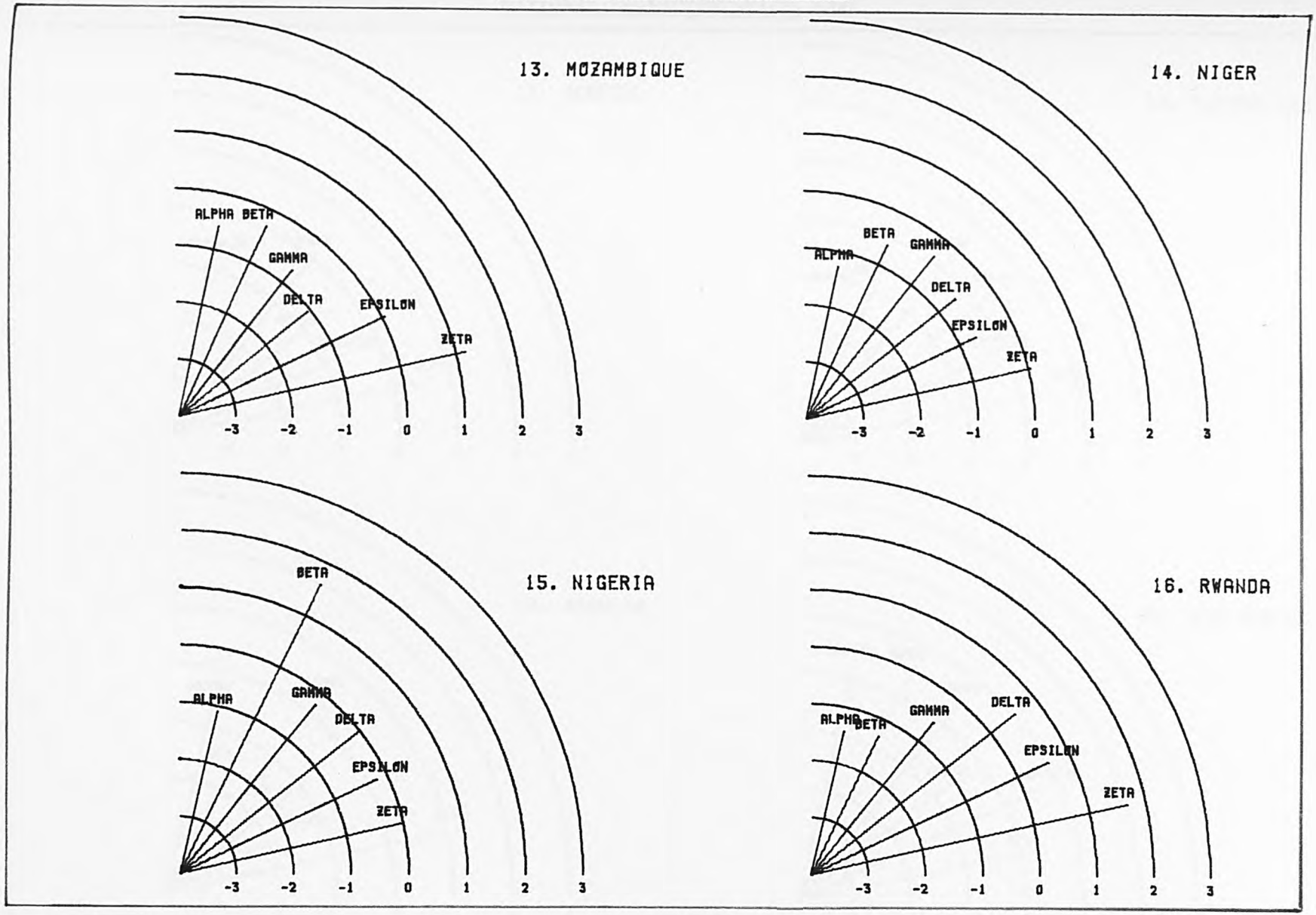
NATIONAL CHARACTERISTICS 1960



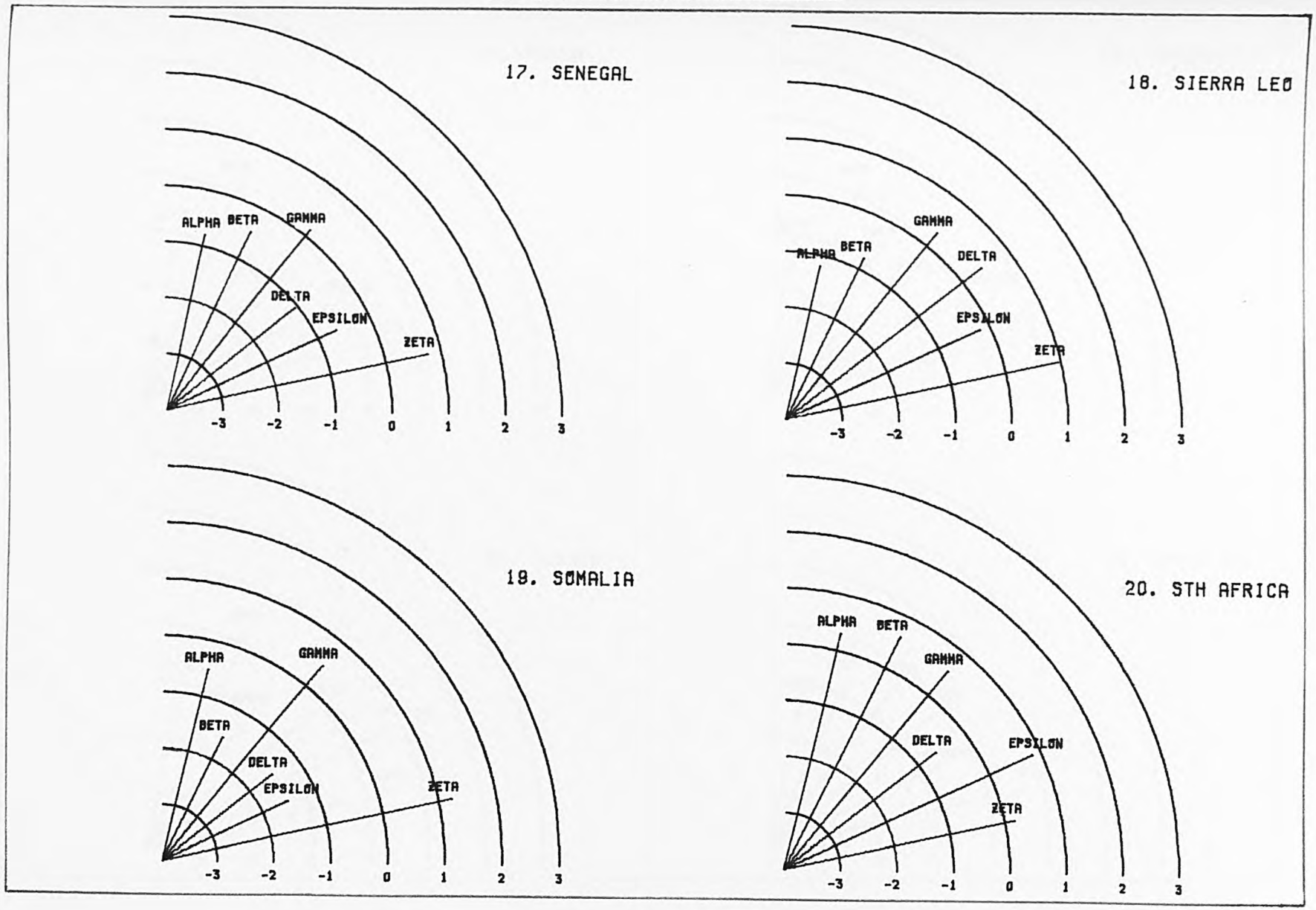
NATIONAL CHARACTERISTICS 1960



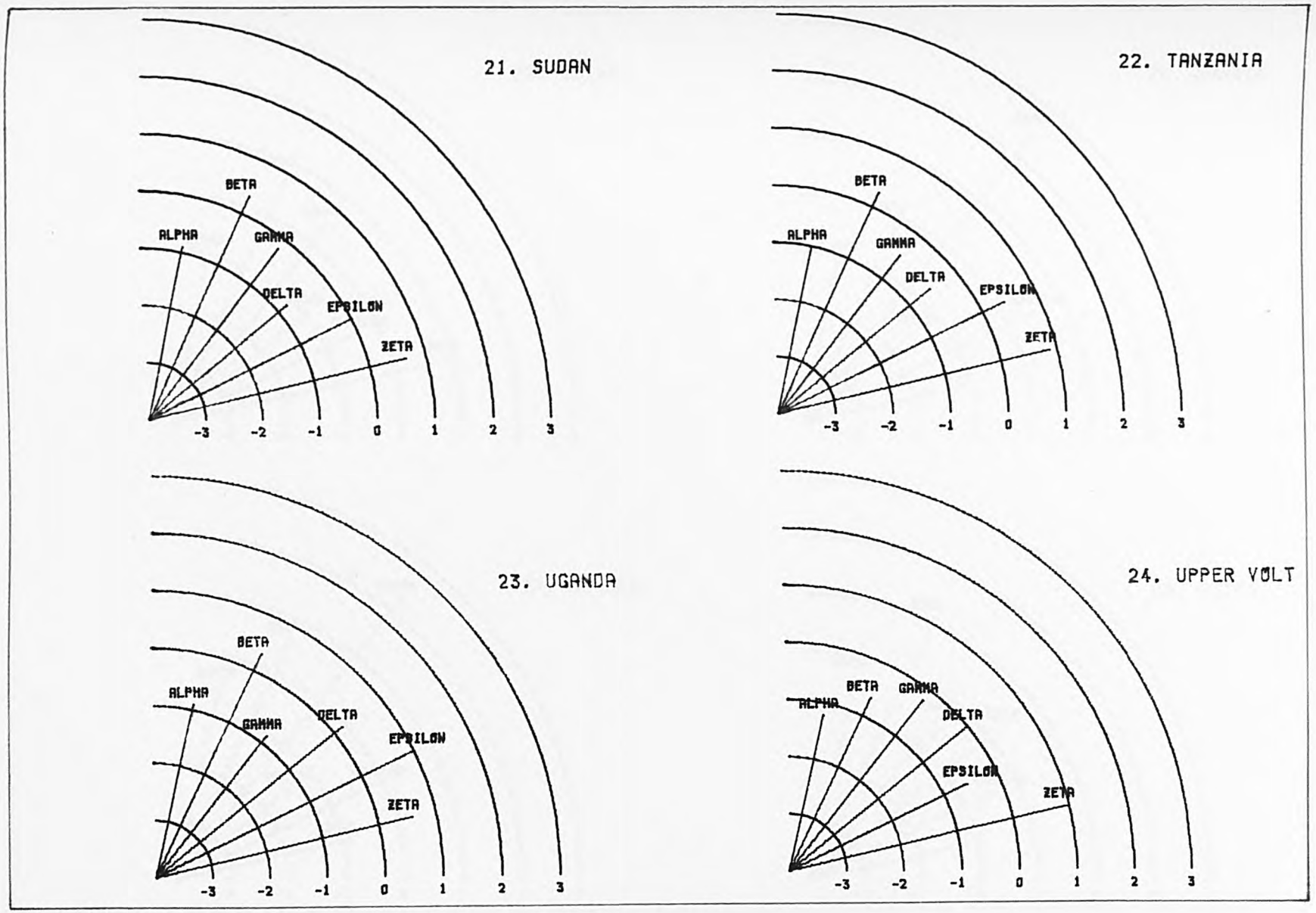
NATIONAL CHARACTERISTICS 1960



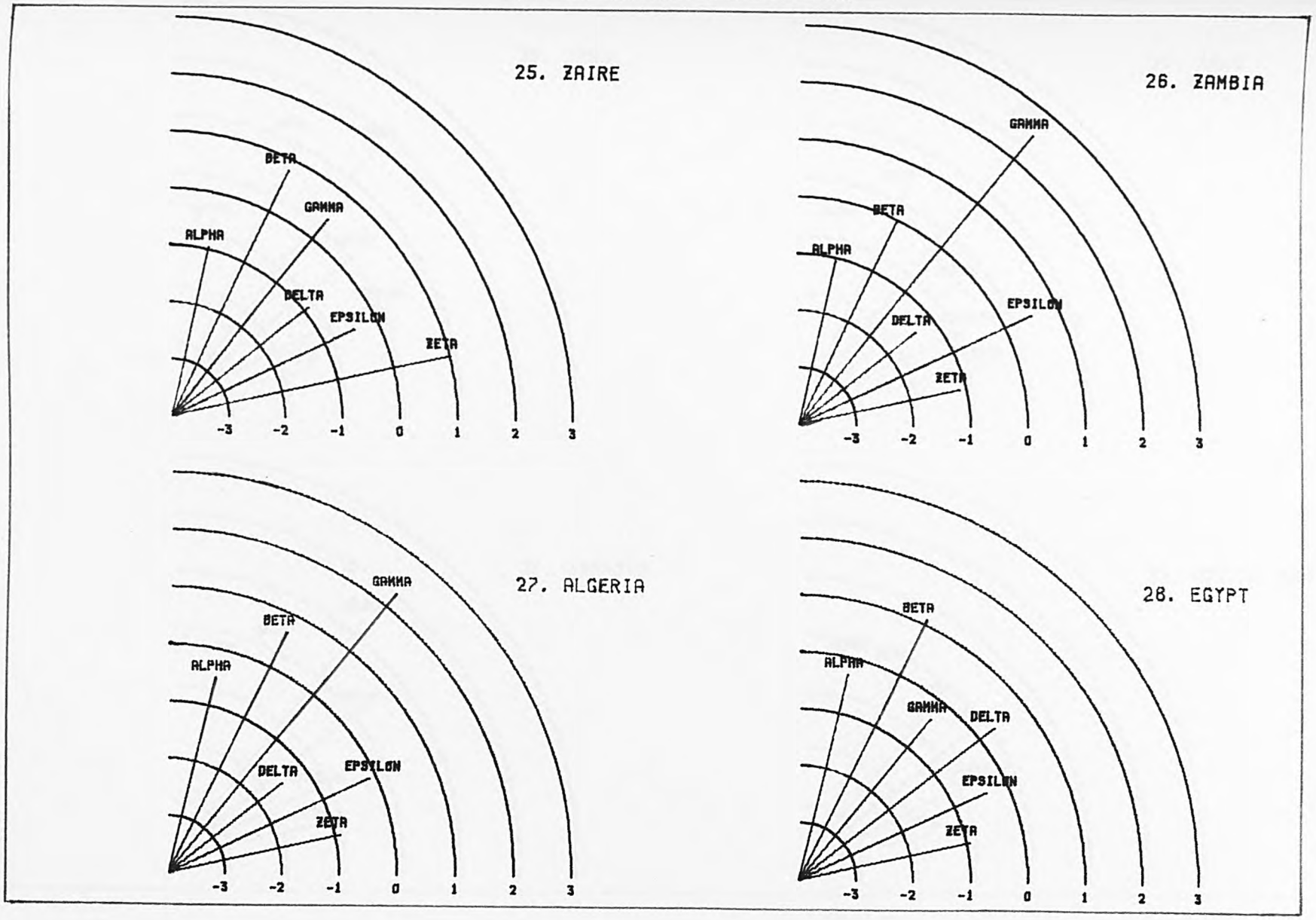
NATIONAL CHARACTERISTICS 1960



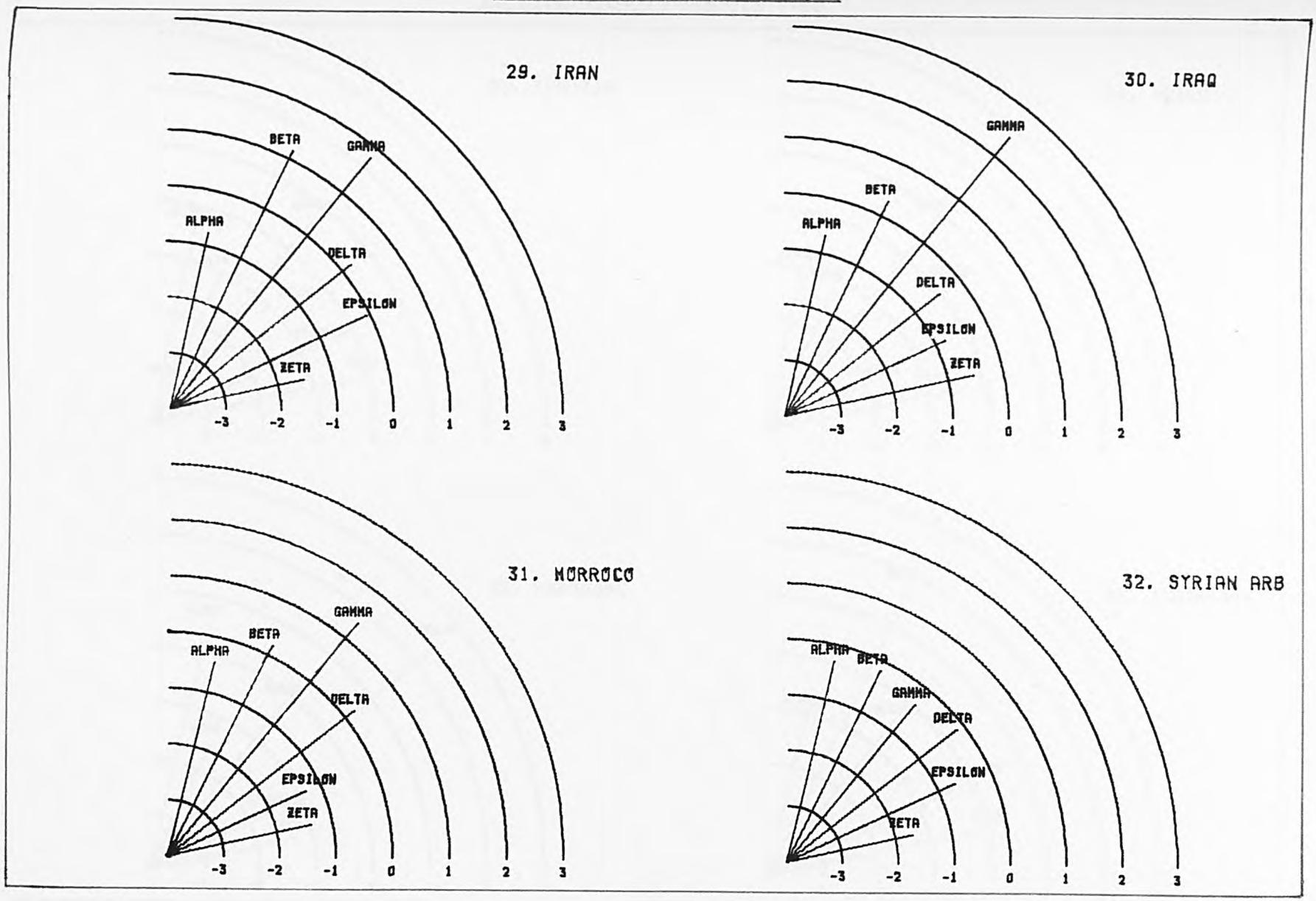
NATIONAL CHARACTERISTISC 1960



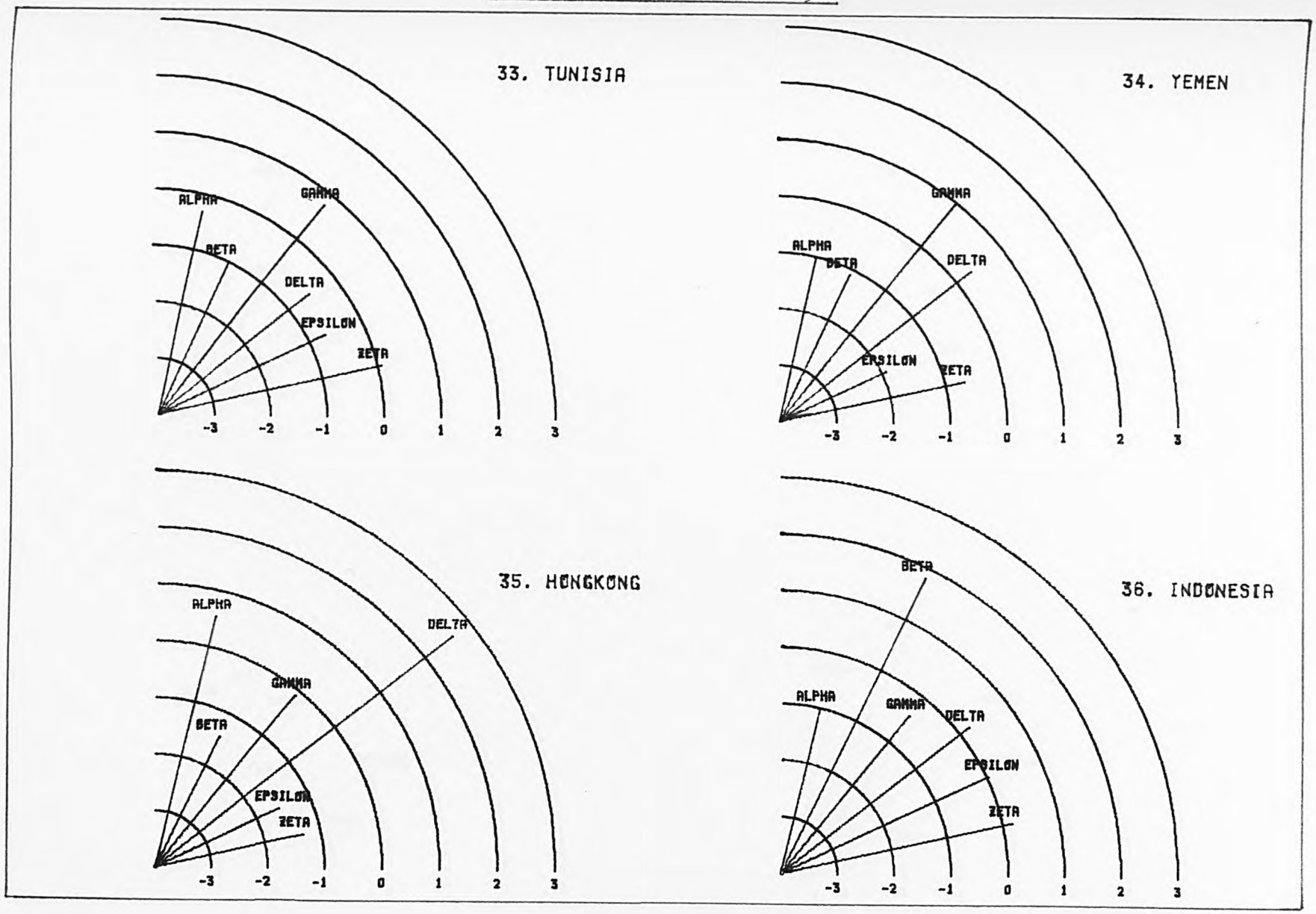
NATIONAL CHARACTERISTICS 1960



NATIONAL CHARACTERISTICS 1960



NATIONAL CHARACTERISTICS 1960



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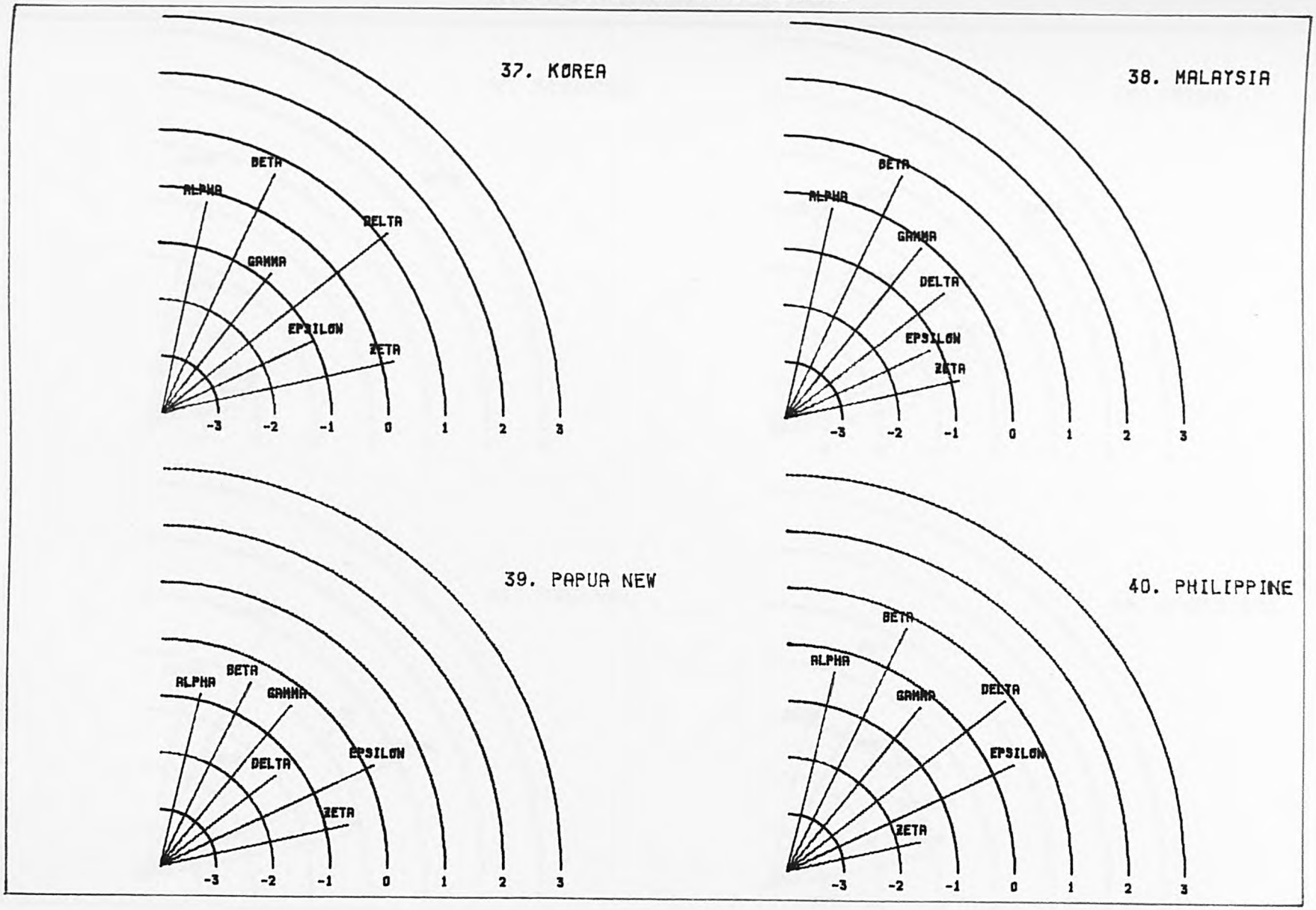
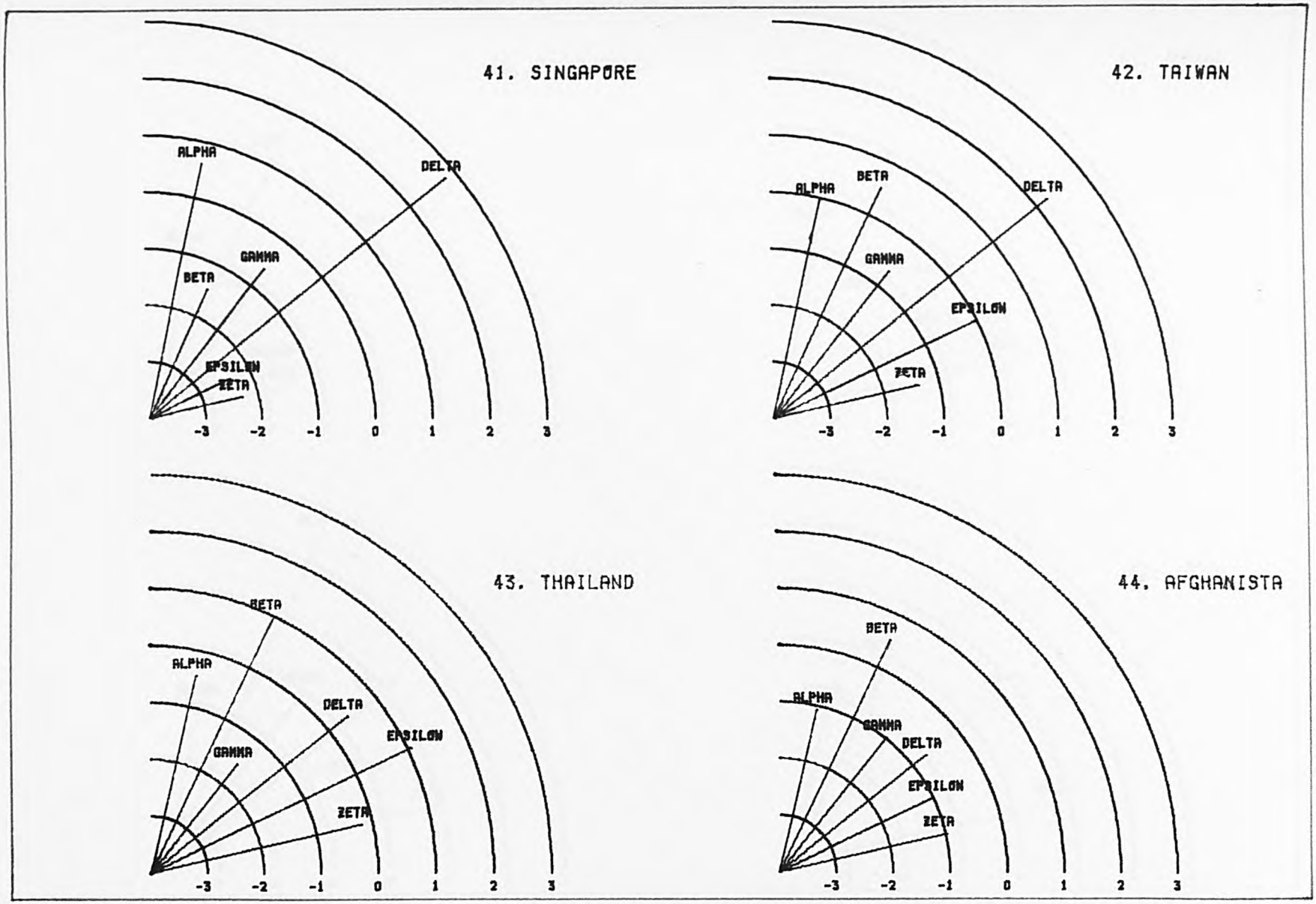
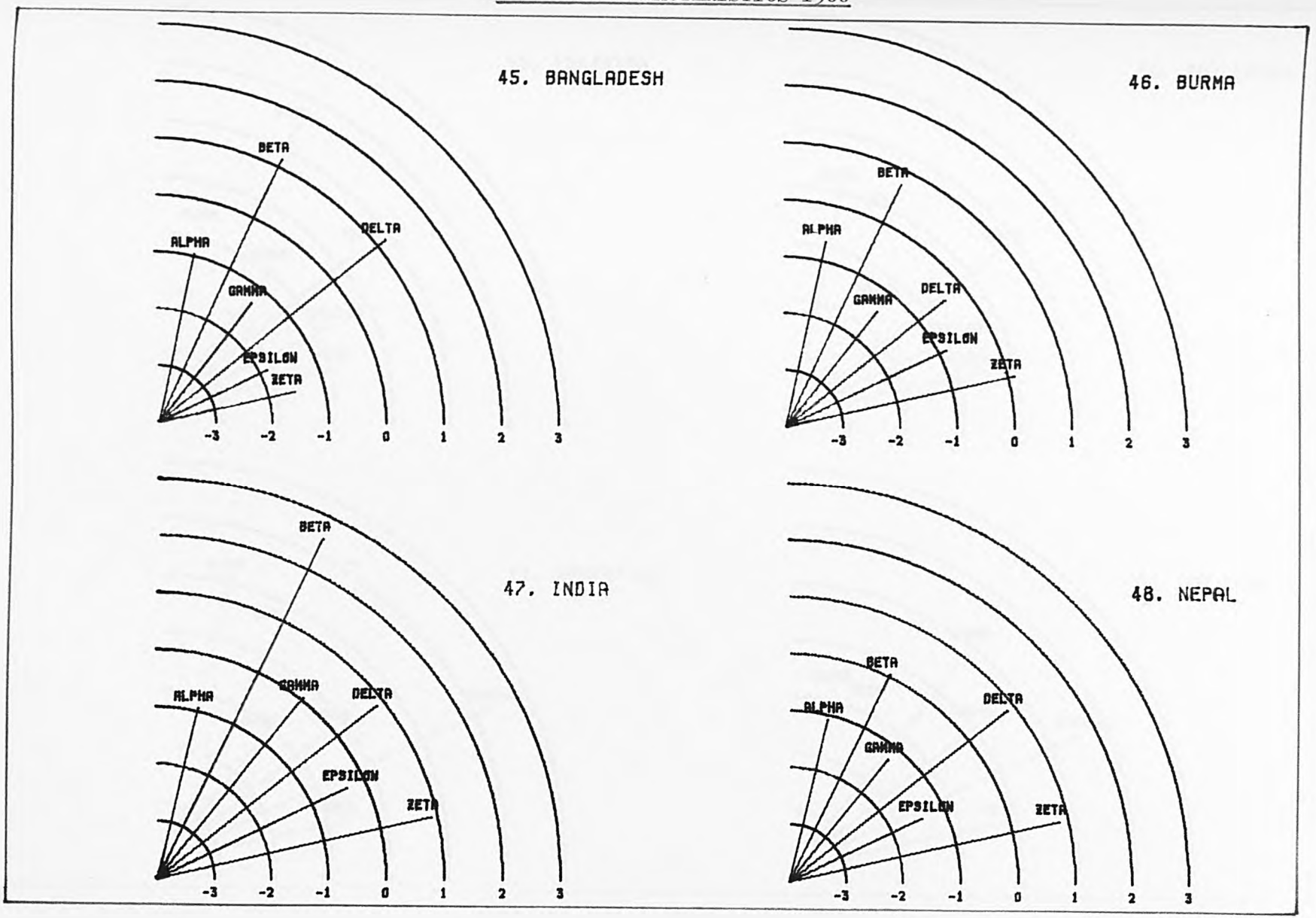
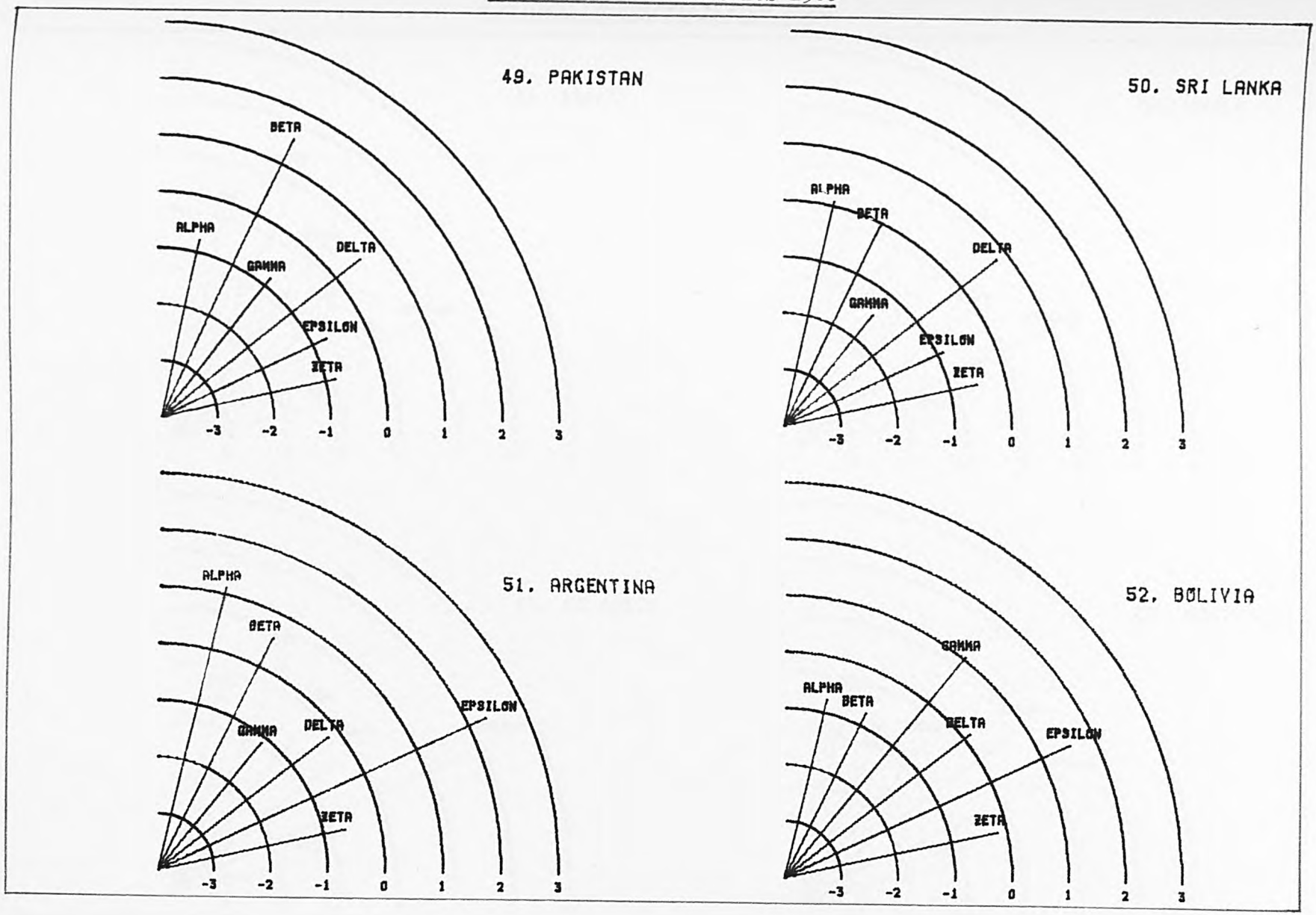


NATIONAL CHARACTERISTICS 1960

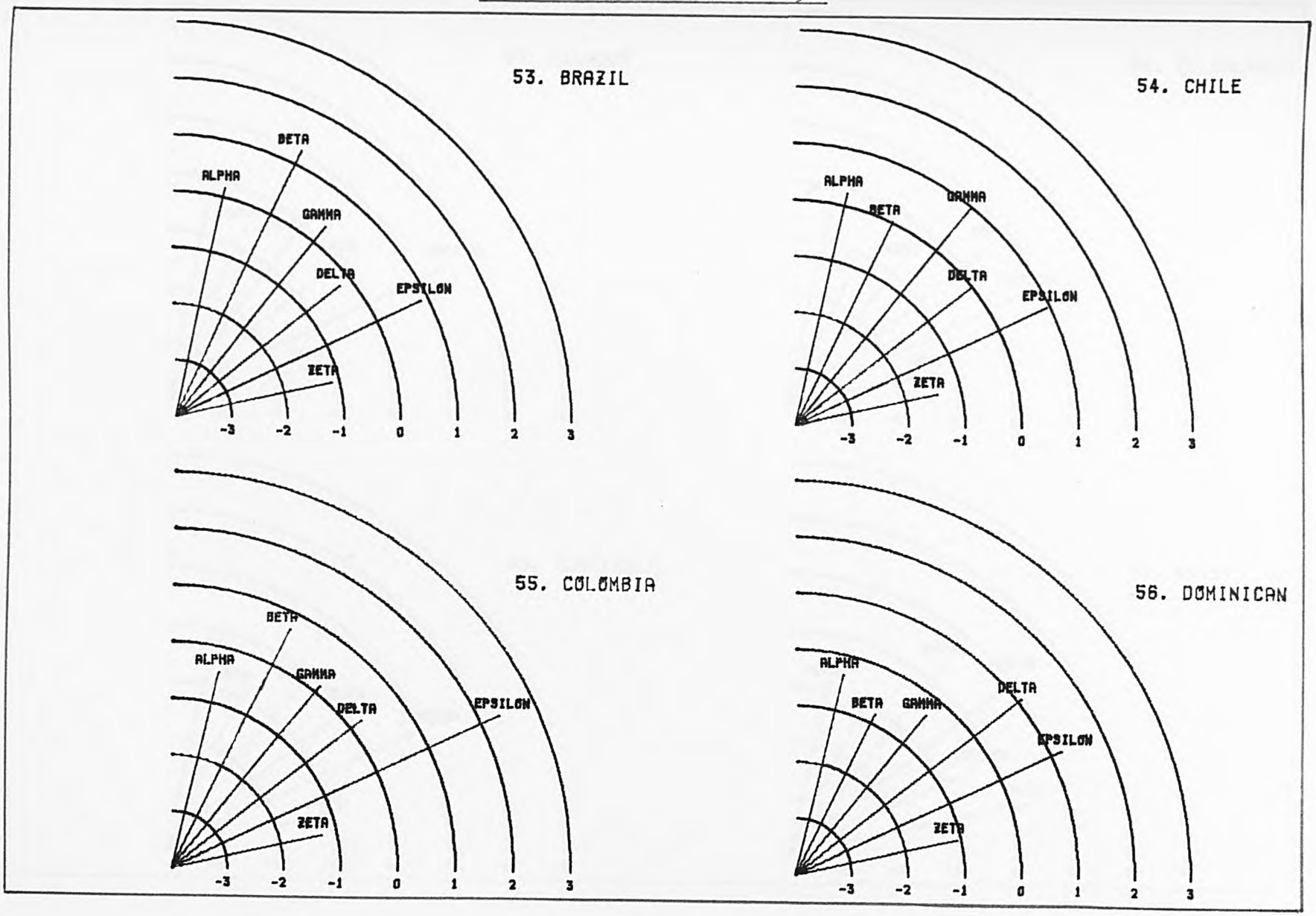


NATIONAL CHARACTERISTICS 1960

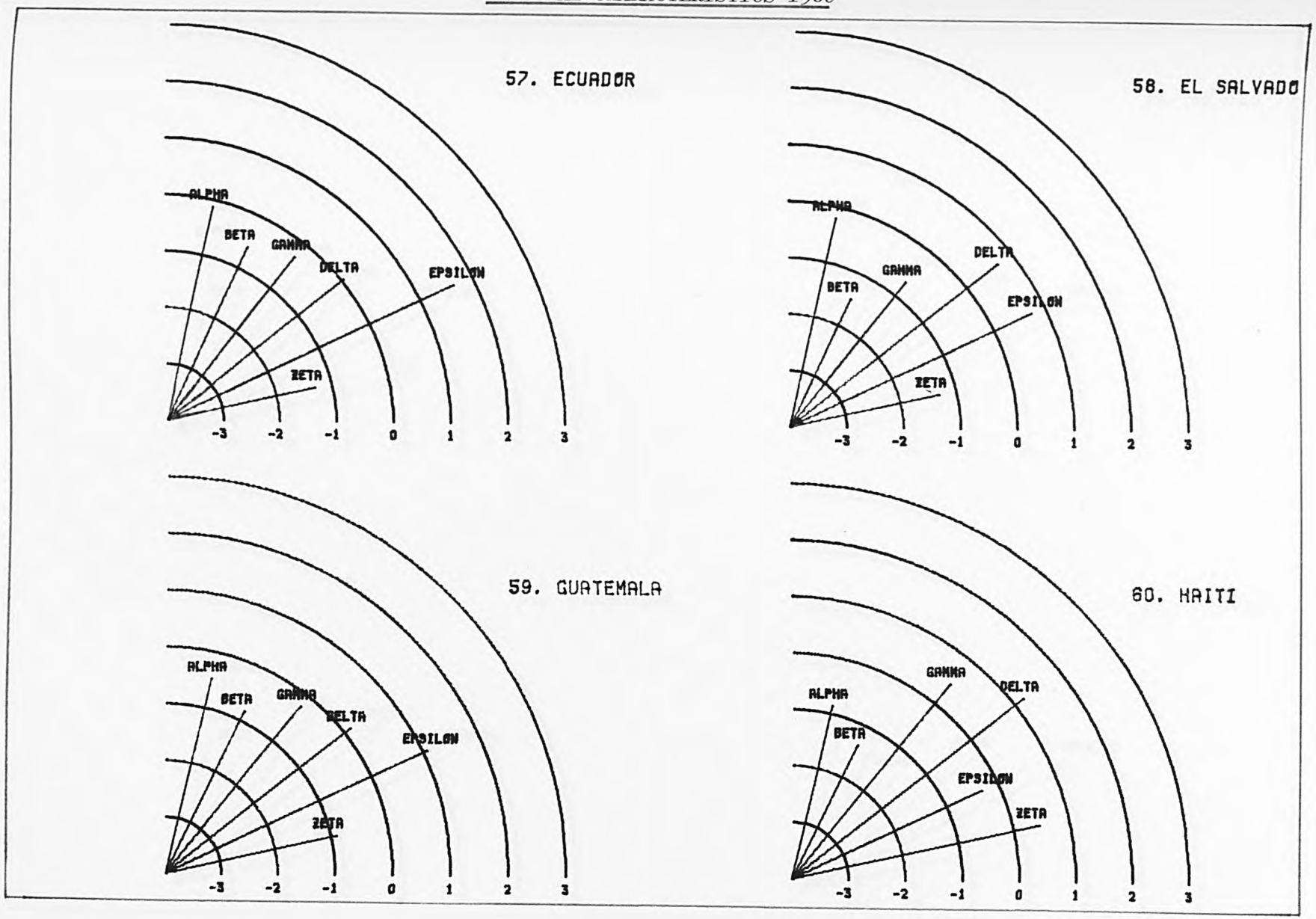



49. PAKISTAN
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
50. SRI LANKA
ALPHA
BETA
DELTA
GAMMA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
51. ARGENTINA
ALPHA
BETA
EPSILON
GAMMA
DELTA
ZETA
-3 -2 -1 0 1 2 3
52. BOLIVIA
GAMMA
ALPHA
BETA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

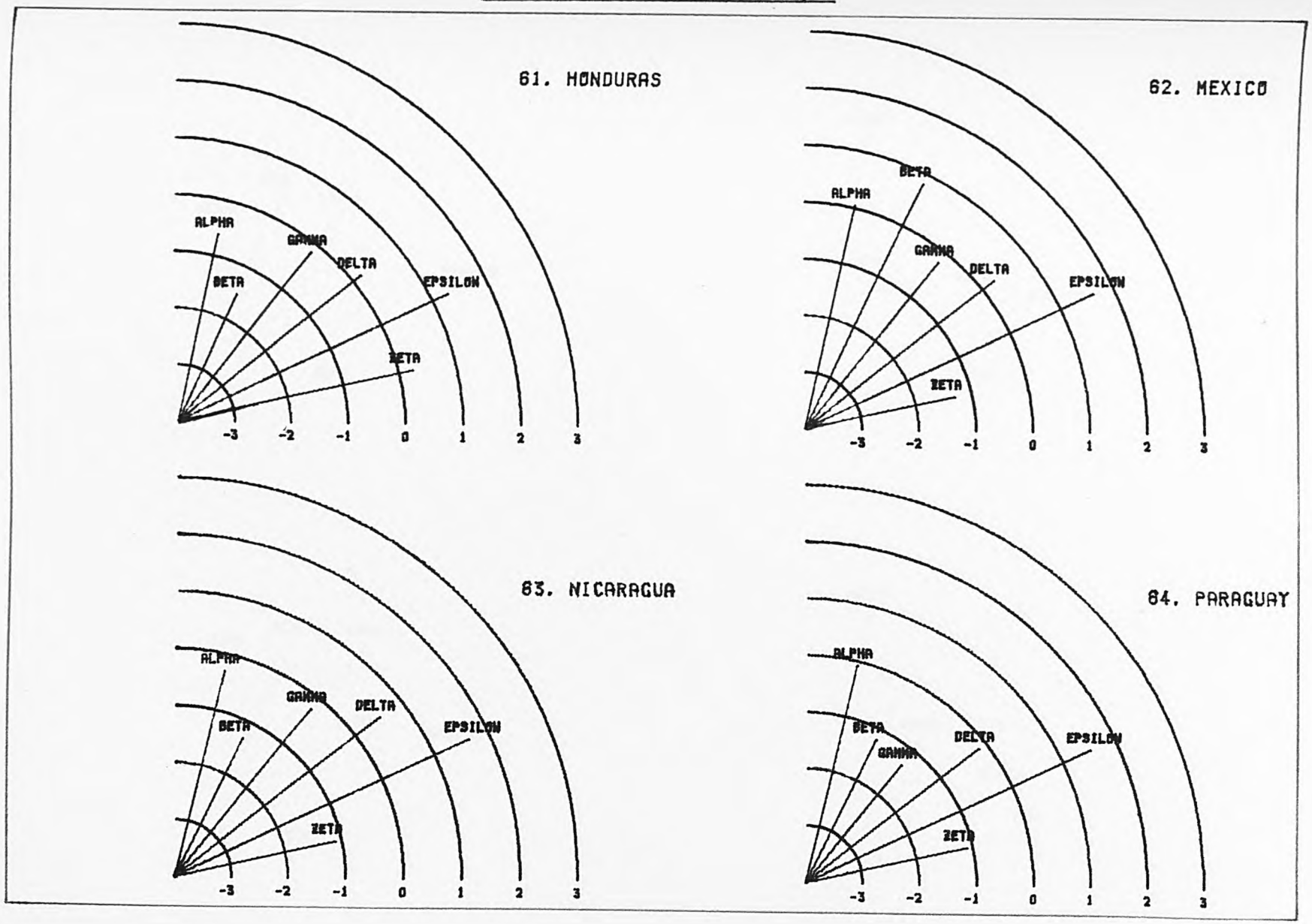
NATIONAL CHARACTERISTICS 1960

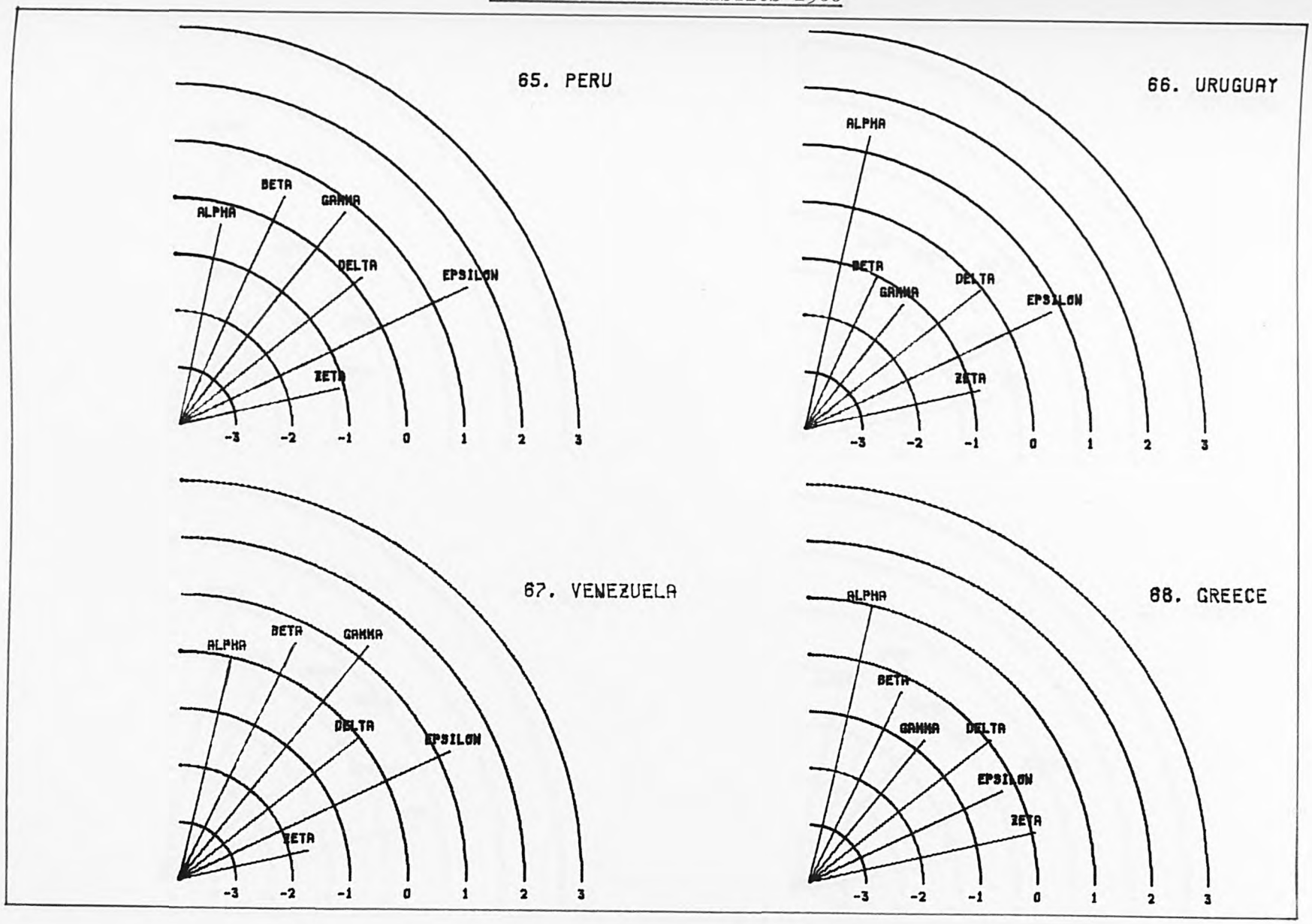


NATIONAL CHARACTERISTICS 1960

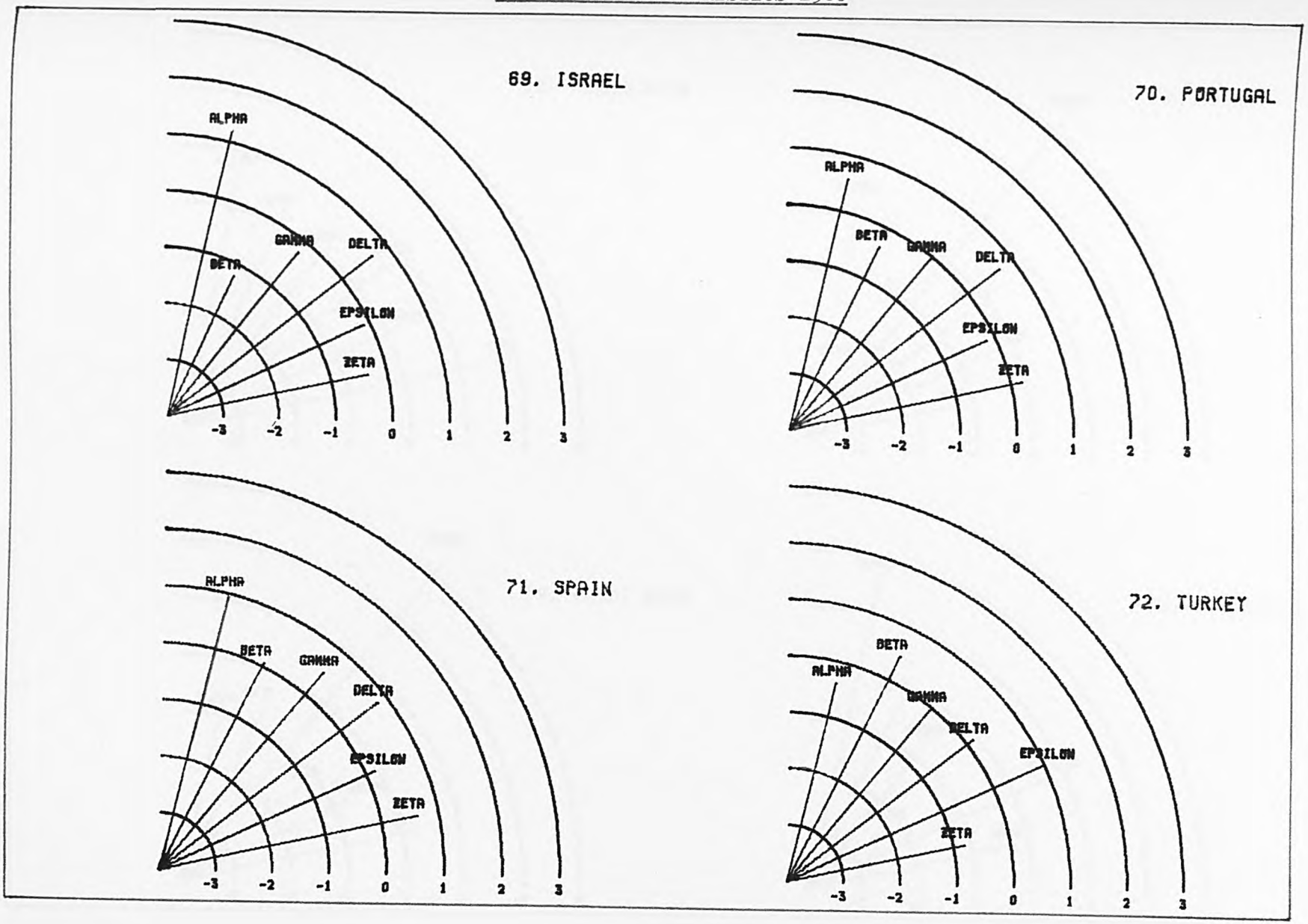


NATIONAL CHARACTERISTICS 1960

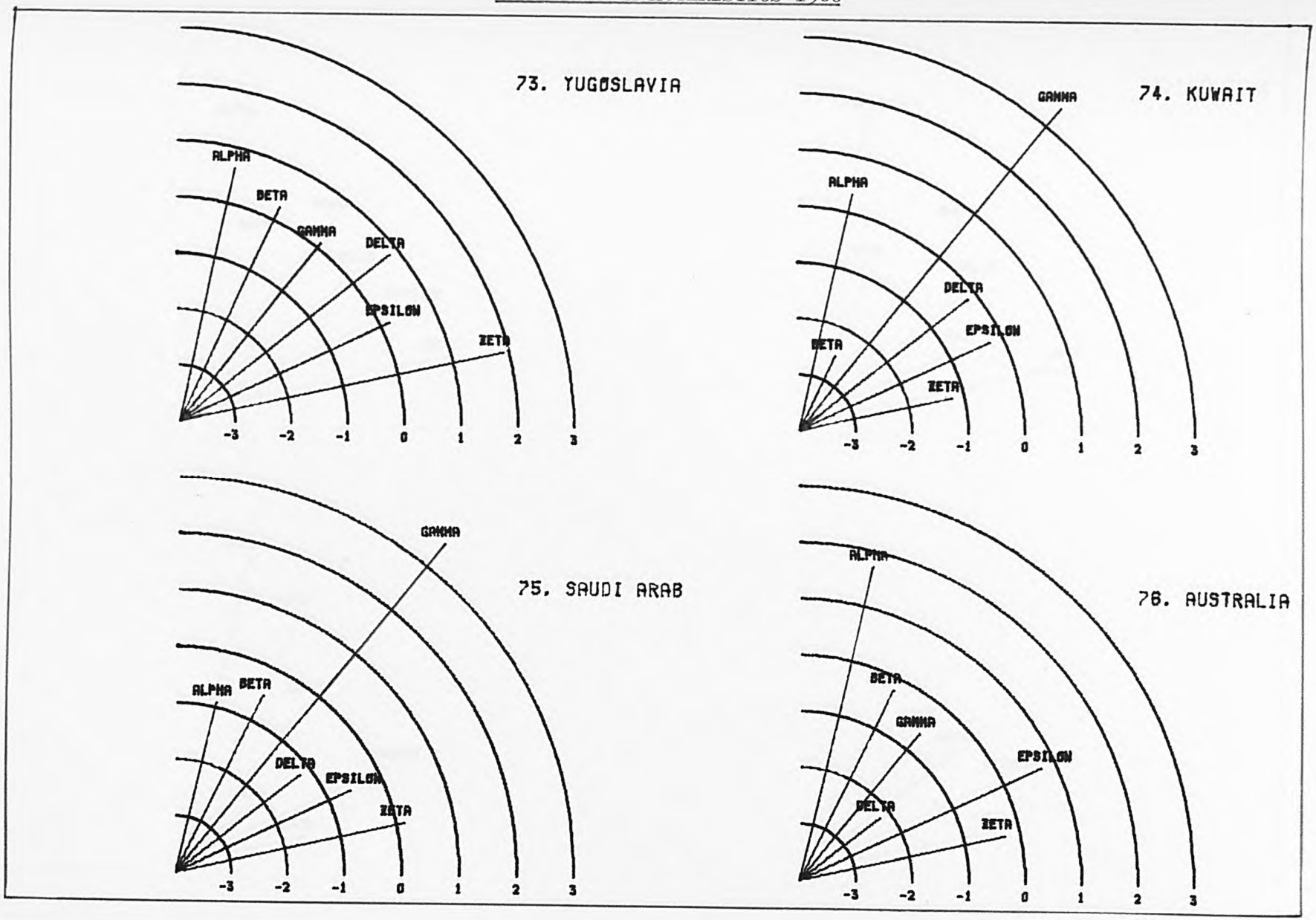



65. PERU
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
66. URUGUAY
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
67. VENEZUELA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
68. GREECE
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

NATIONAL CHARACTERISTICS 1960



NATIONAL CHARACTERISTICS 1960



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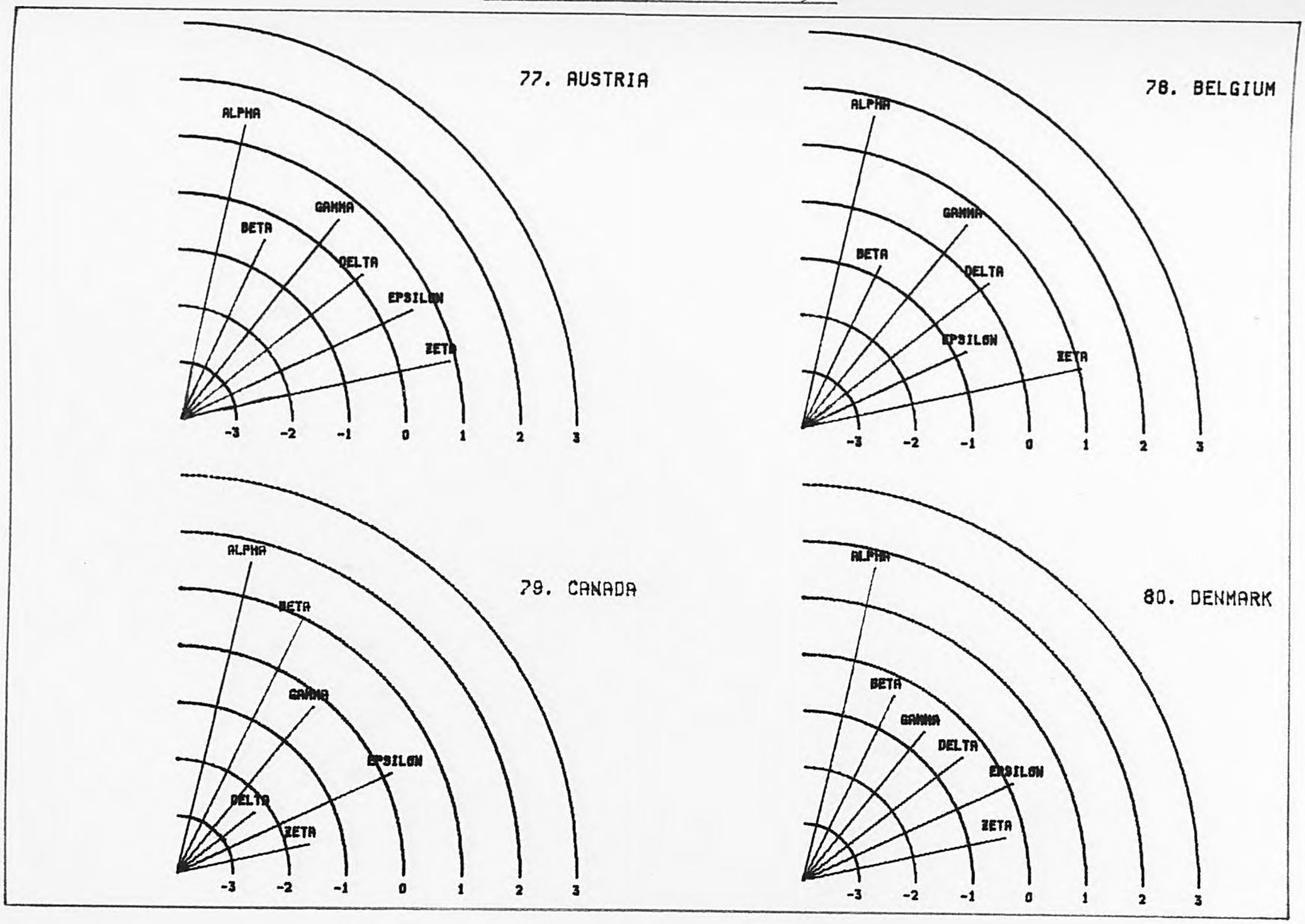
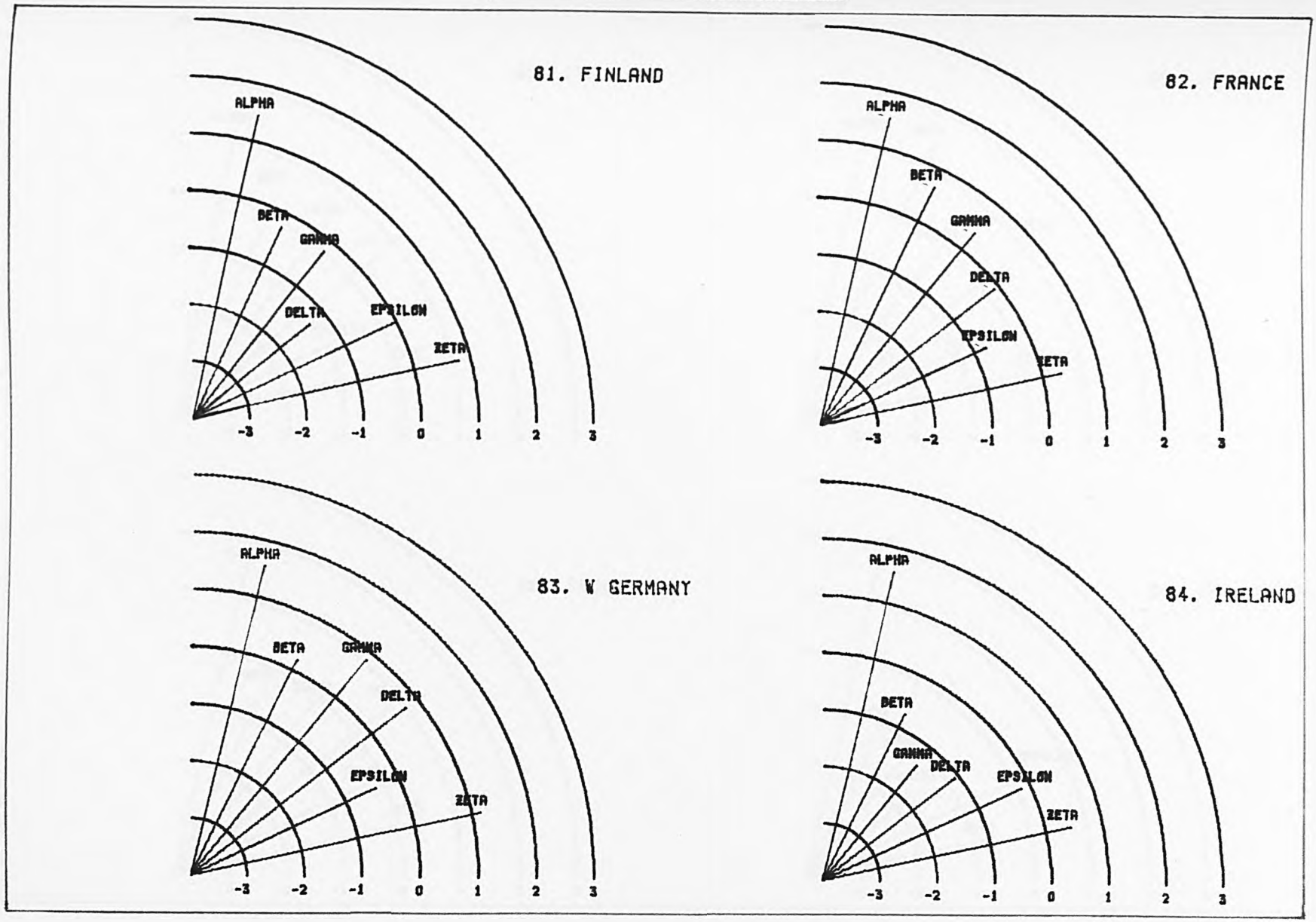
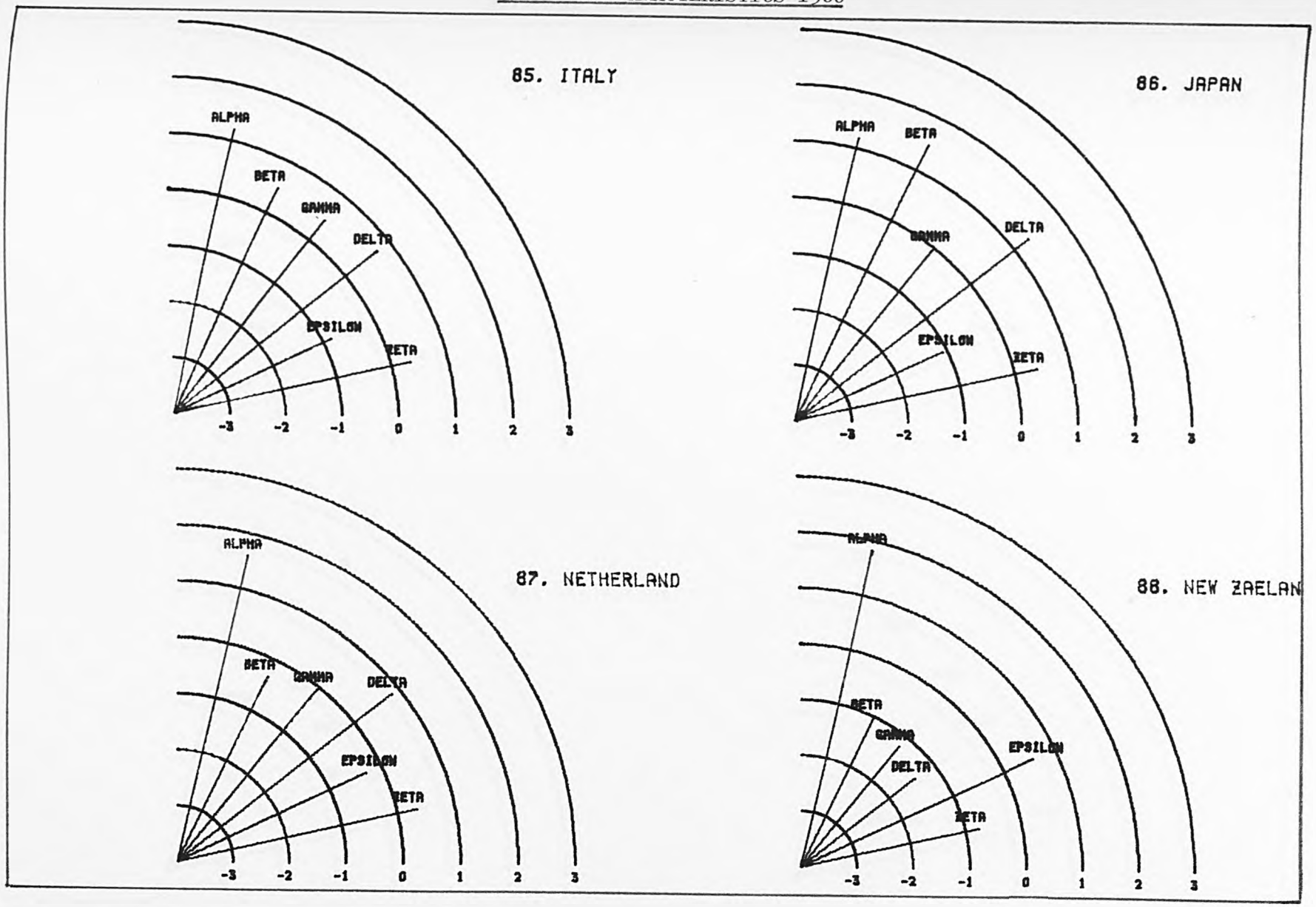


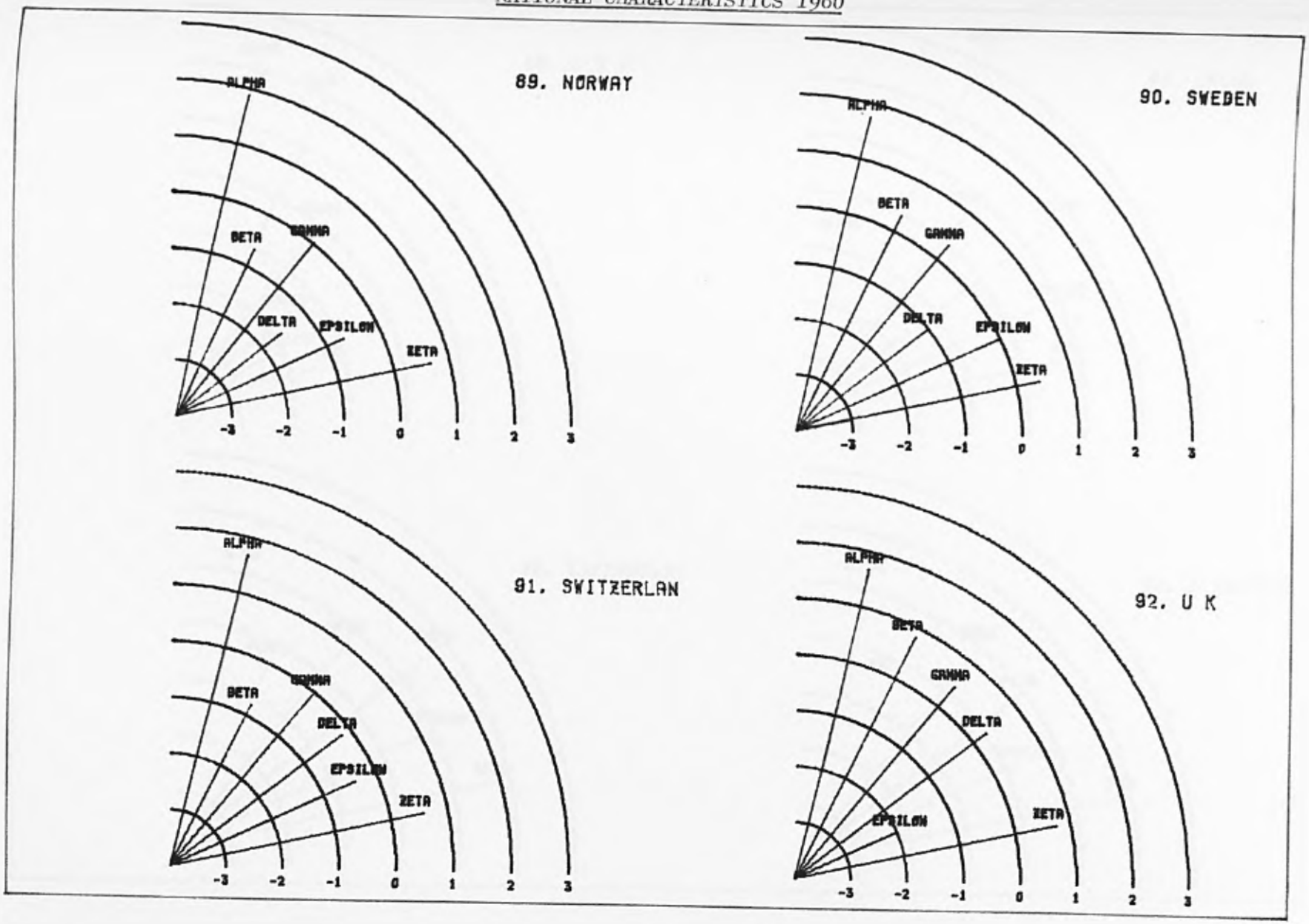
NATIONAL CHARACTERISTICS 1960



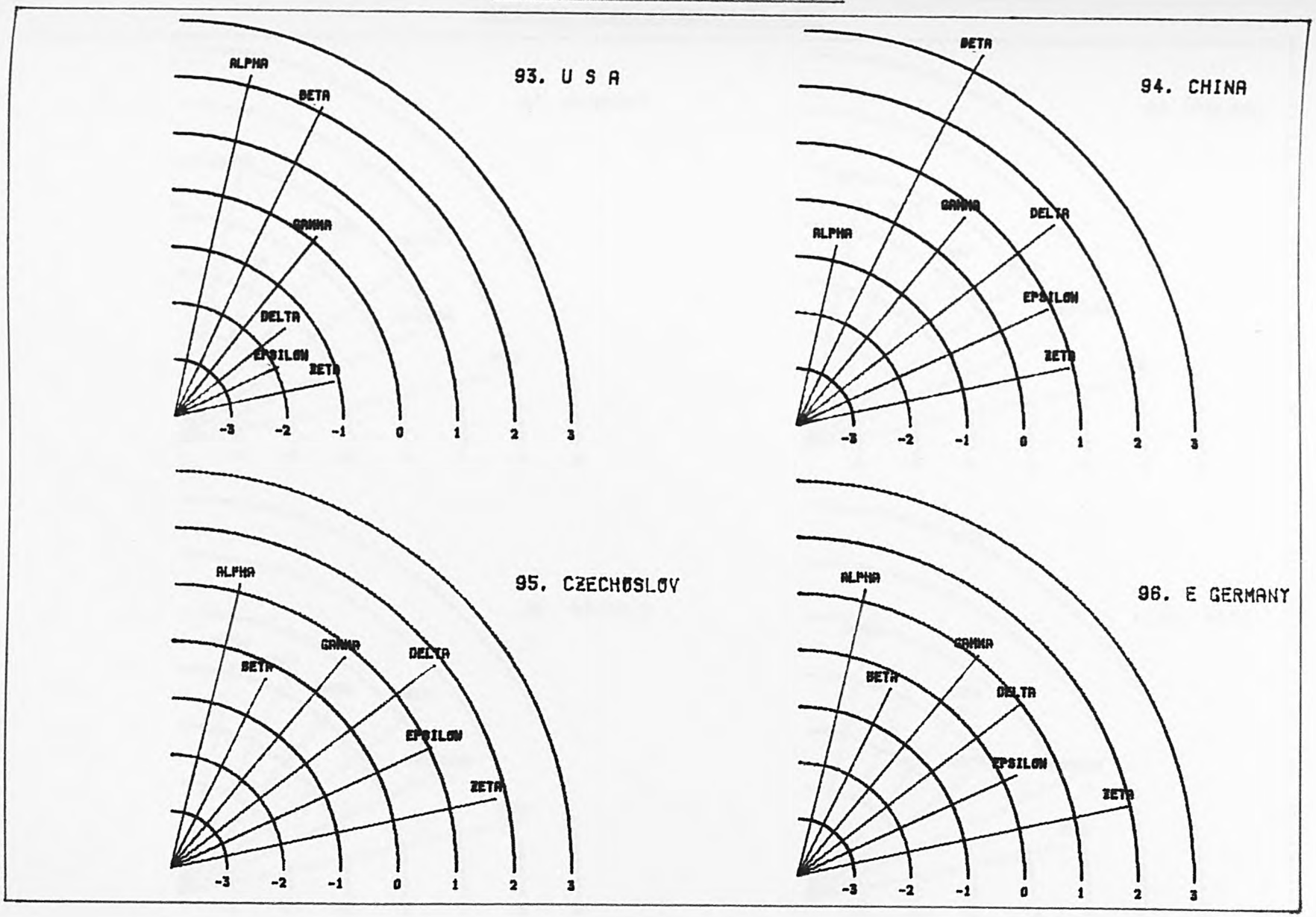
NATIONAL CHARACTERISTICS 1960



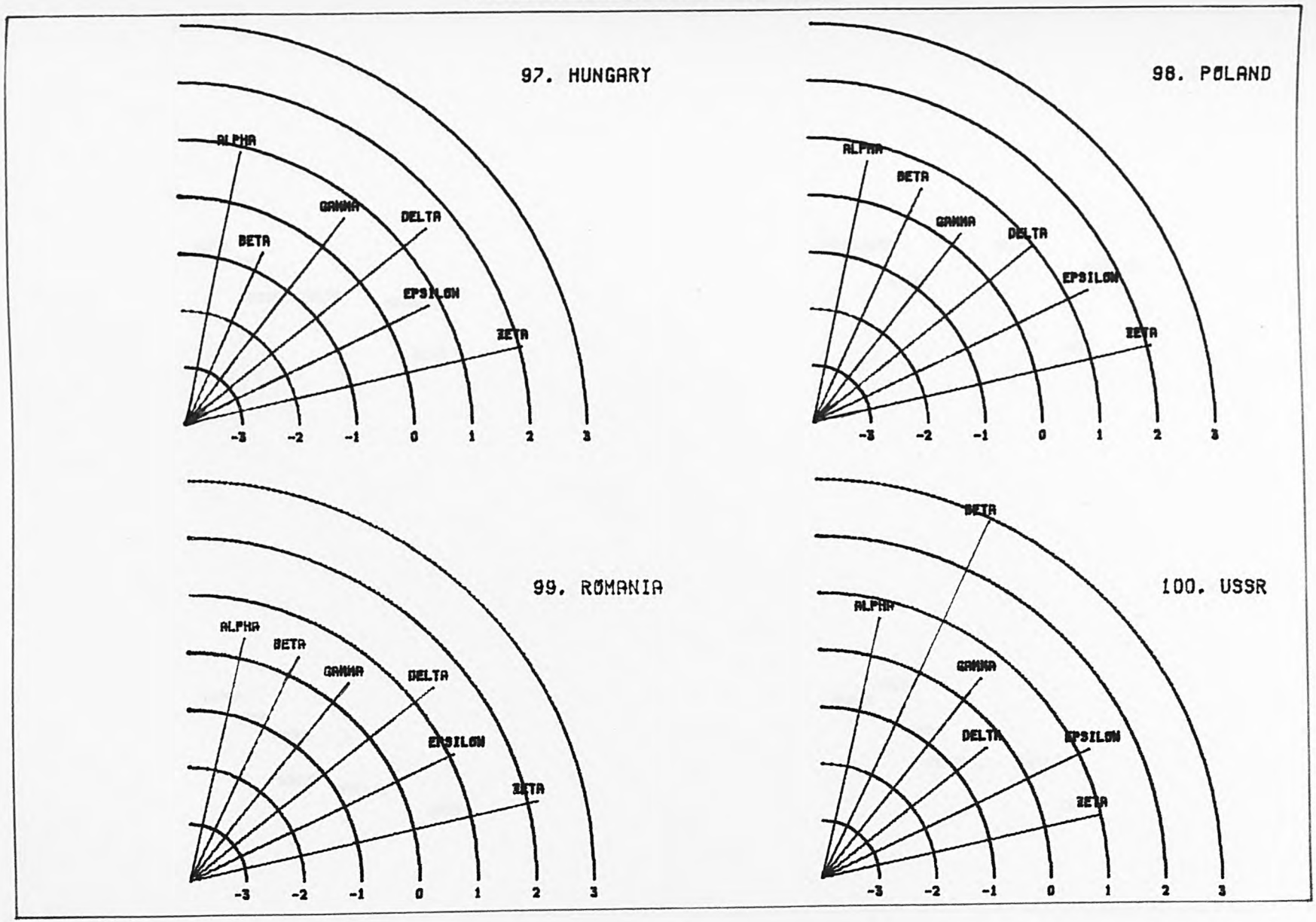
NATIONAL CHARACTERISTICS 1960



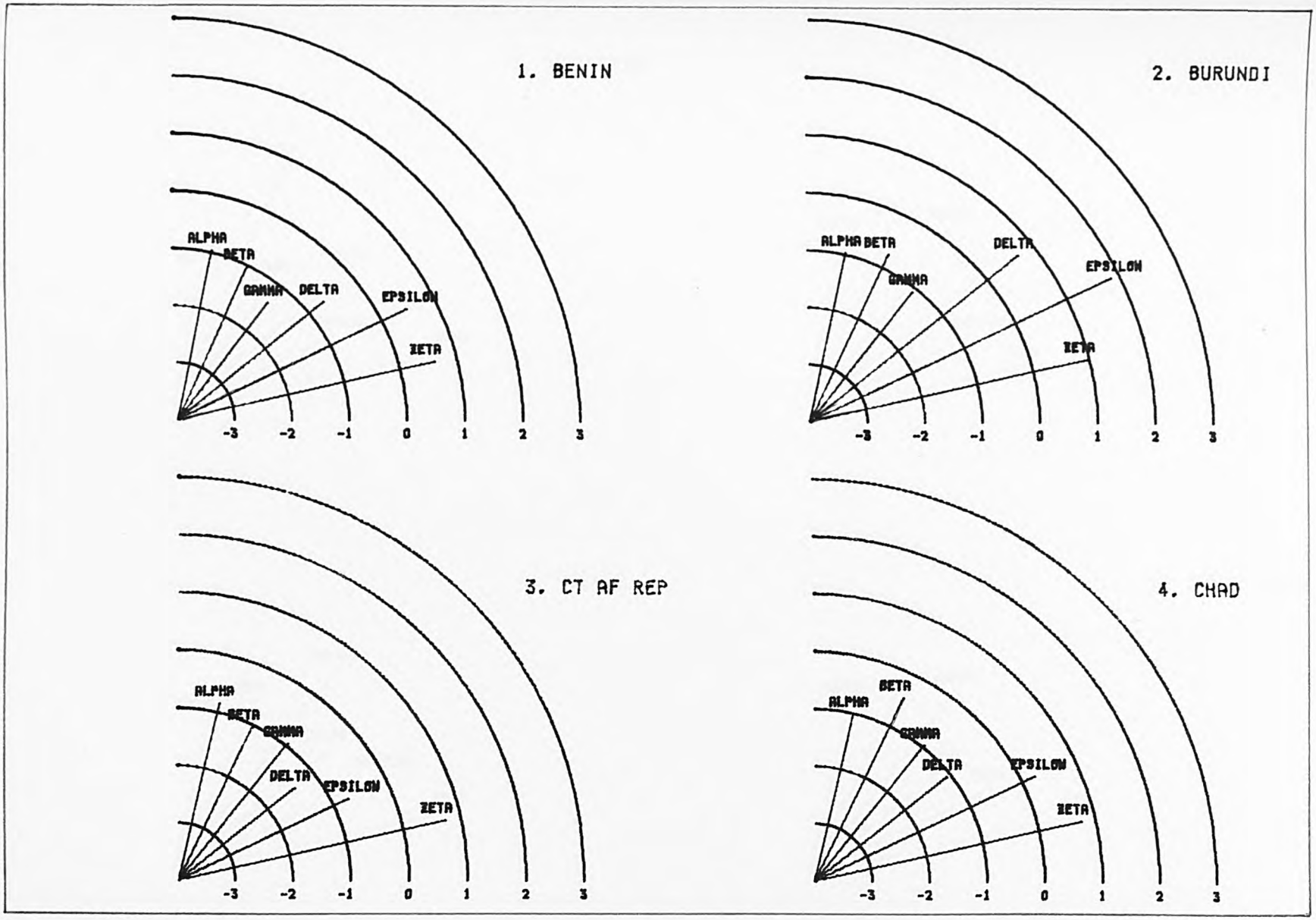
NATIONAL CHARACTERISTICS 1960



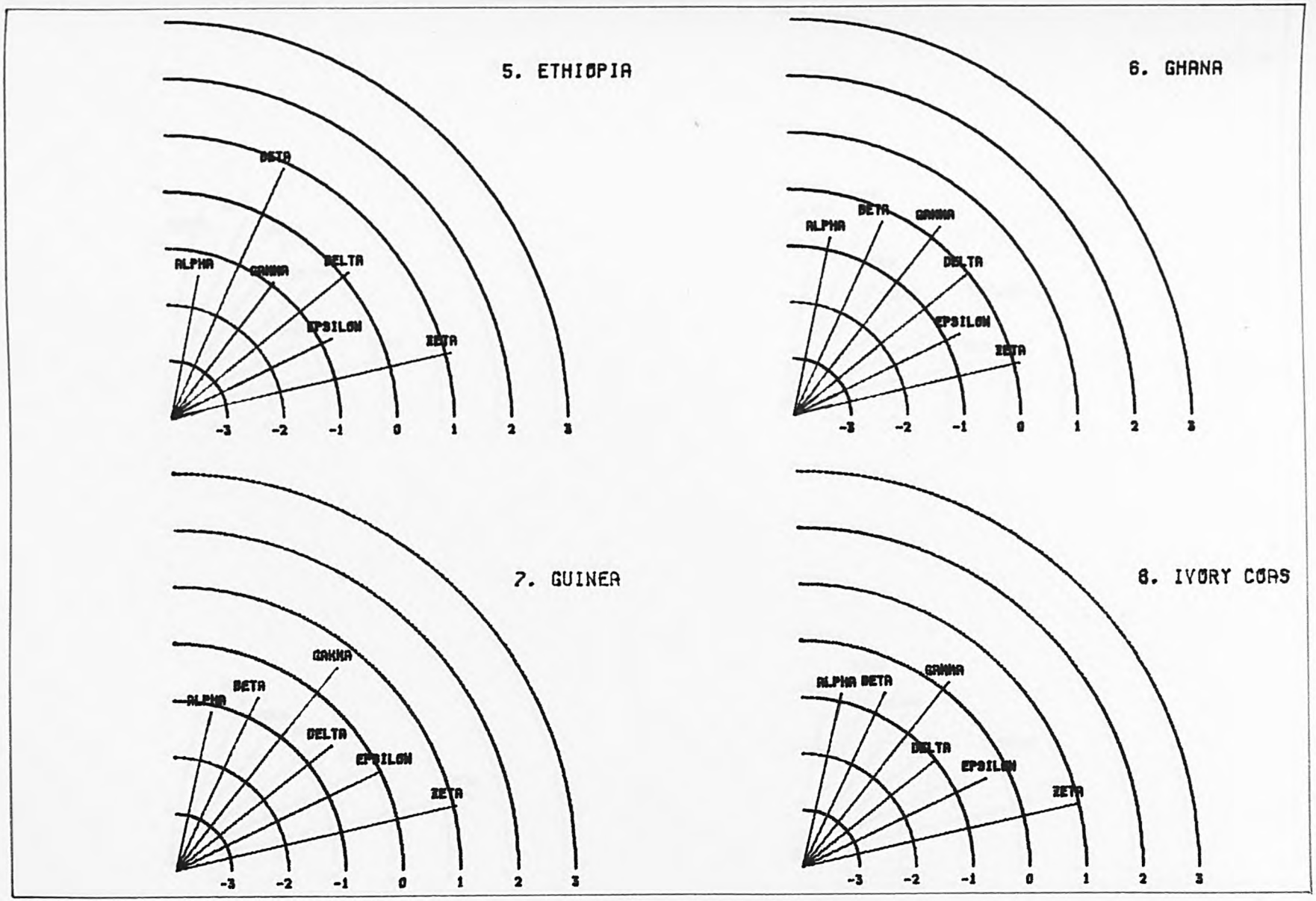
NATIONAL CHARACTERISTICS 1960



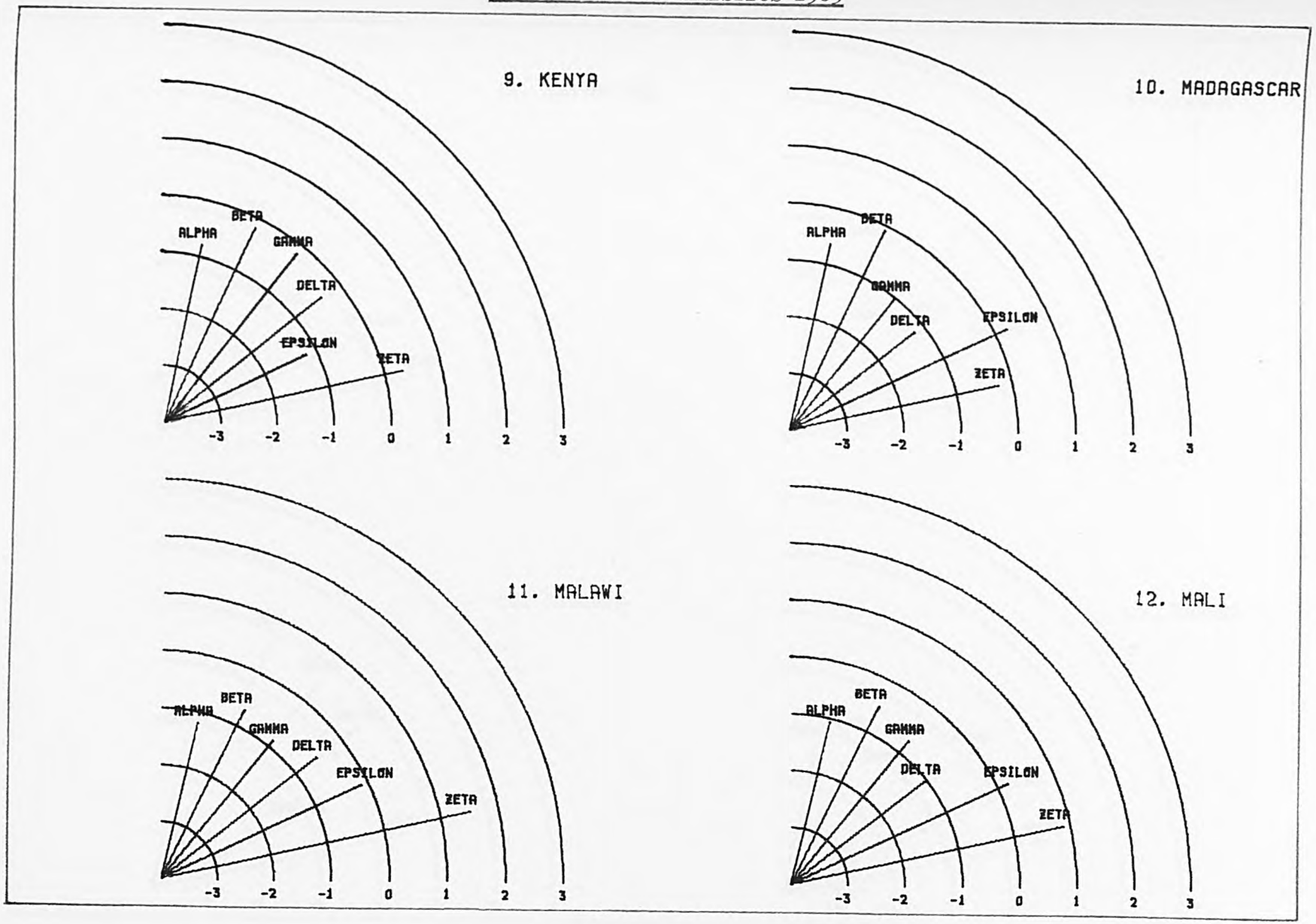
NATIONAL CHARACTERISTICS 1965



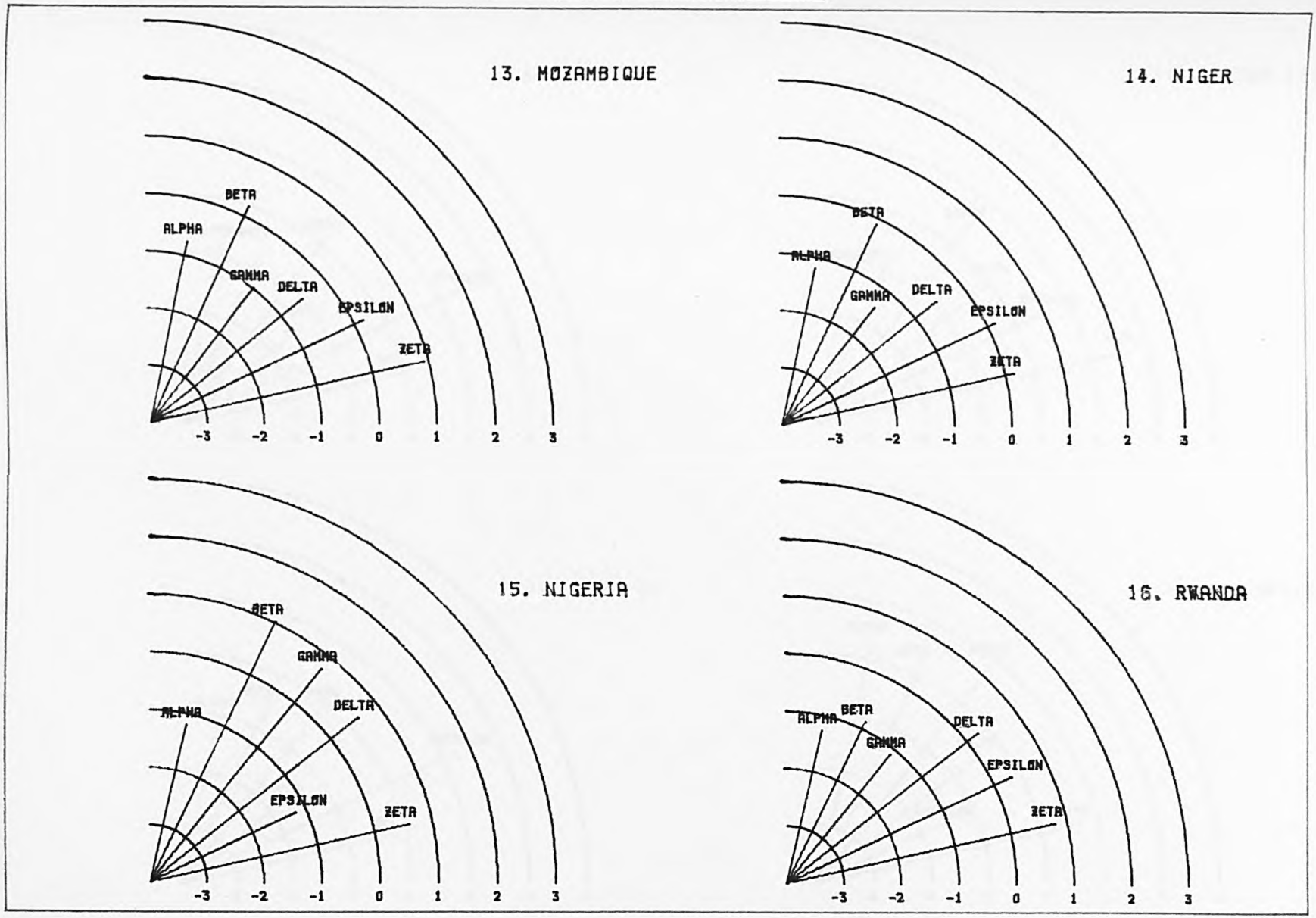
NATIONAL CHARACTERISTICS 1965



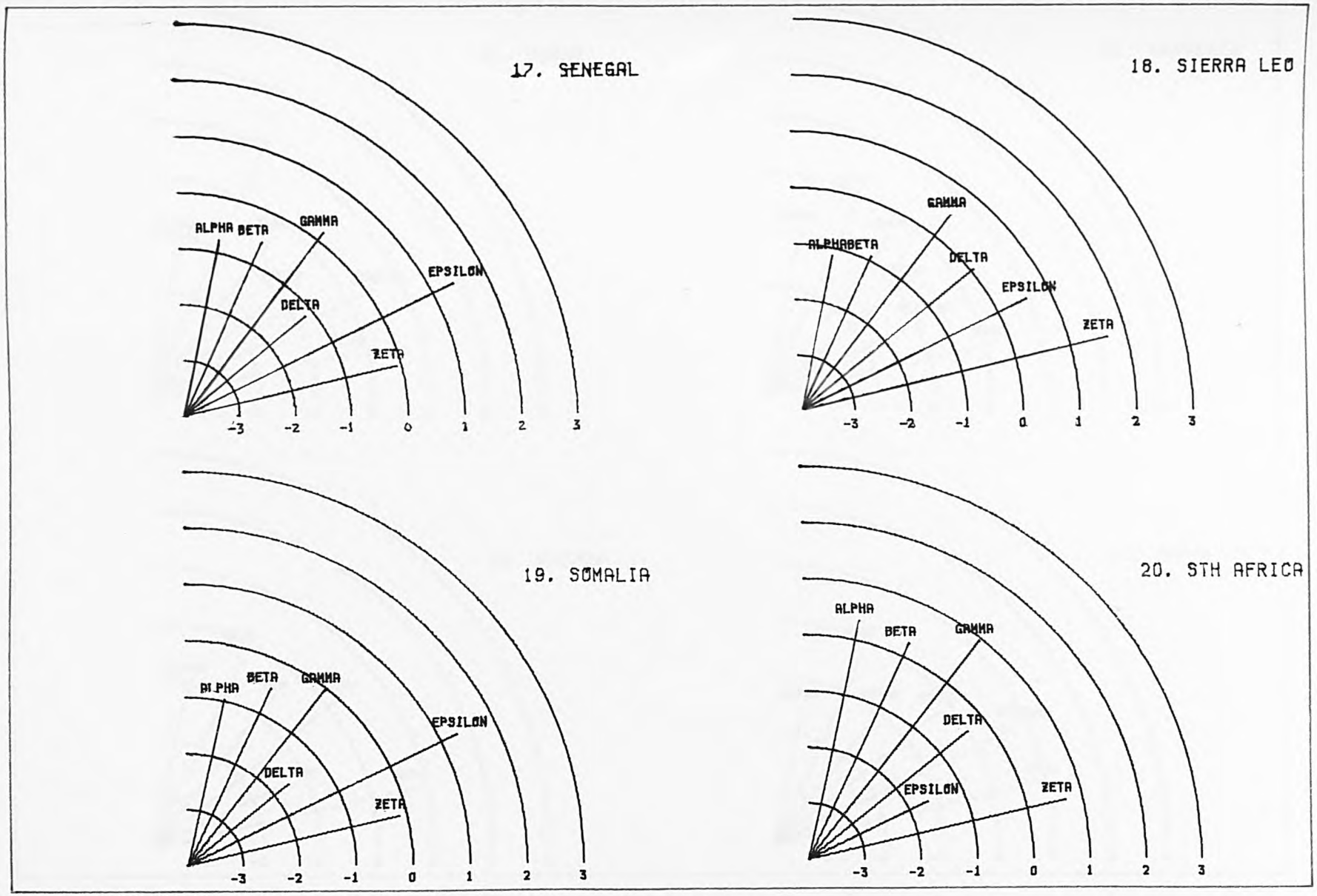
NATIONAL CHARACTERISTICS 1965

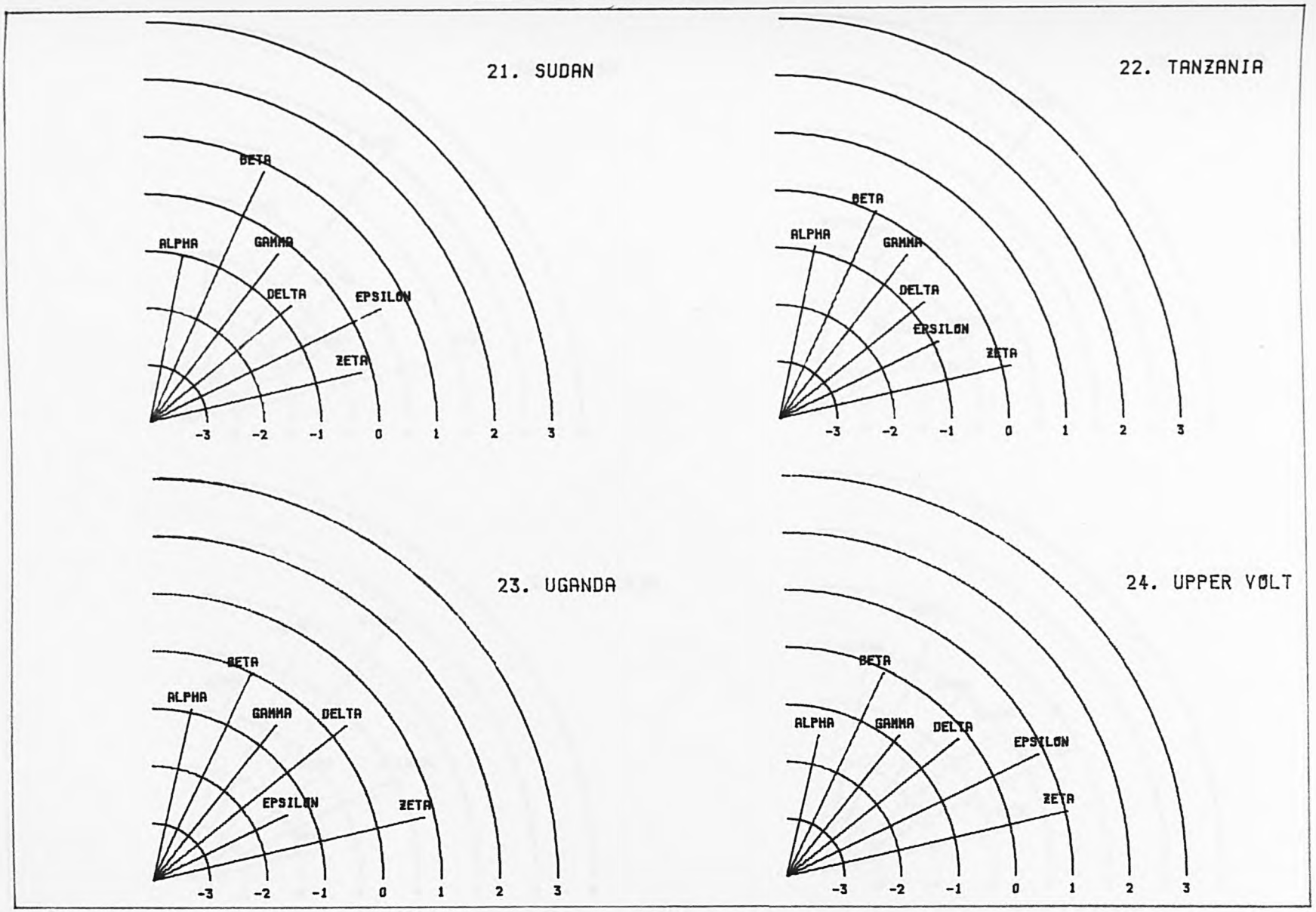


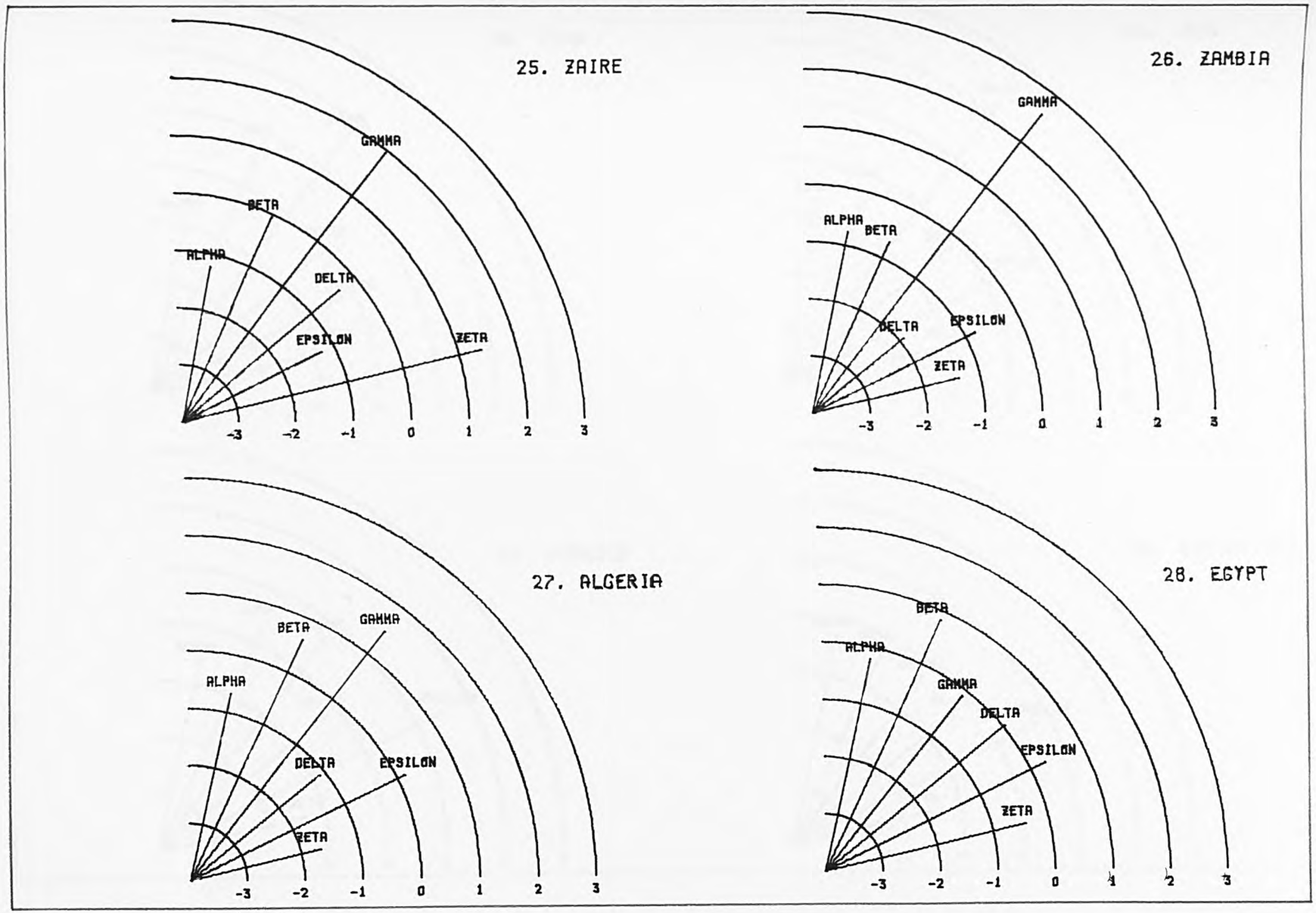
NATIONAL CHARACTERISTICS 1965



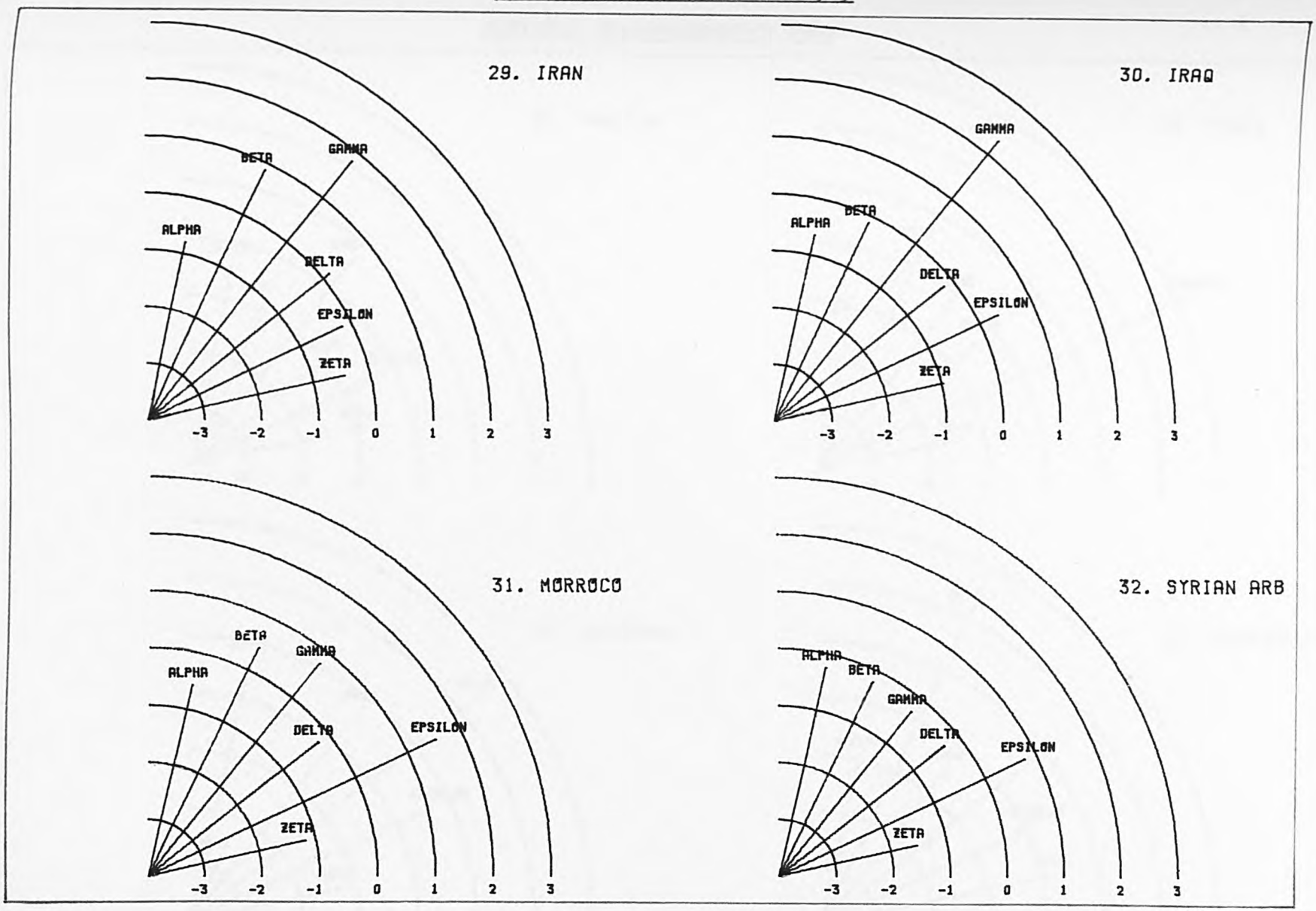
NATIONAL CHARACTERISTICS 1965



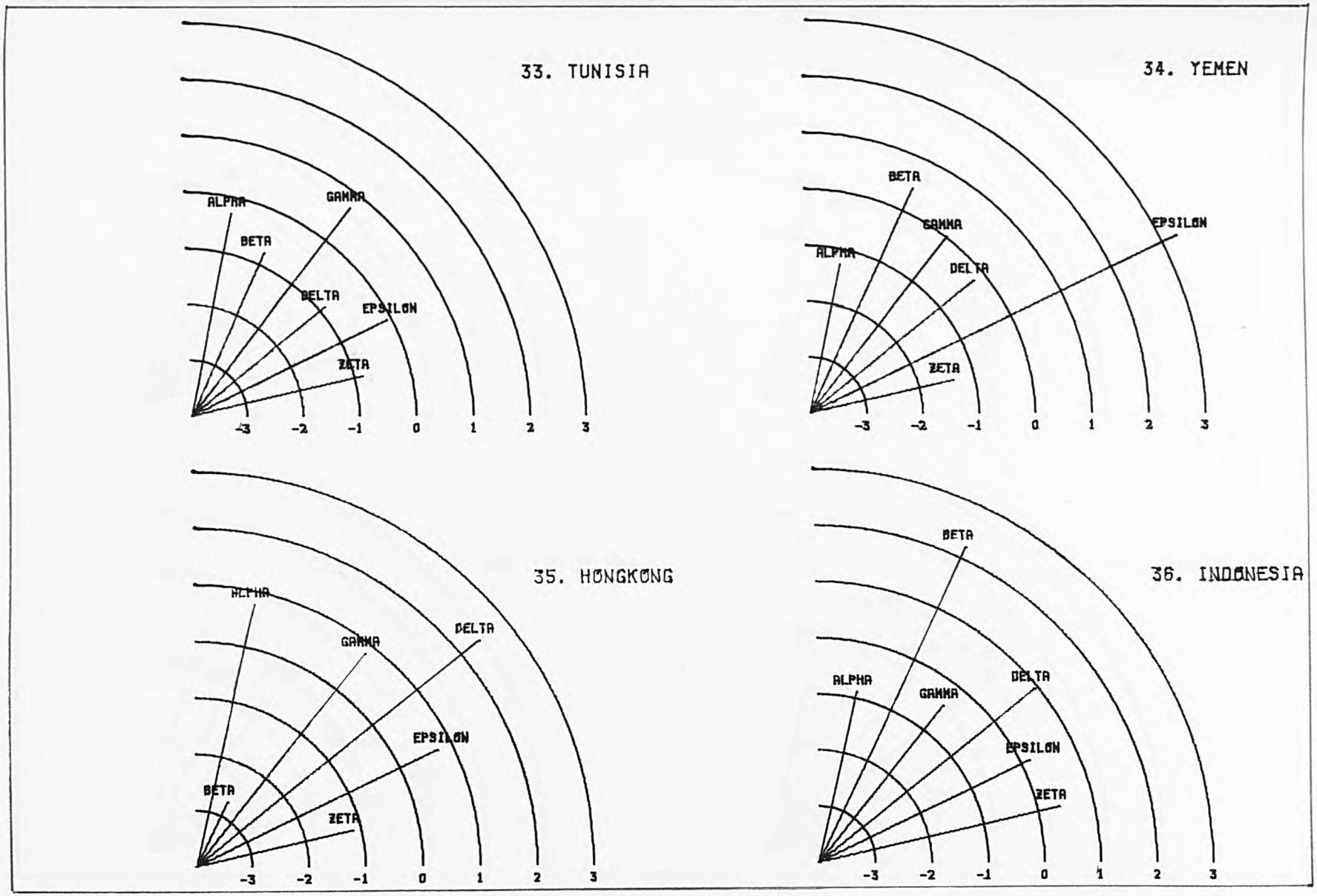

21. SUDAN
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
22. TANZANIA
BETA
ALPHA
GAMMA
DELTA
ERSILON
ZETA
-3 -2 -1 0 1 2 3
23. UGANDA
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
24. UPPER VOLT
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3


25. ZAIRE
GAMMA
BETA
ALPHA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
26. ZAMBIA
GAMMA
ALPHA
BETA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
27. ALGERIA
BETA
GAMMA
ALPHA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
28. EGYPT
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

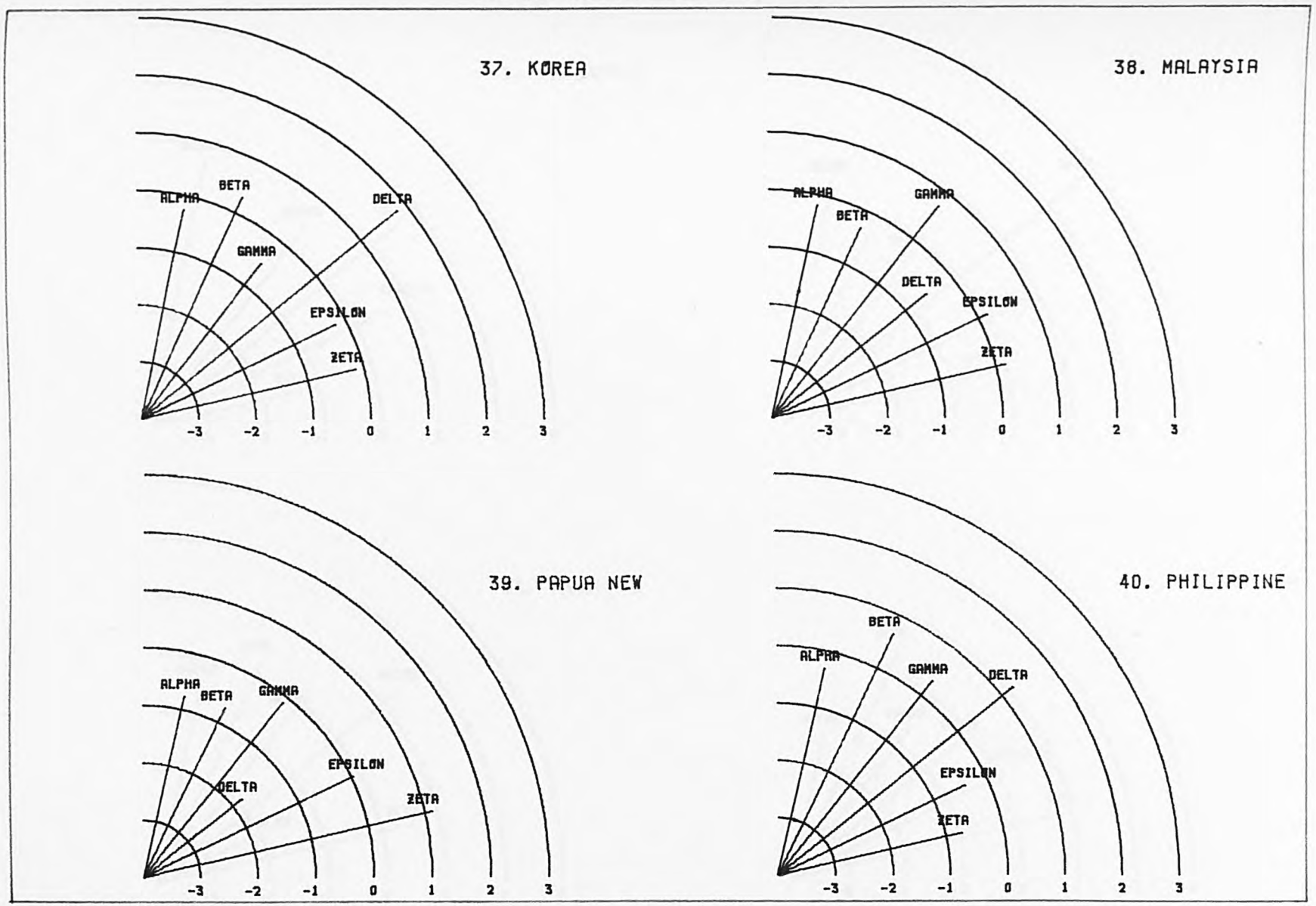
NATIONAL CHARACTERISTICS 1965

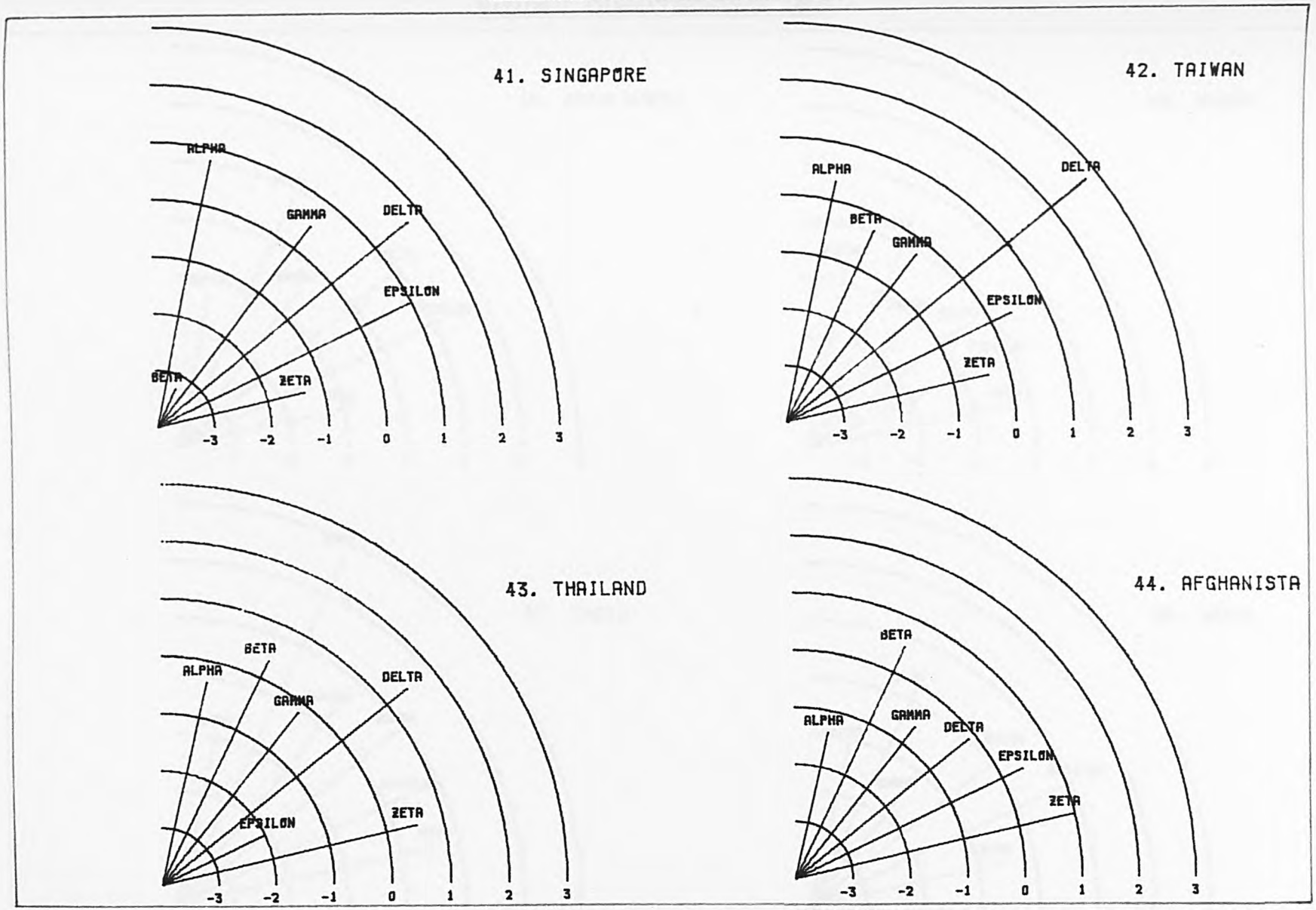


NATIONAL CHARACTERISTICS 1965

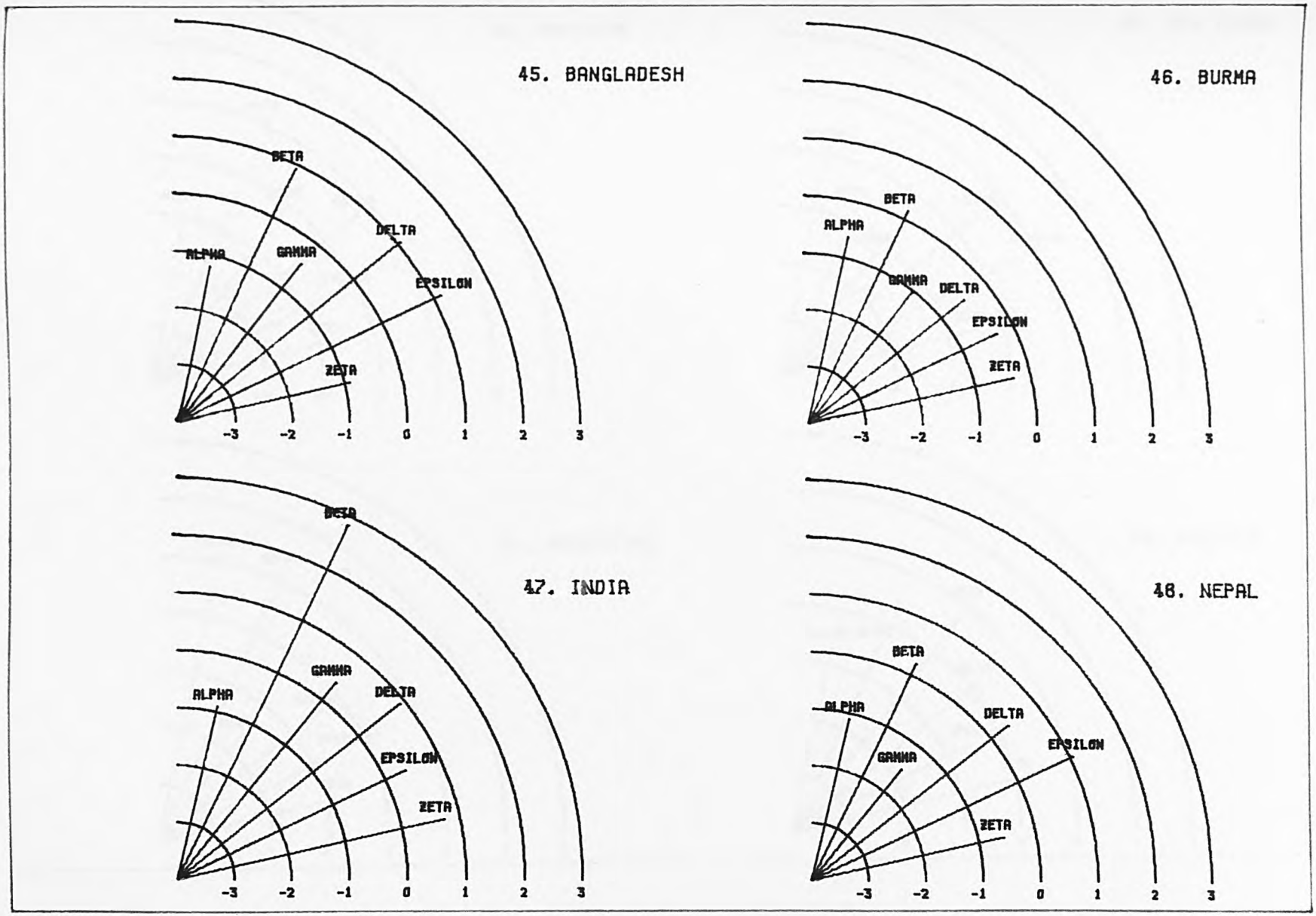


NATIONAL CHARACTERISTICS 1965

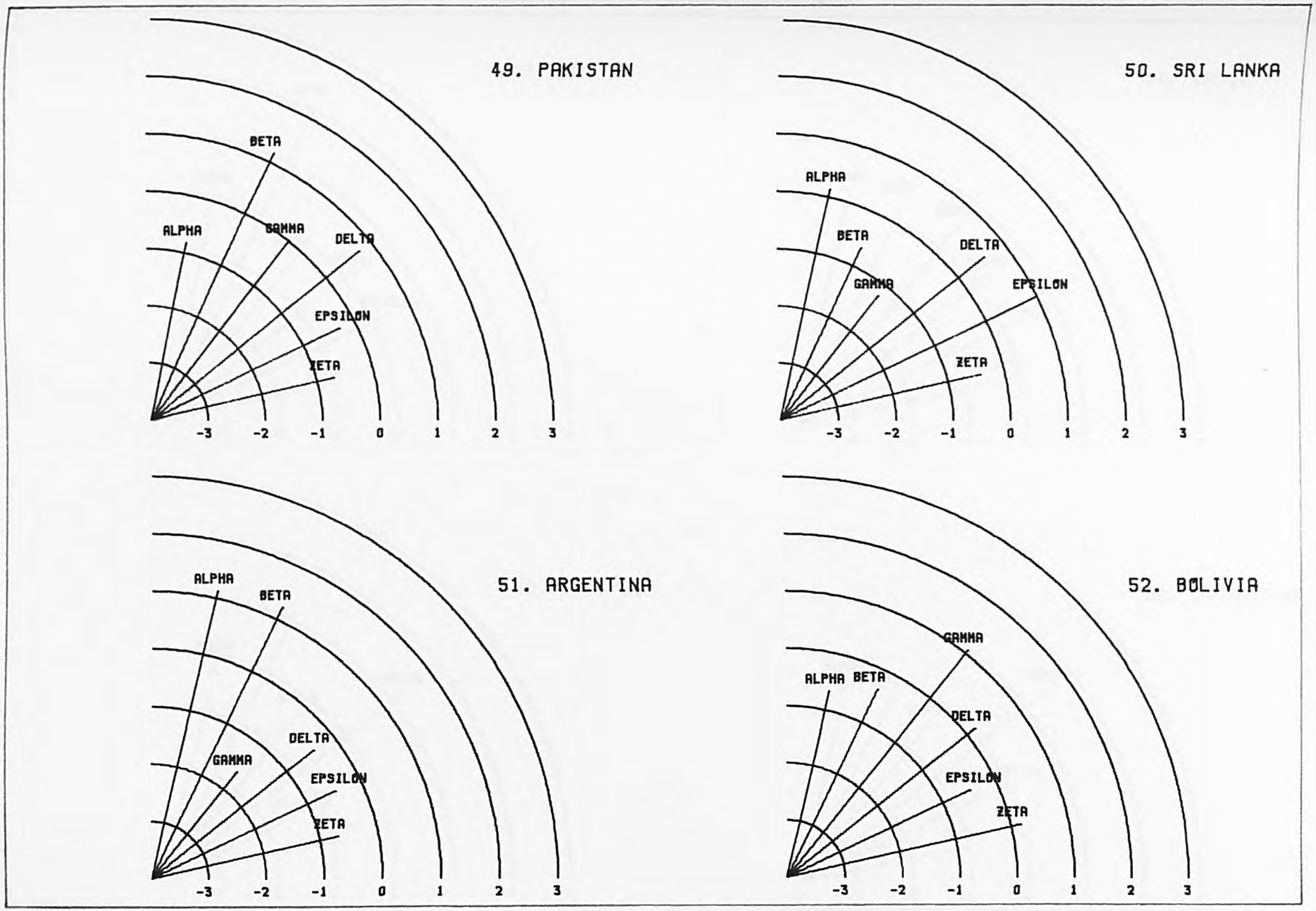



41. SINGAPORE
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
42. TAIWAN
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
43. THAILAND
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
44. AFGHANISTA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

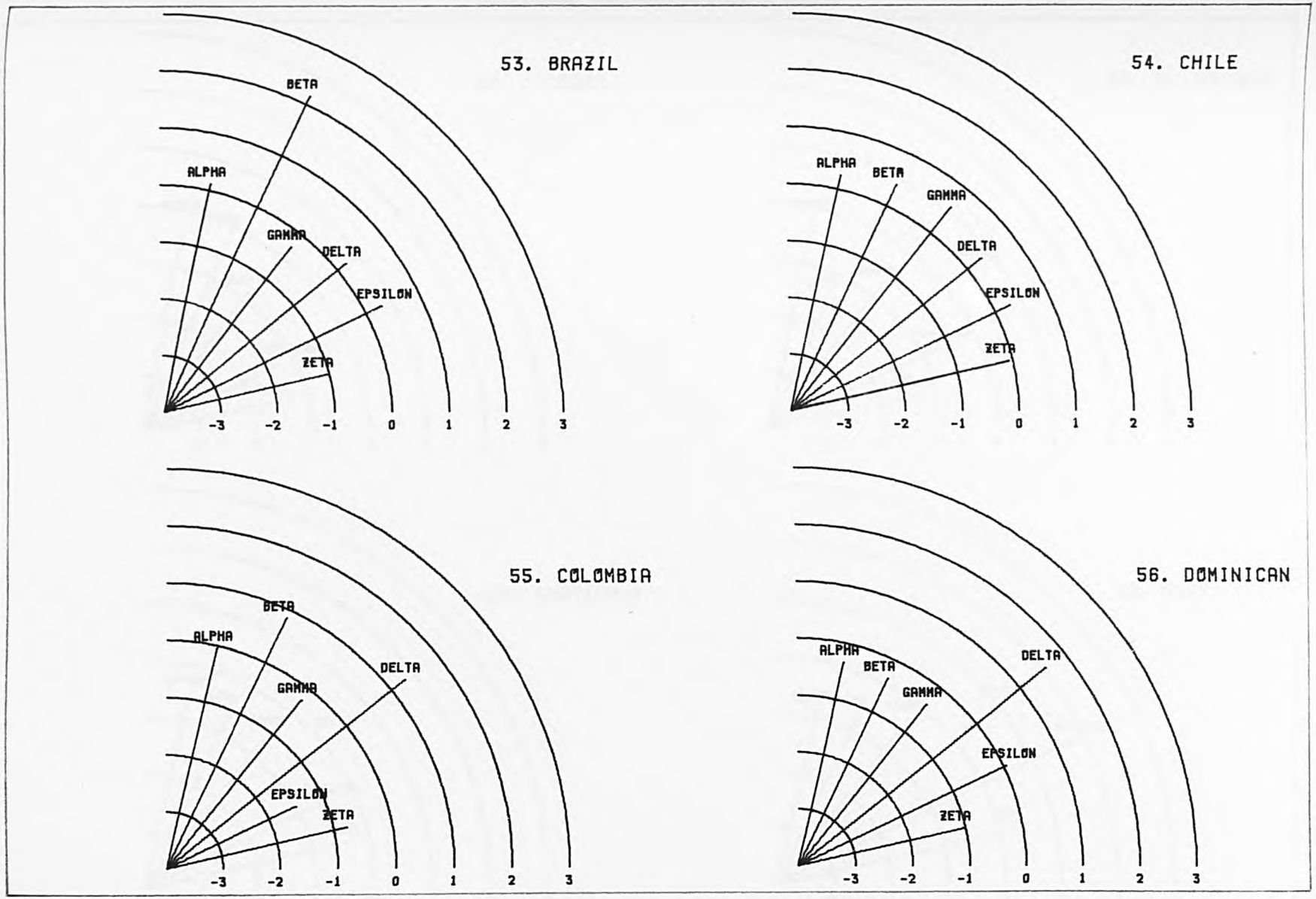
NATIONAL CHARACTERISTICS 1965



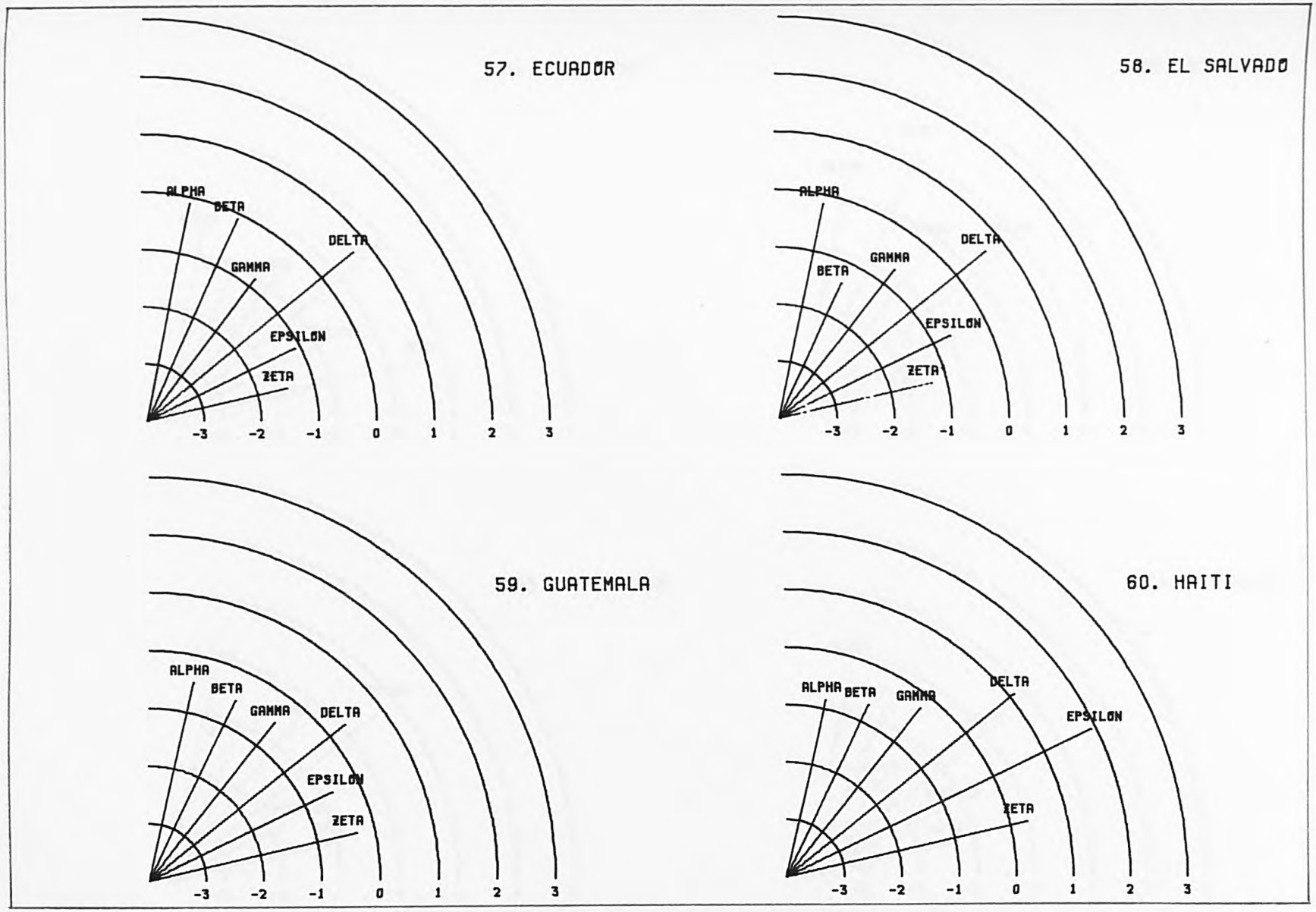
NATIONAL CHARACTERISTICS 1965



NATIONAL CHARACTERISTICS 1965



NATIONAL CHARACTERISTICS 1965



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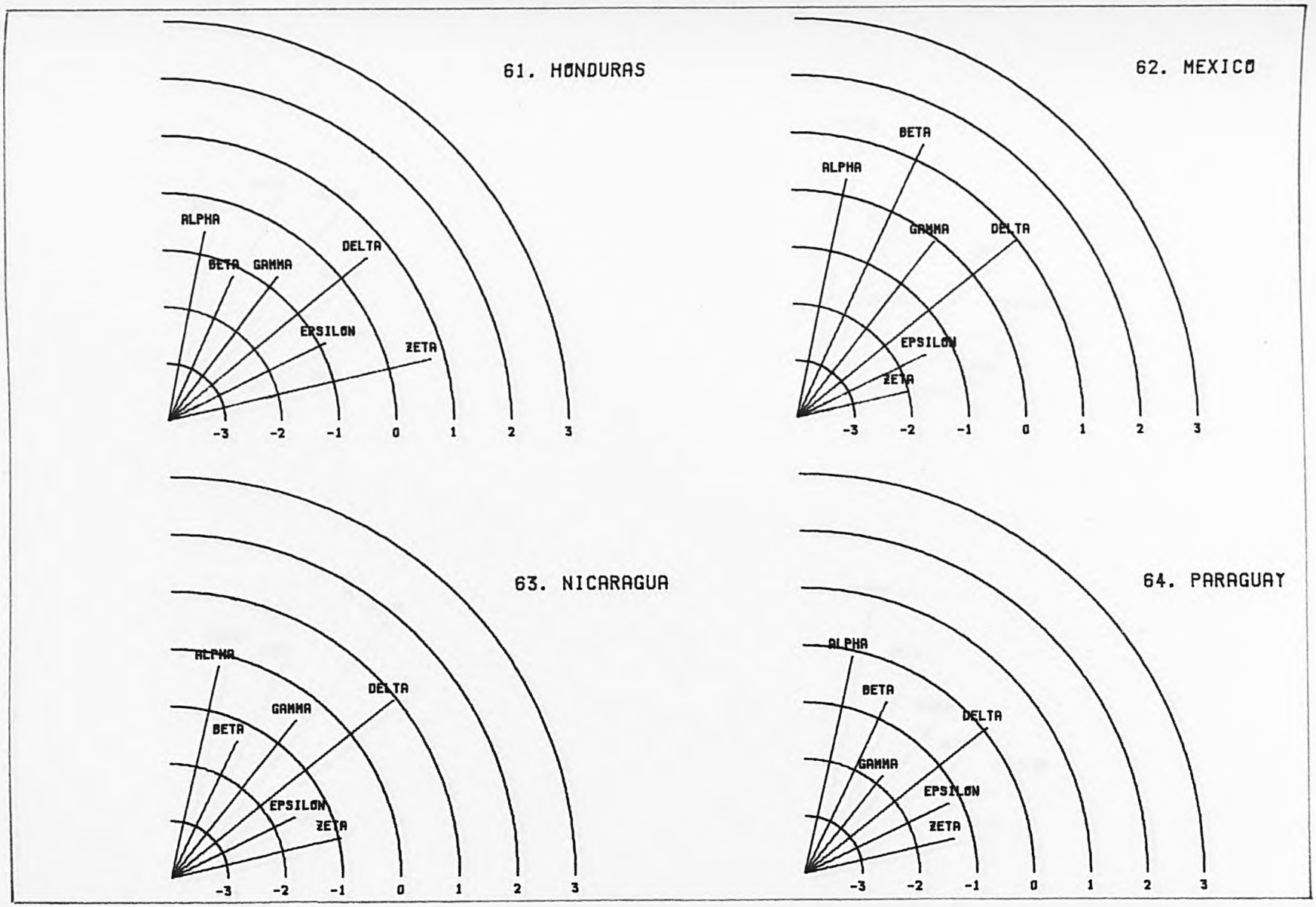
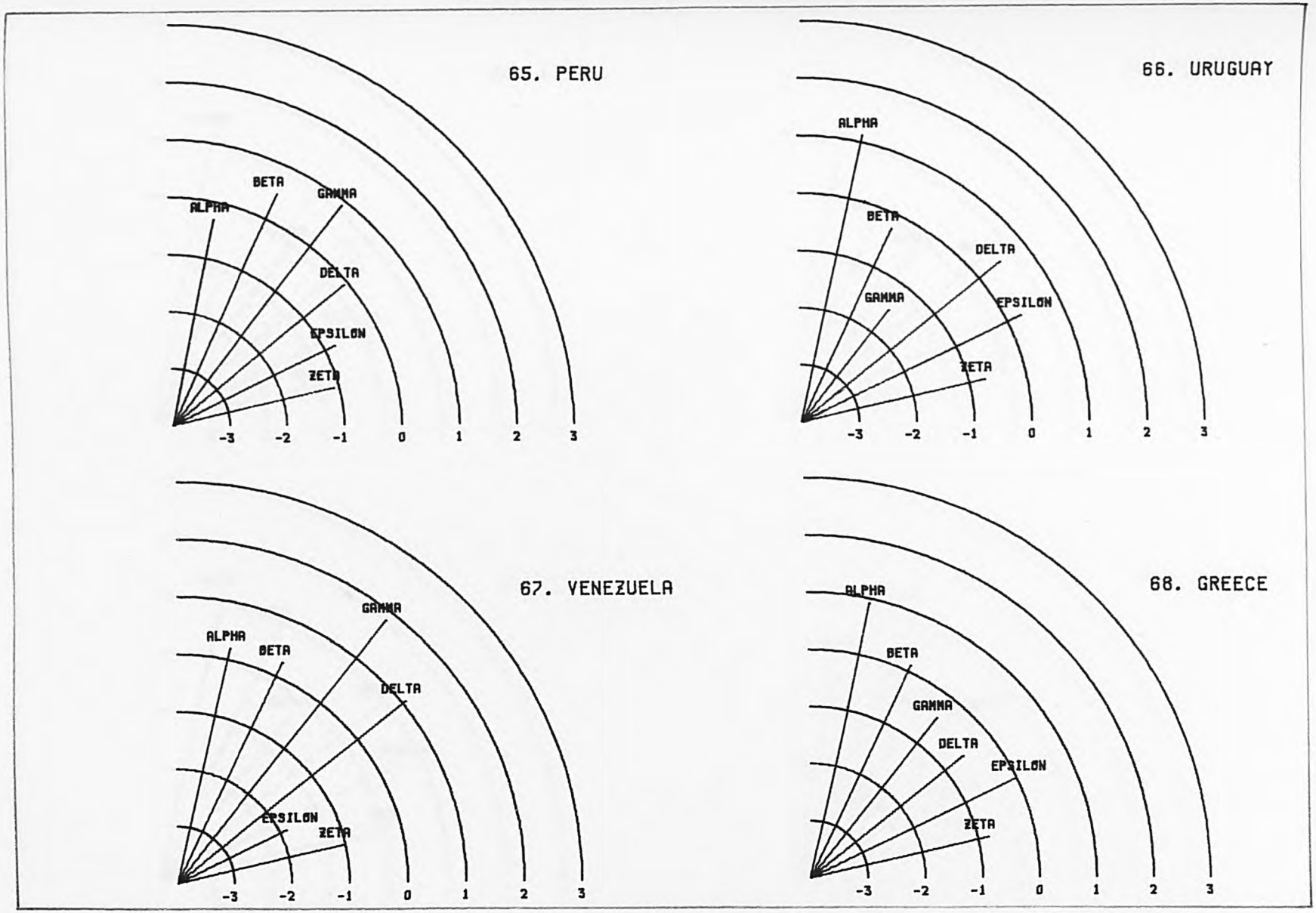
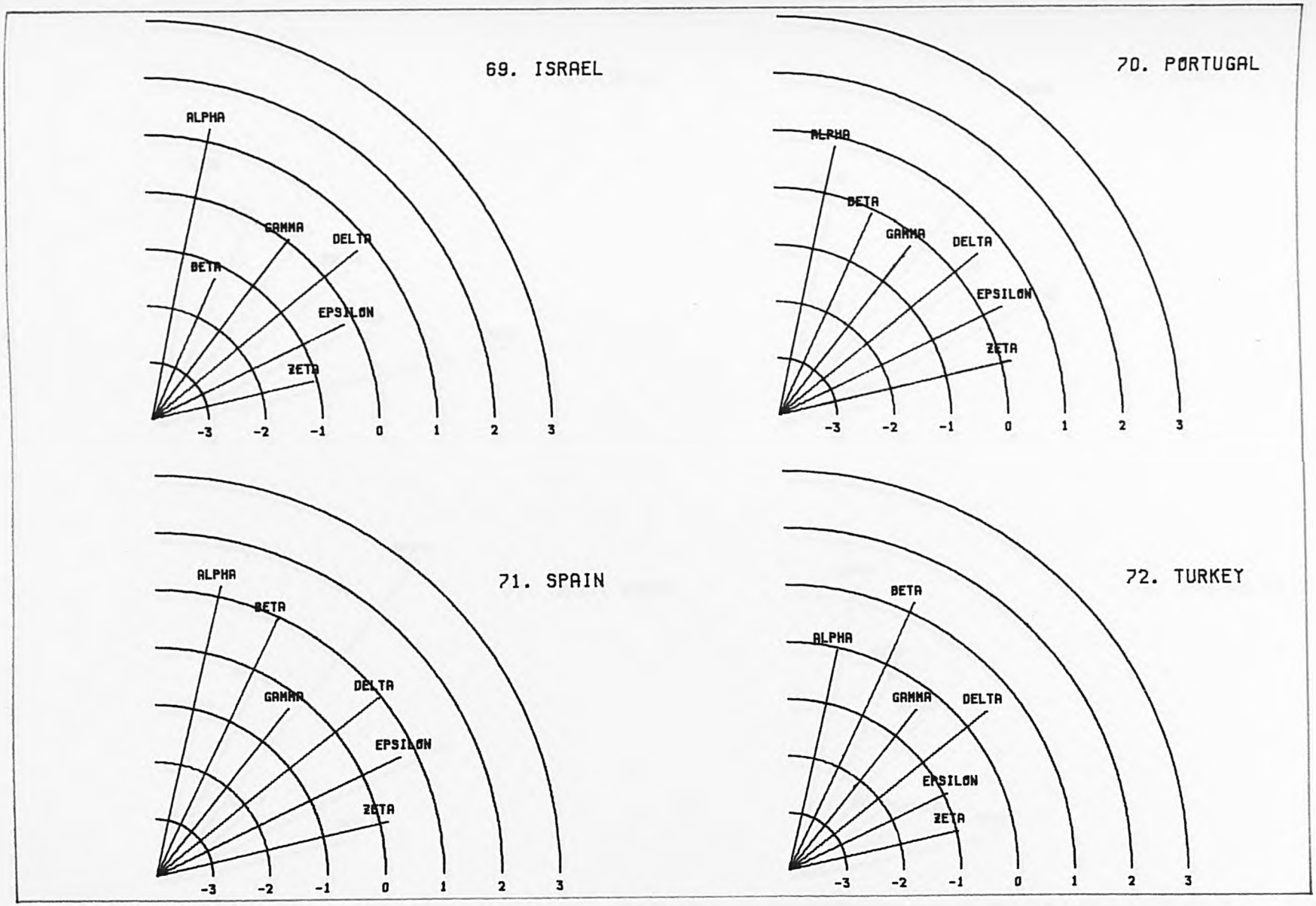


NATIONAL CHARACTERISTICS 1965



NATIONAL CHARACTERISTICS 1965



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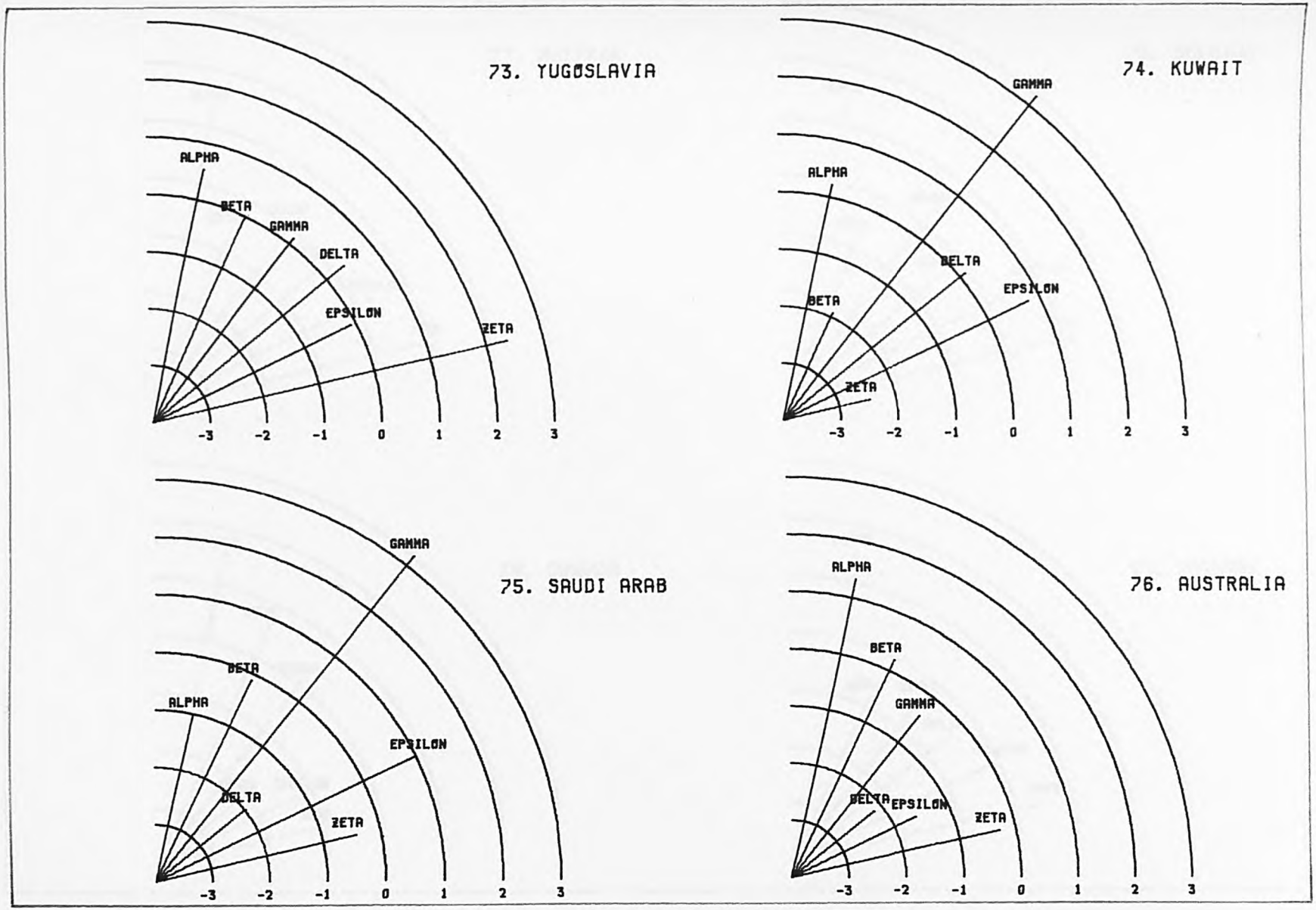
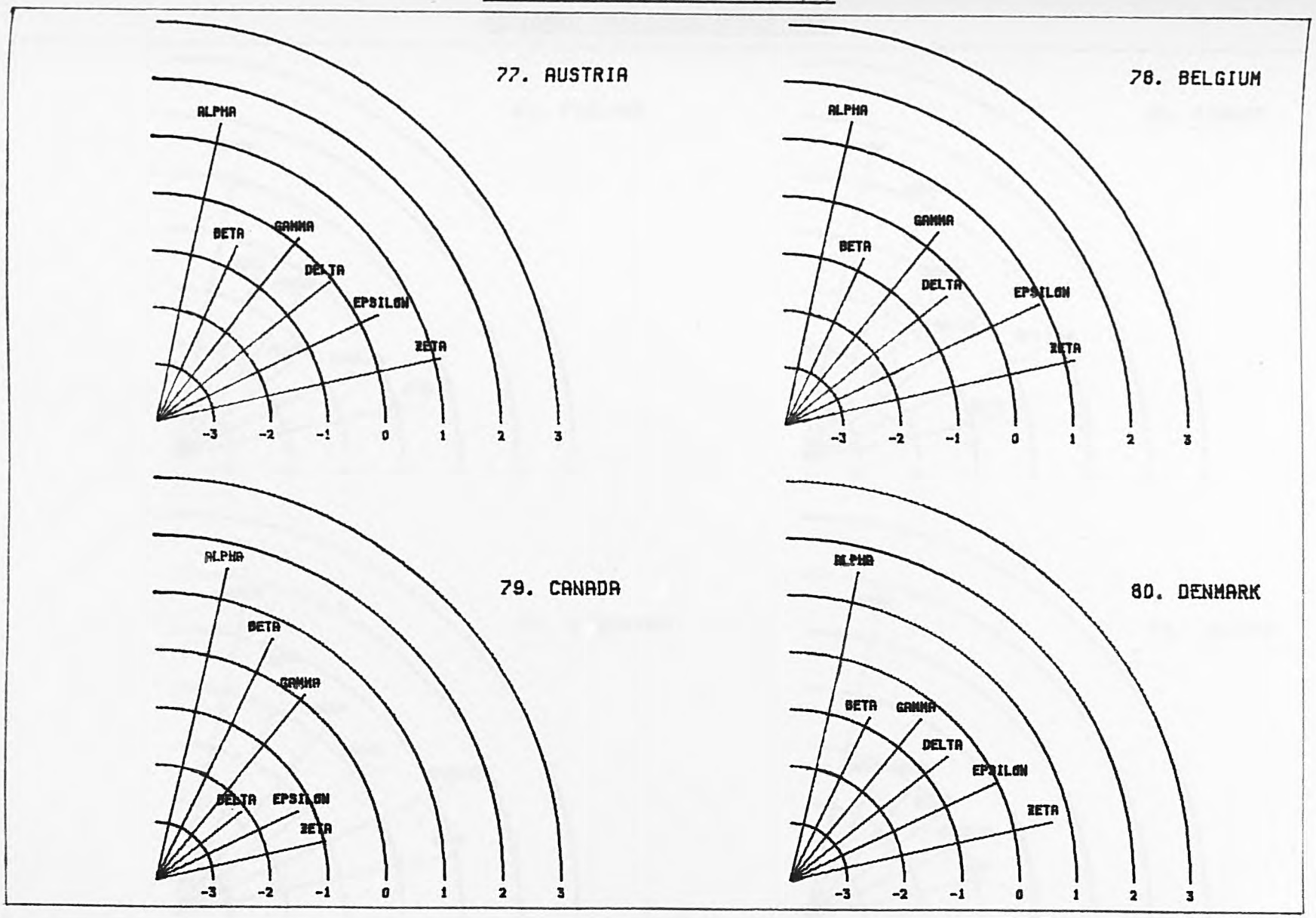
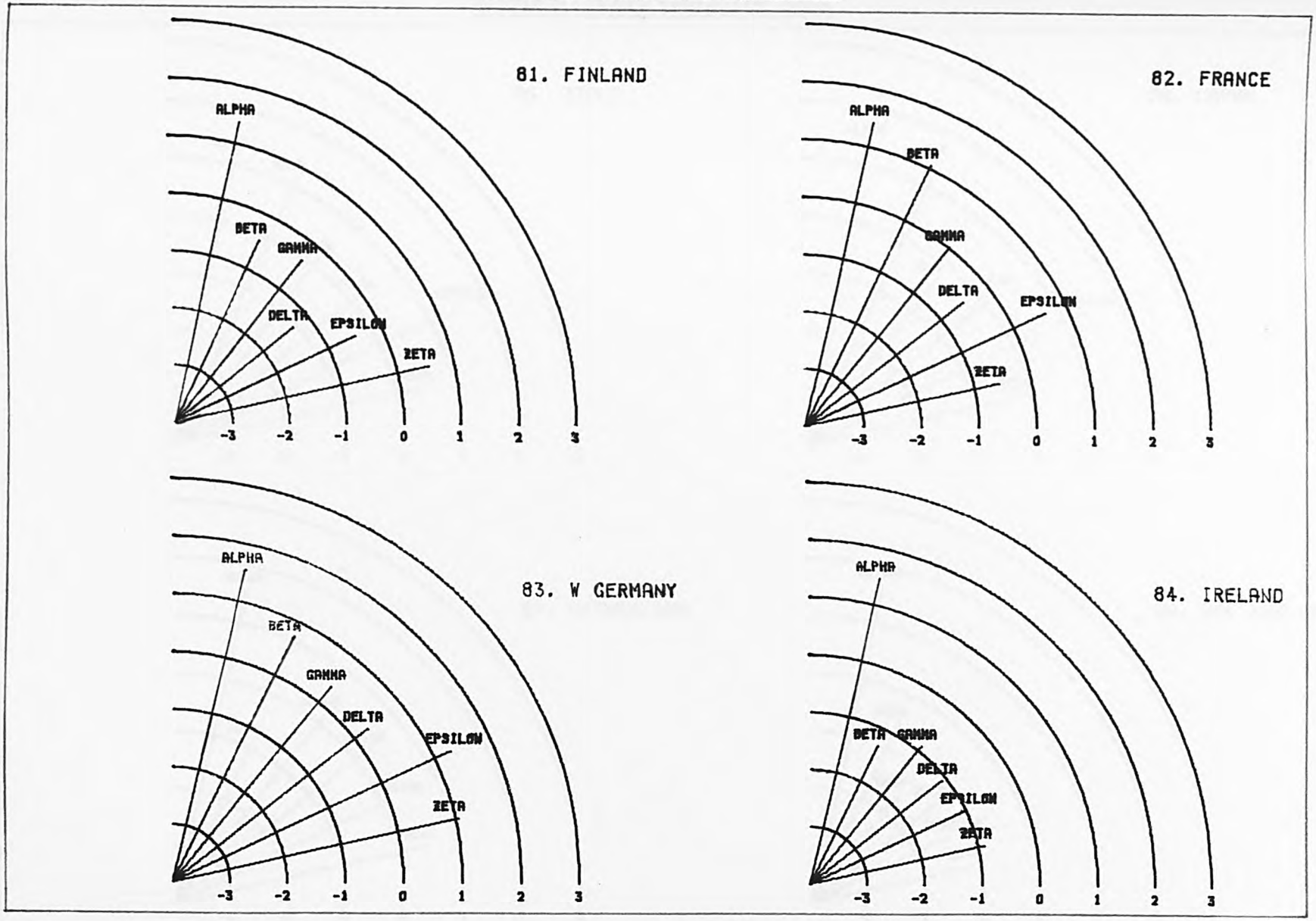


NATIONAL CHARACTERISTICS 1965



NATIONAL CHARACTERISTICS 1965



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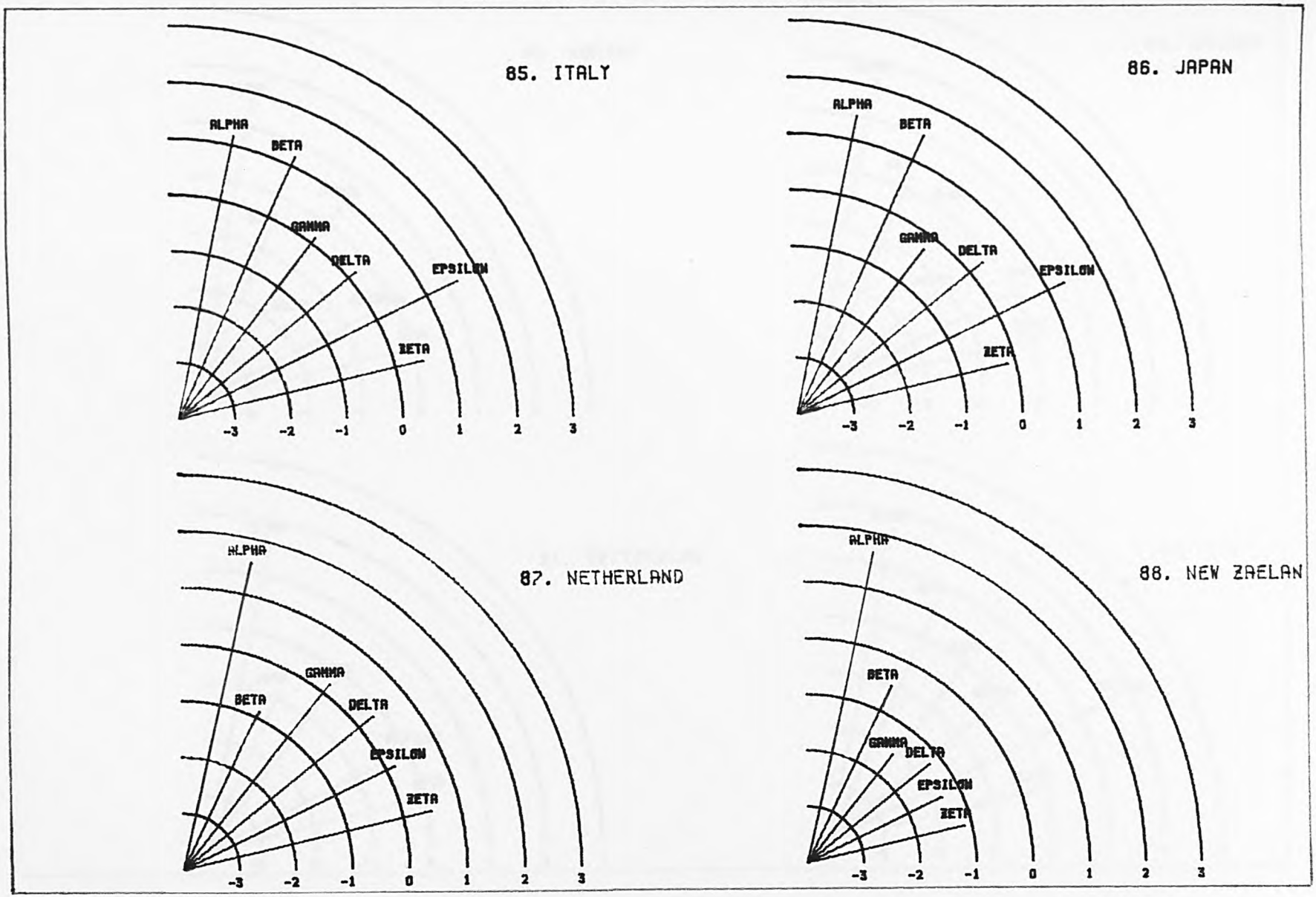
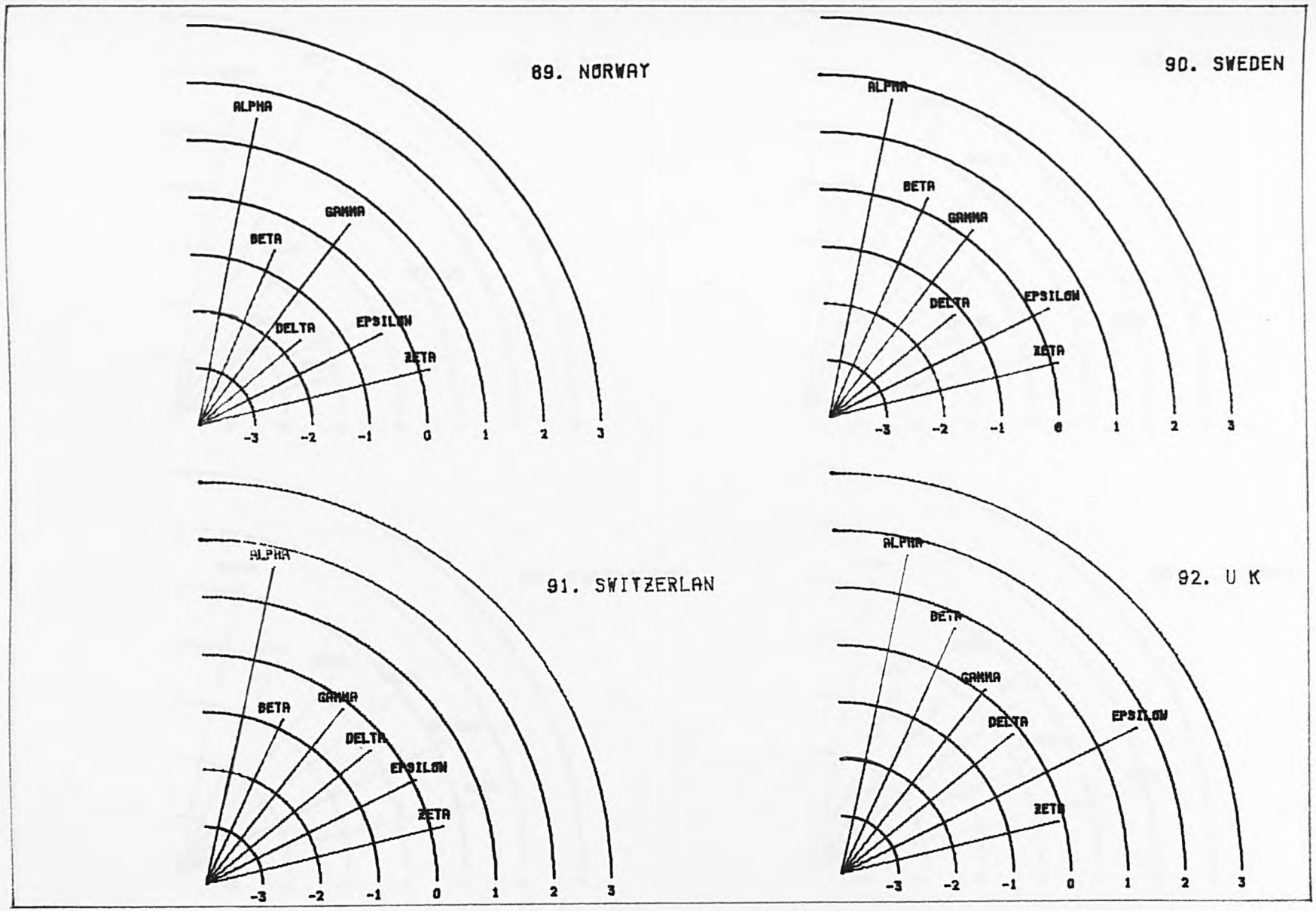


NATIONAL CHARACTERISTICS 1965



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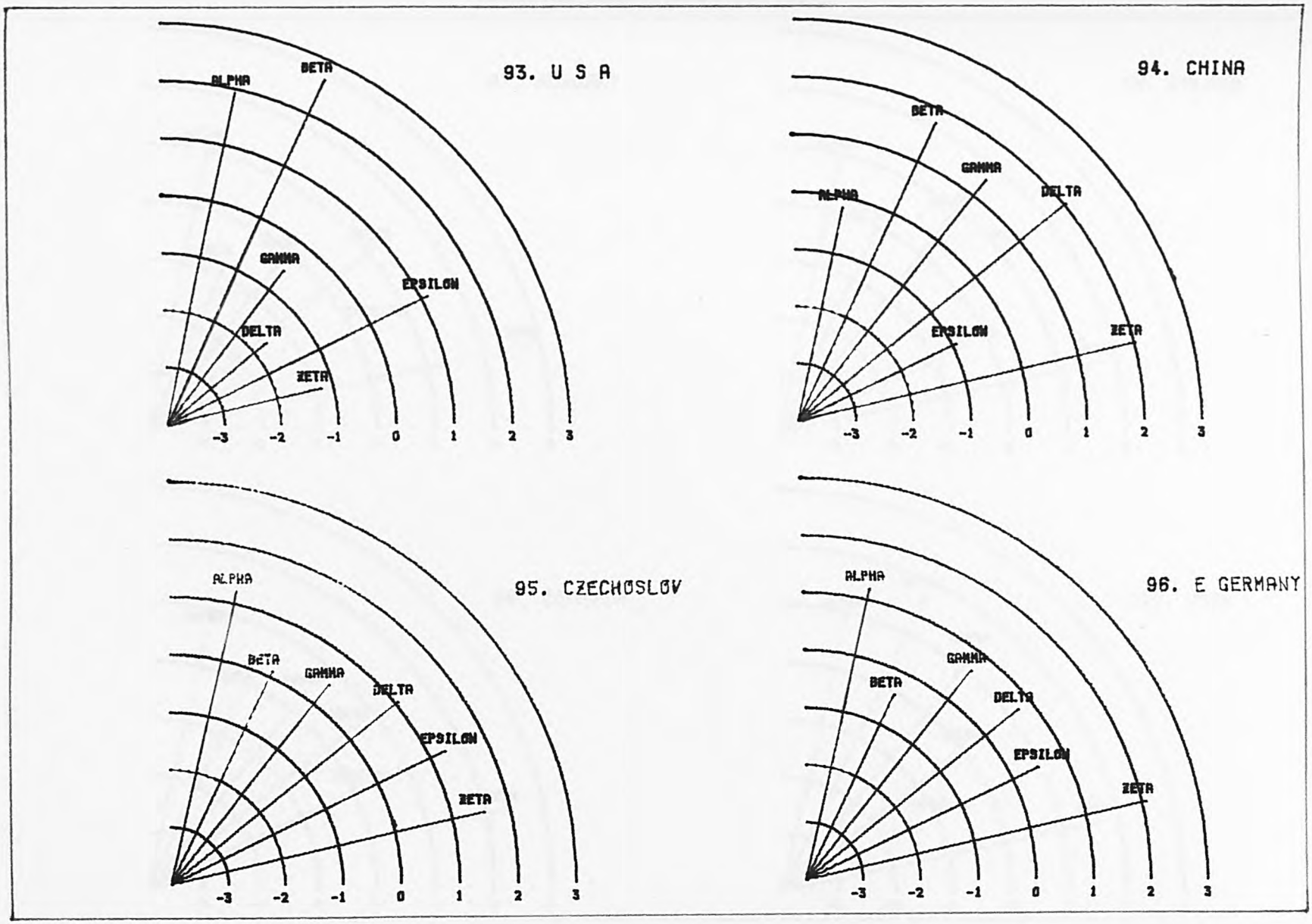
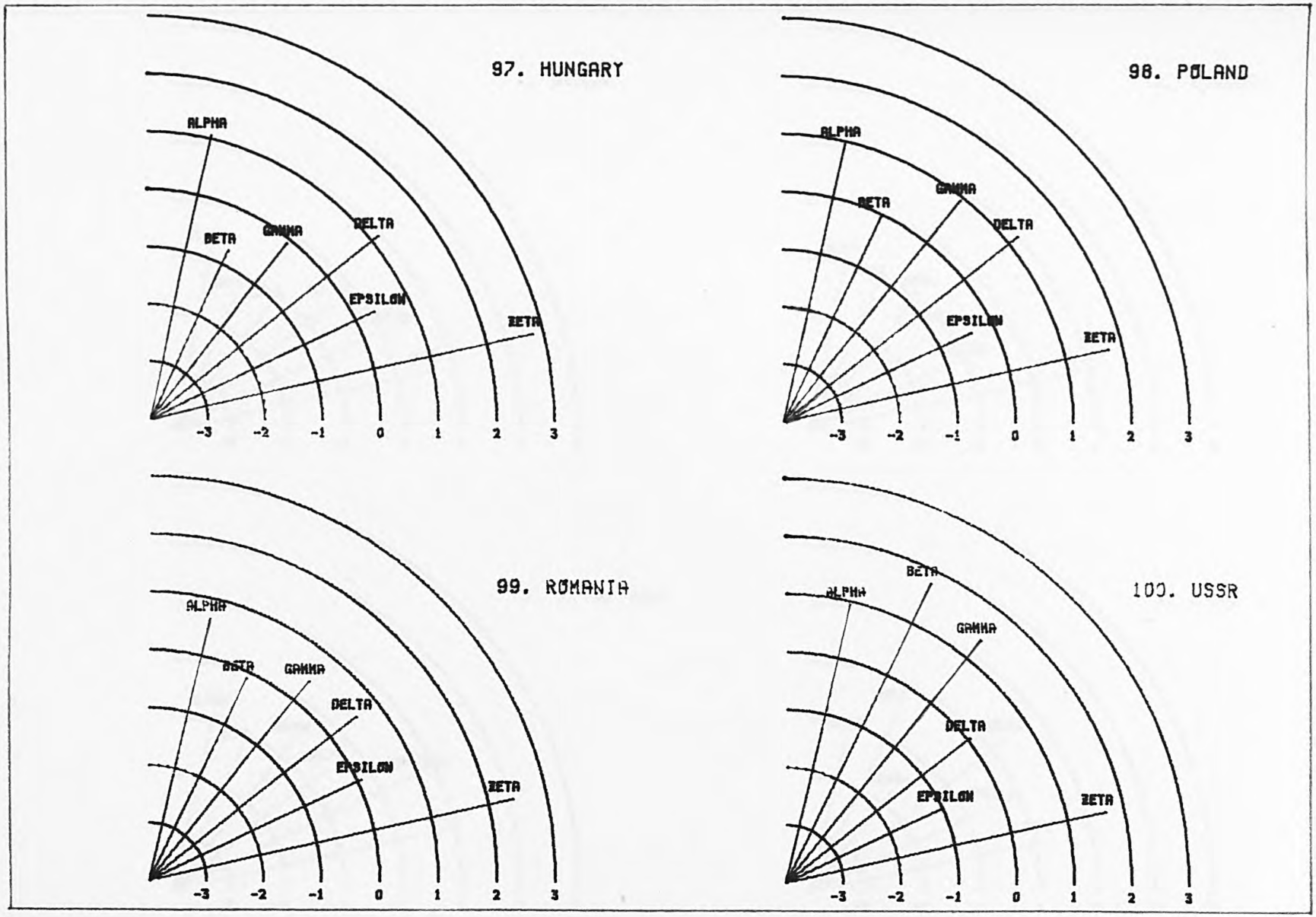
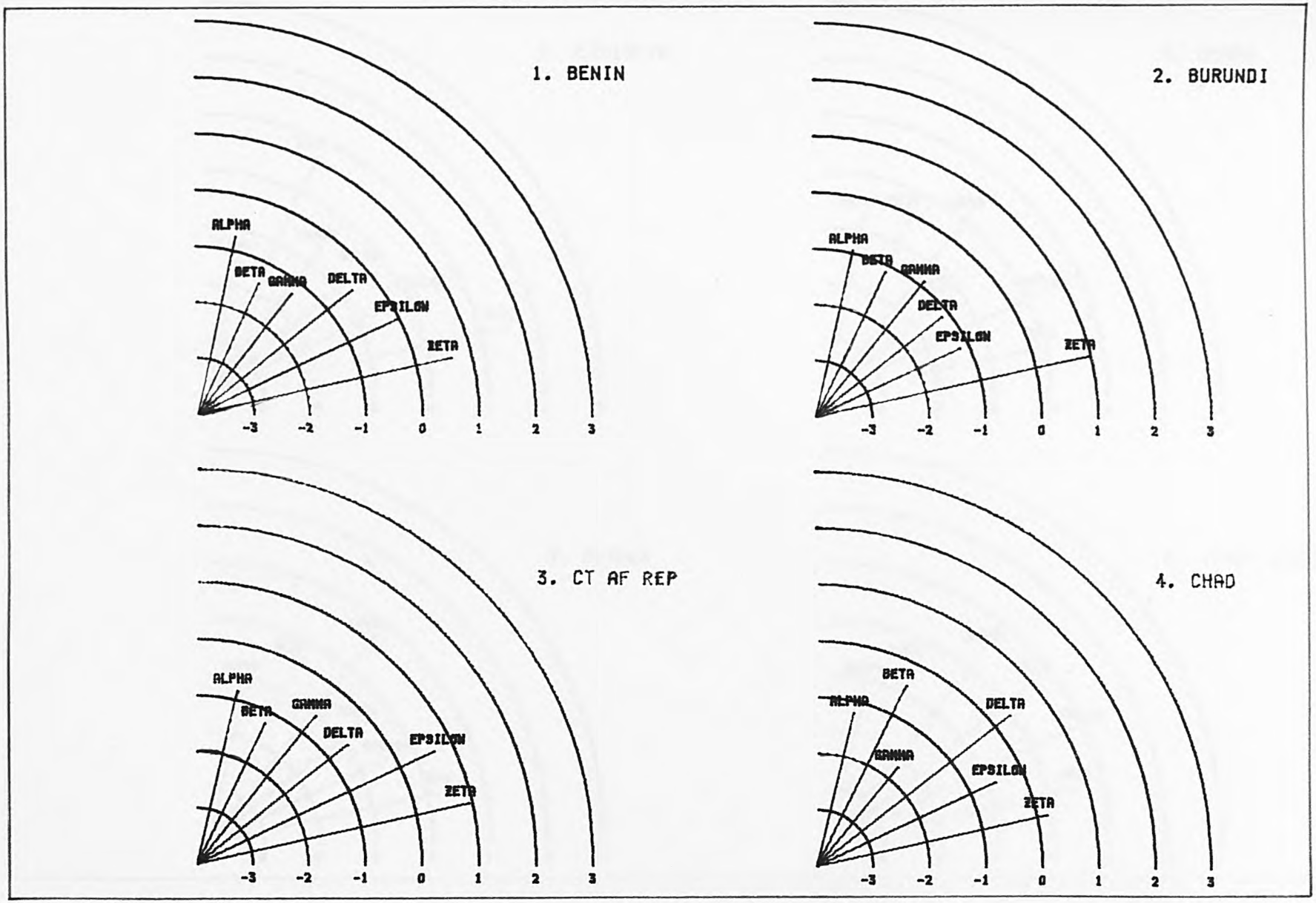


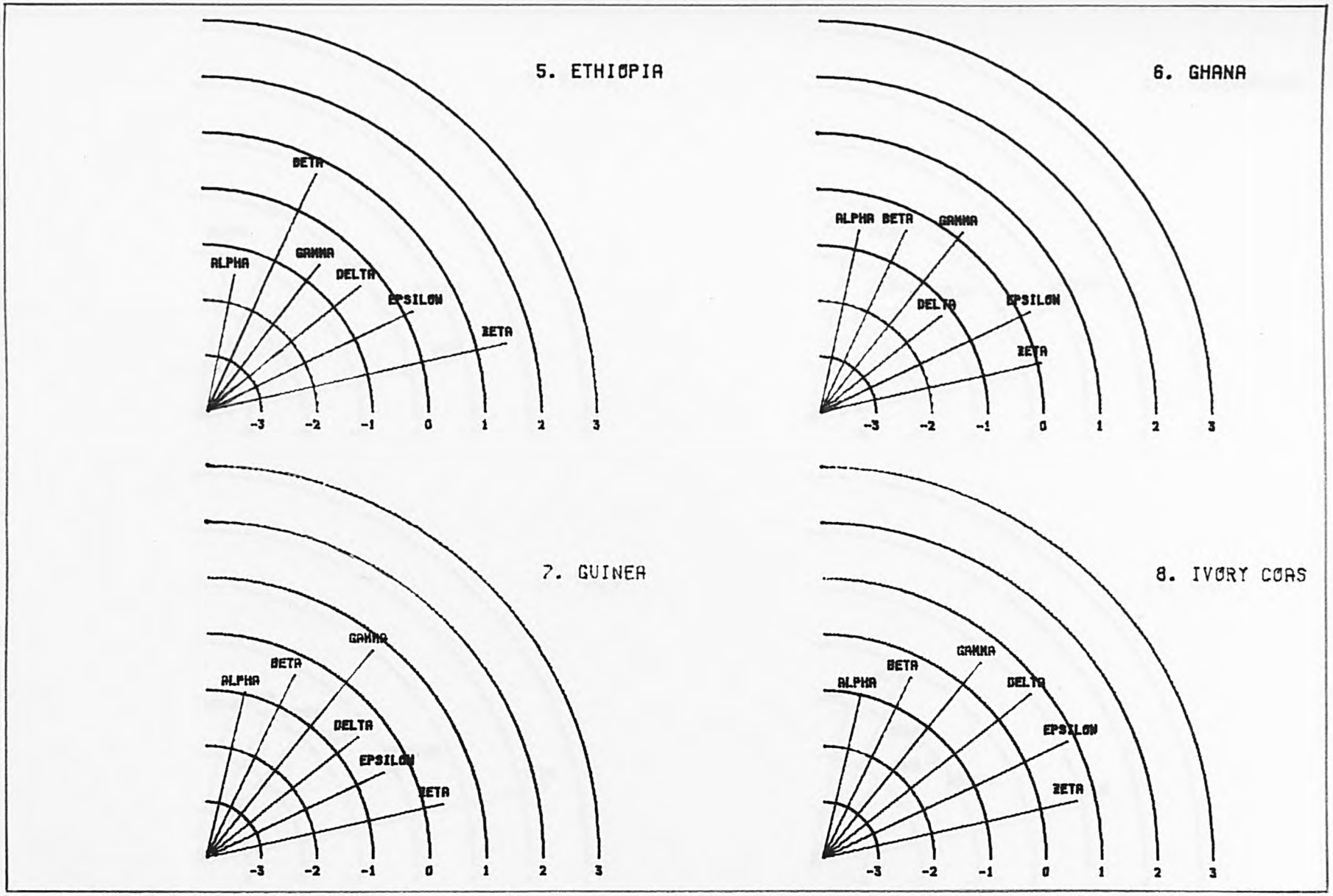
NATIONAL CHARACTERISTICS 1965

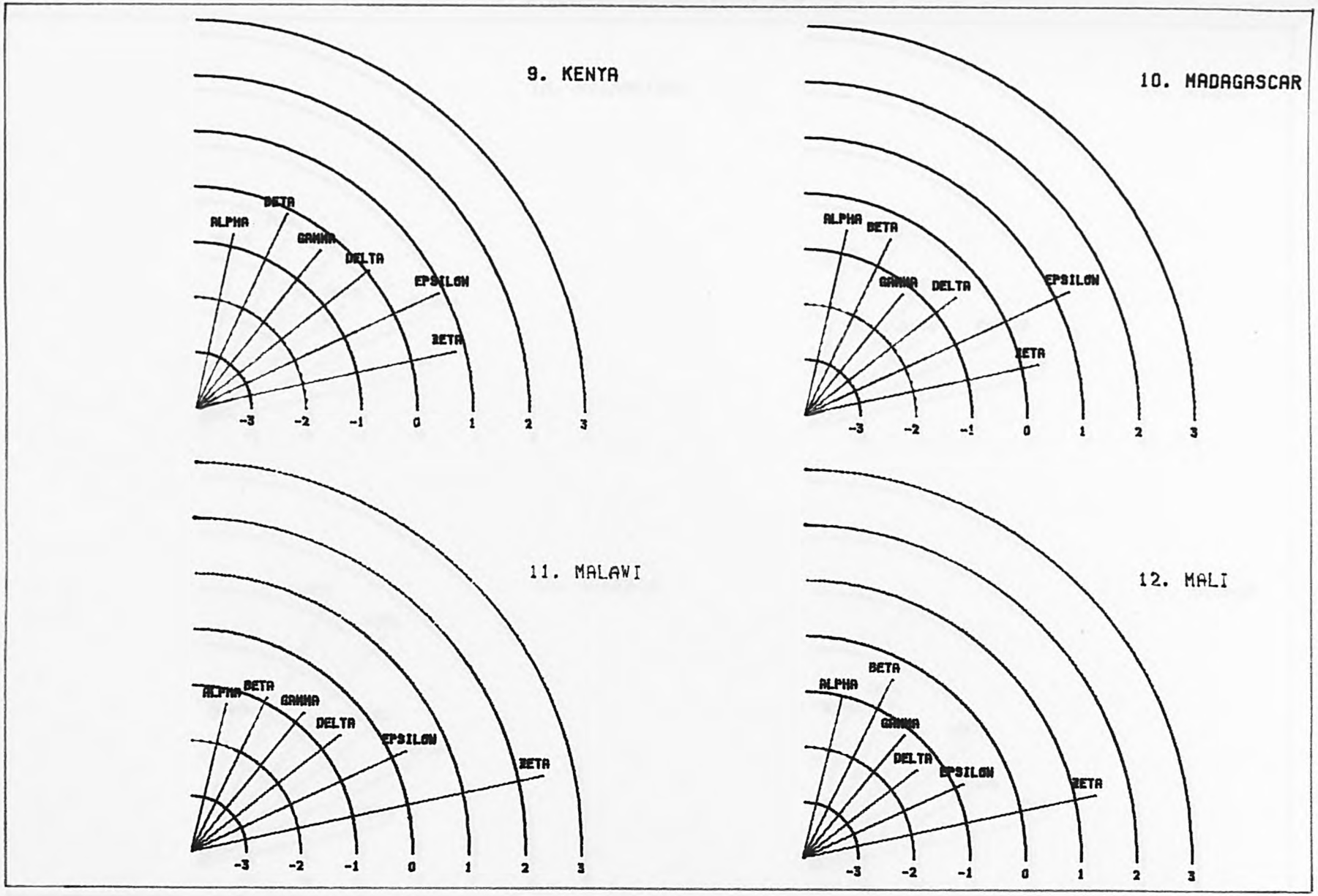


NATIONAL CHARACTERISTICS 1970



NATIONAL CHARACTERISTICS 1970




9. KENYA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
10. MADAGASCAR
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
11. MALAWI
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
12. MALI
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
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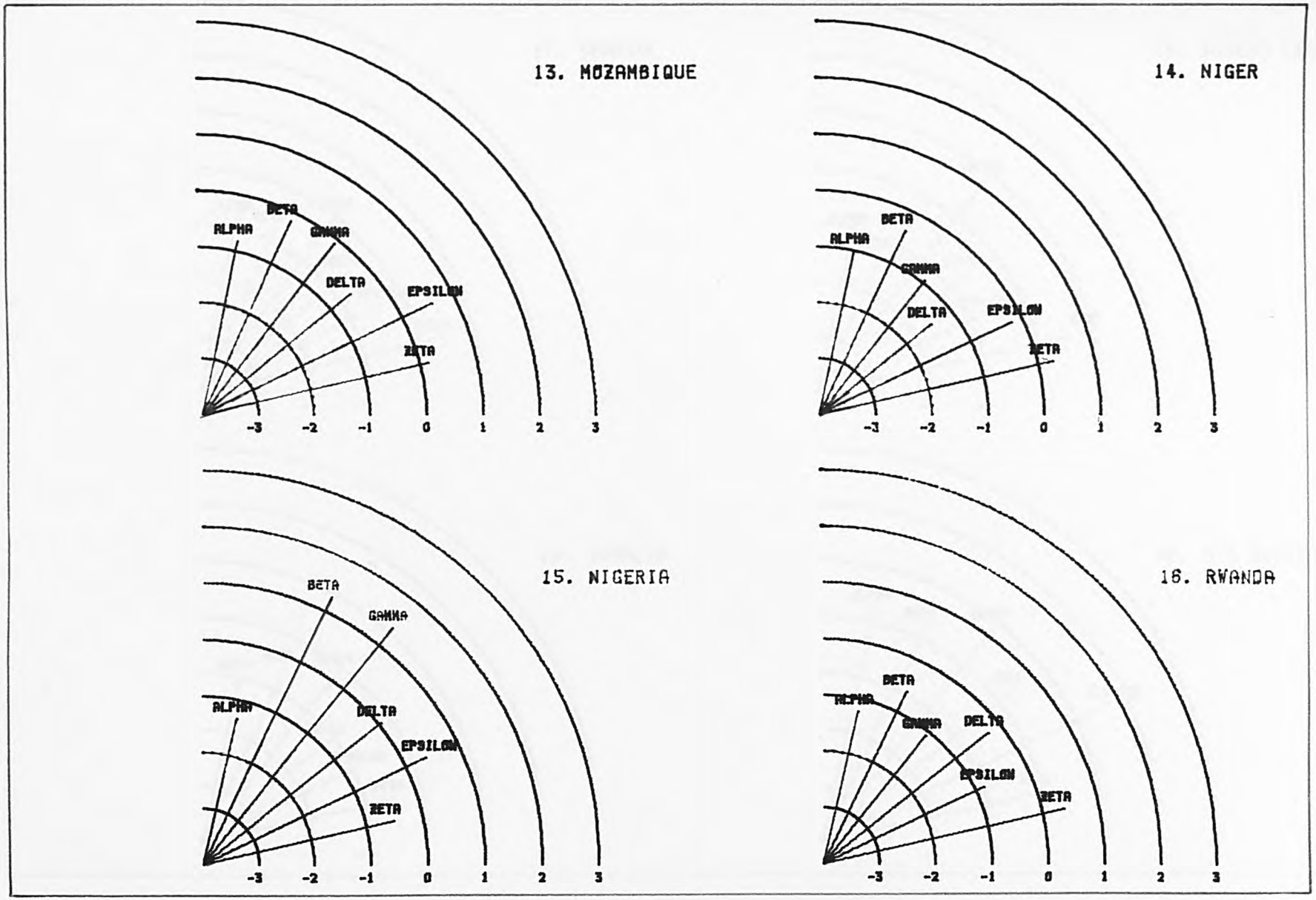
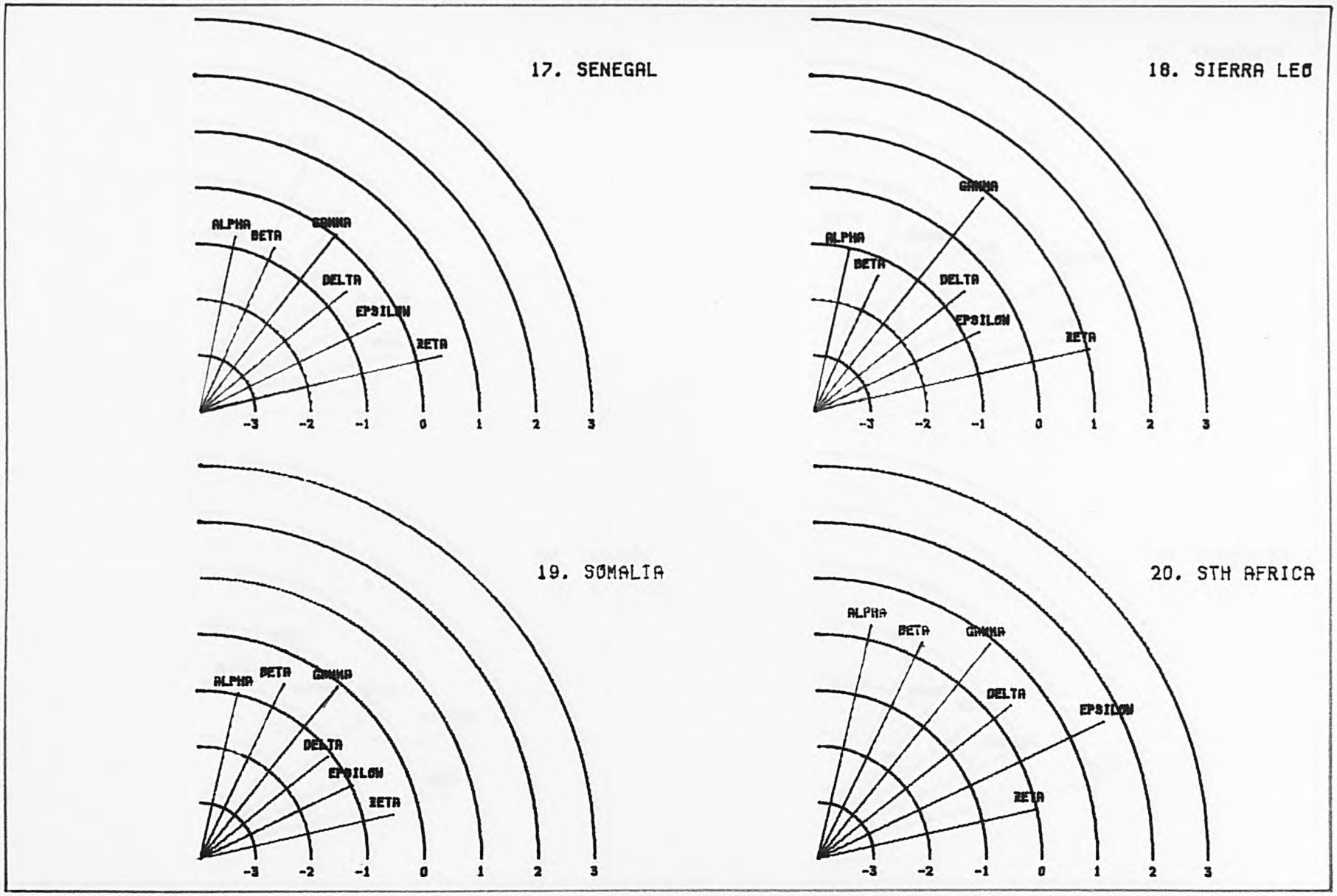
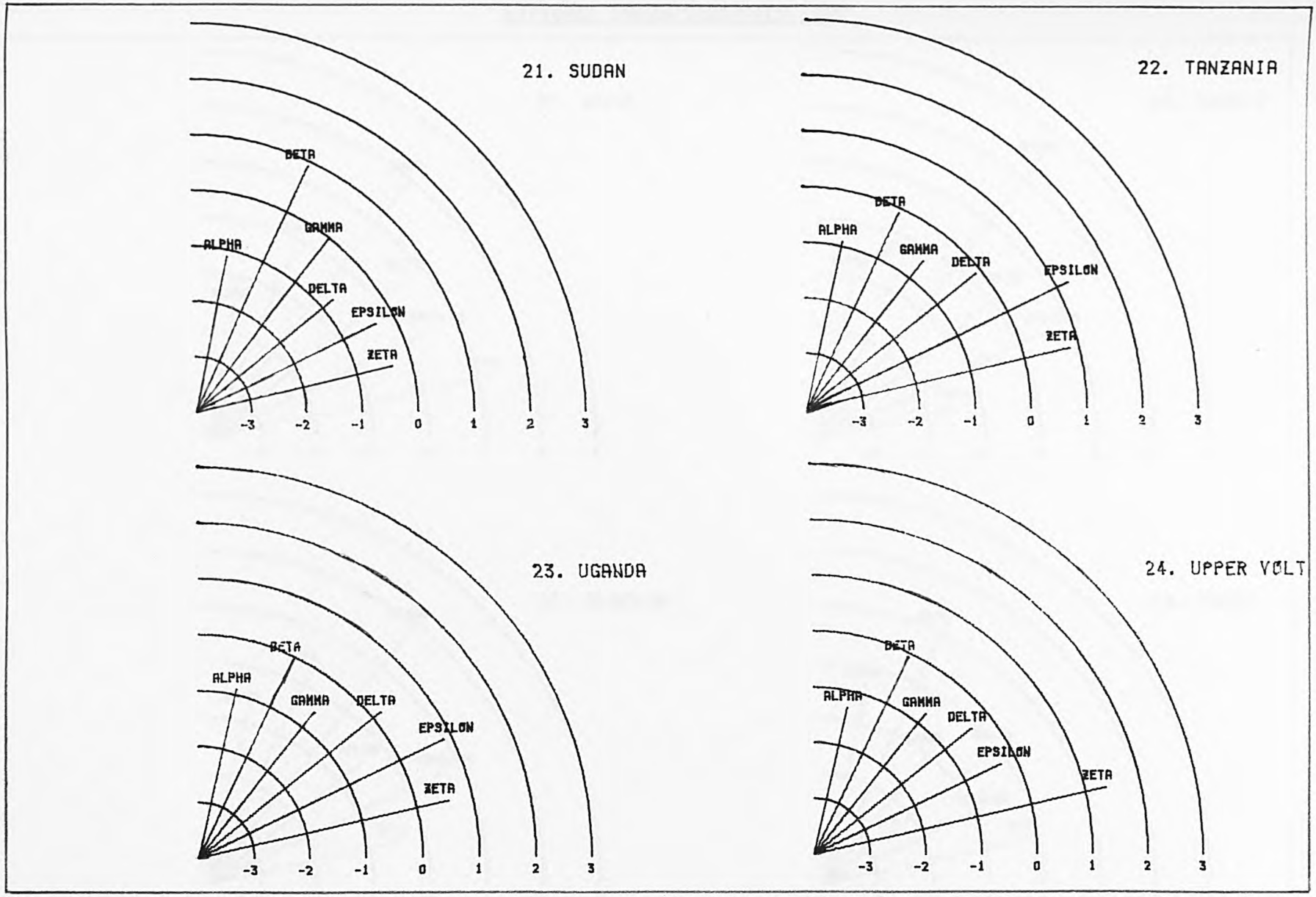
-2
-1
0
1
2
3

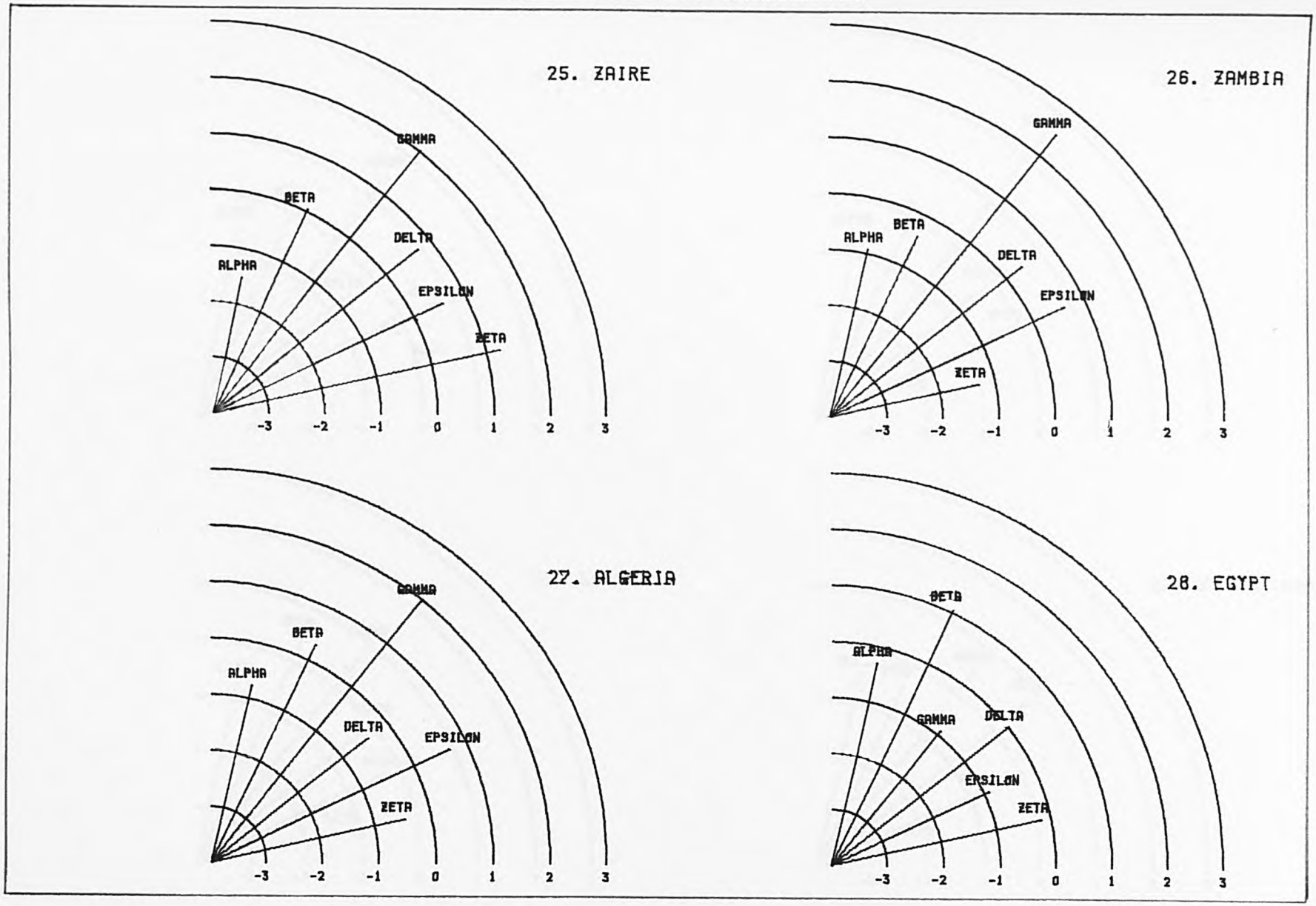
NATIONAL CHARACTERISTICS 1970



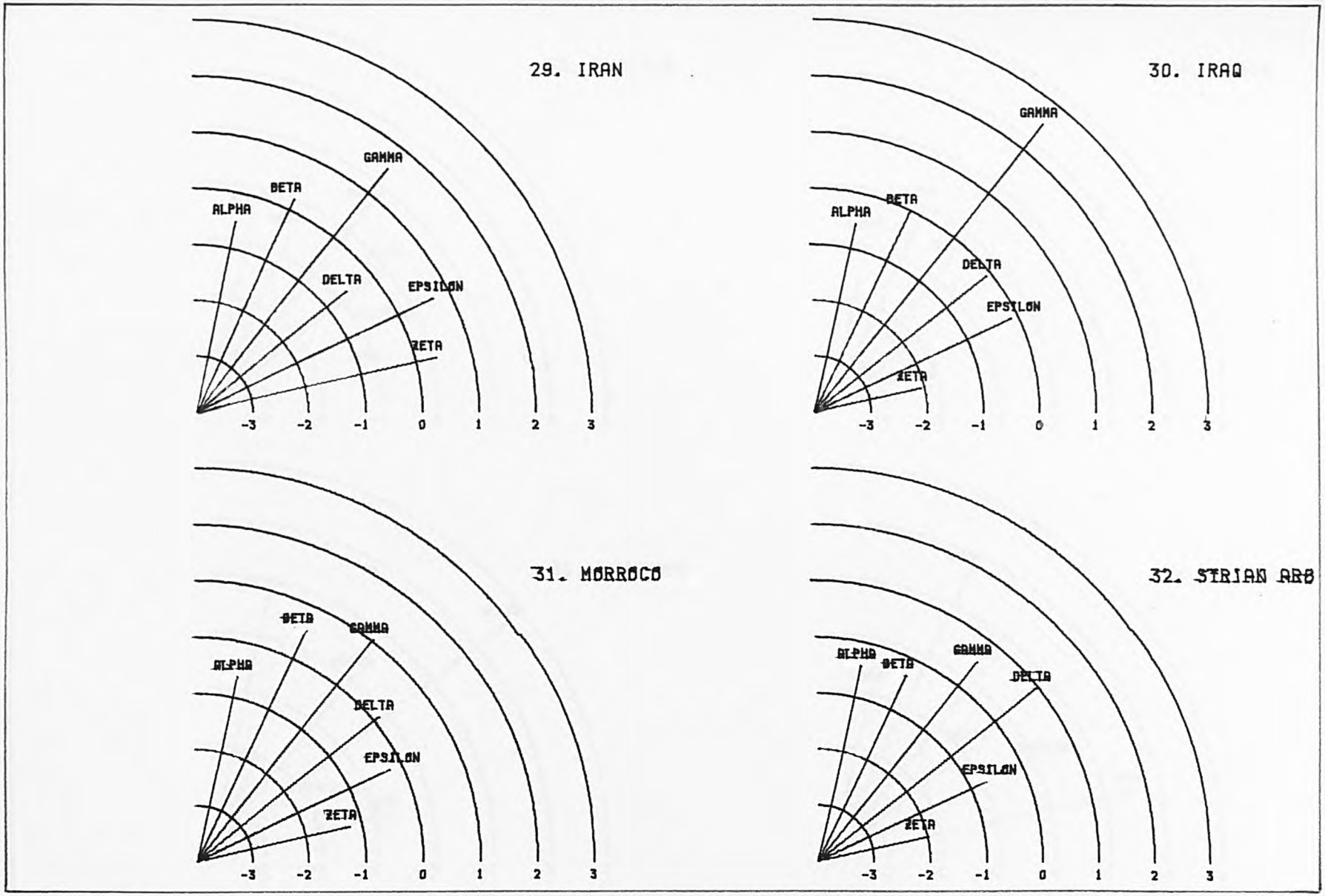

17. SENEGAL
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
18. SIERRA LEO
GAMMA
ALPHA
BETA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
19. SOMALIA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
20. STH AFRICA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3


21. SUDAN
BETA
GAMMA
ALPHA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
22. TANZANIA
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
23. UGANDA
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
24. UPPER VOLT
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

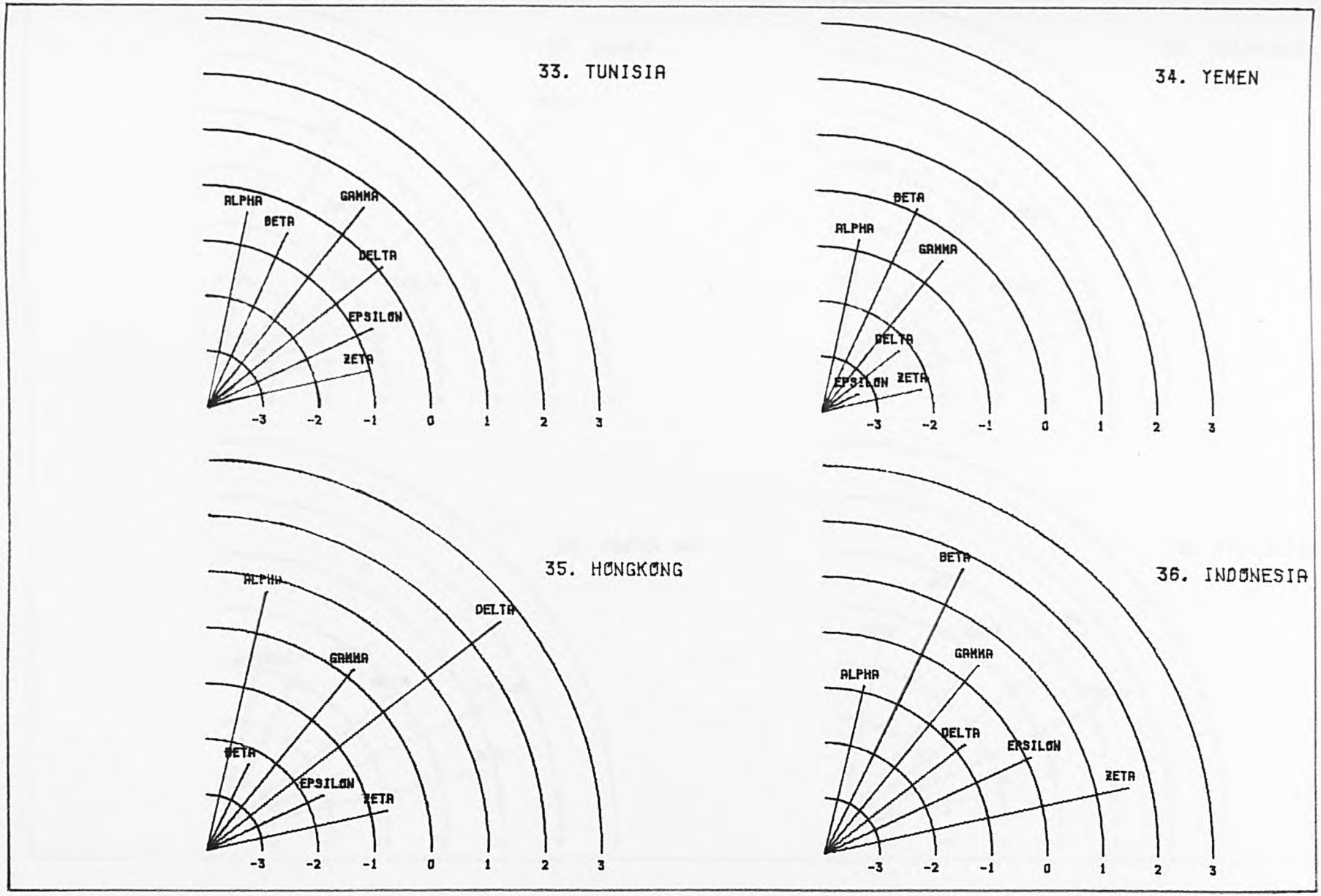
NATIONAL CHARACTERISTICS 1970

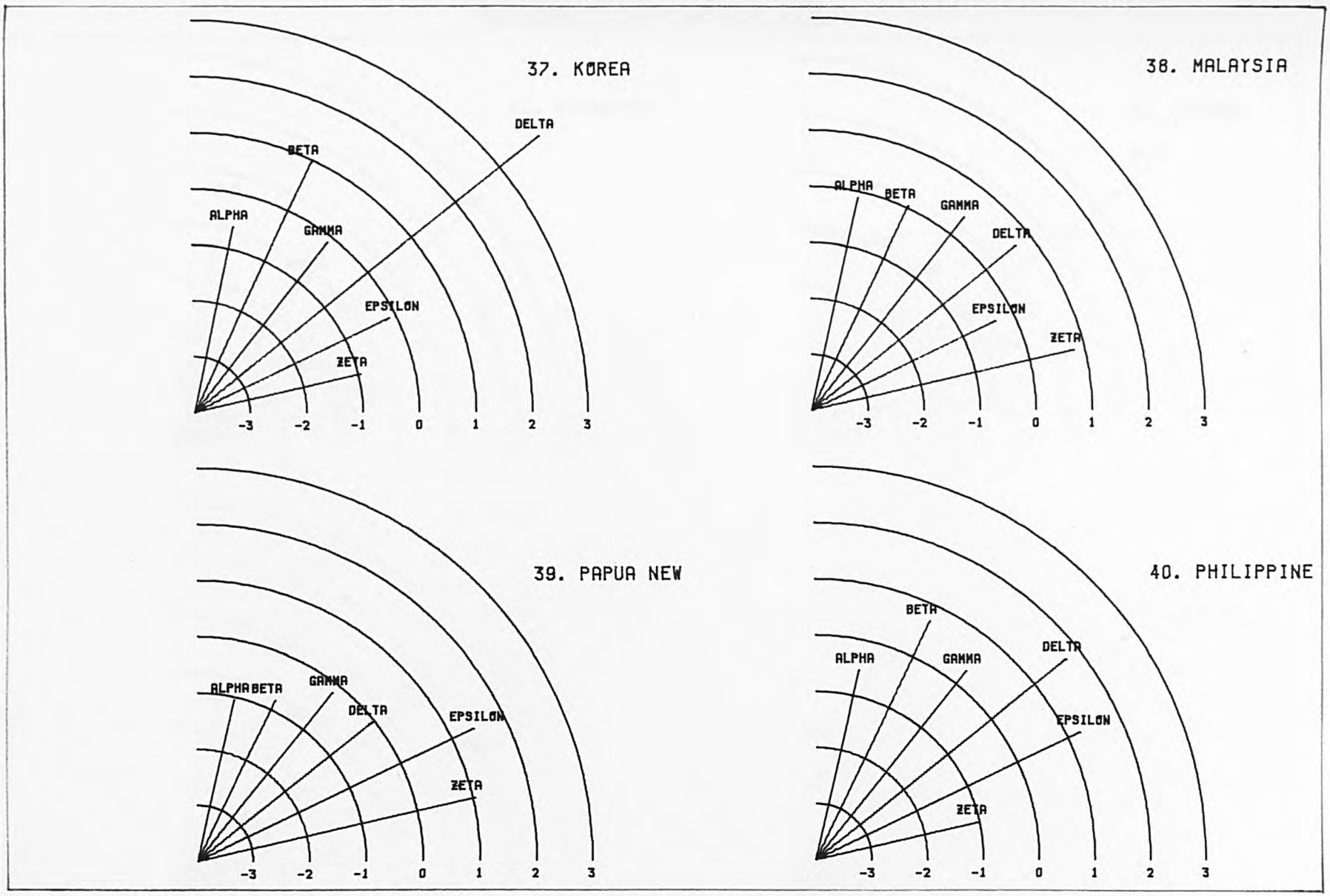


NATIONAL CHARACTERISTICS 1970



NATIONAL CHARACTERISTICS 1970




37. KOREA
DELTA
BETA
ALPHA
GAMMA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
38. MALAYSIA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
39. PAPUA NEW
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
40. PHILIPPINE
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
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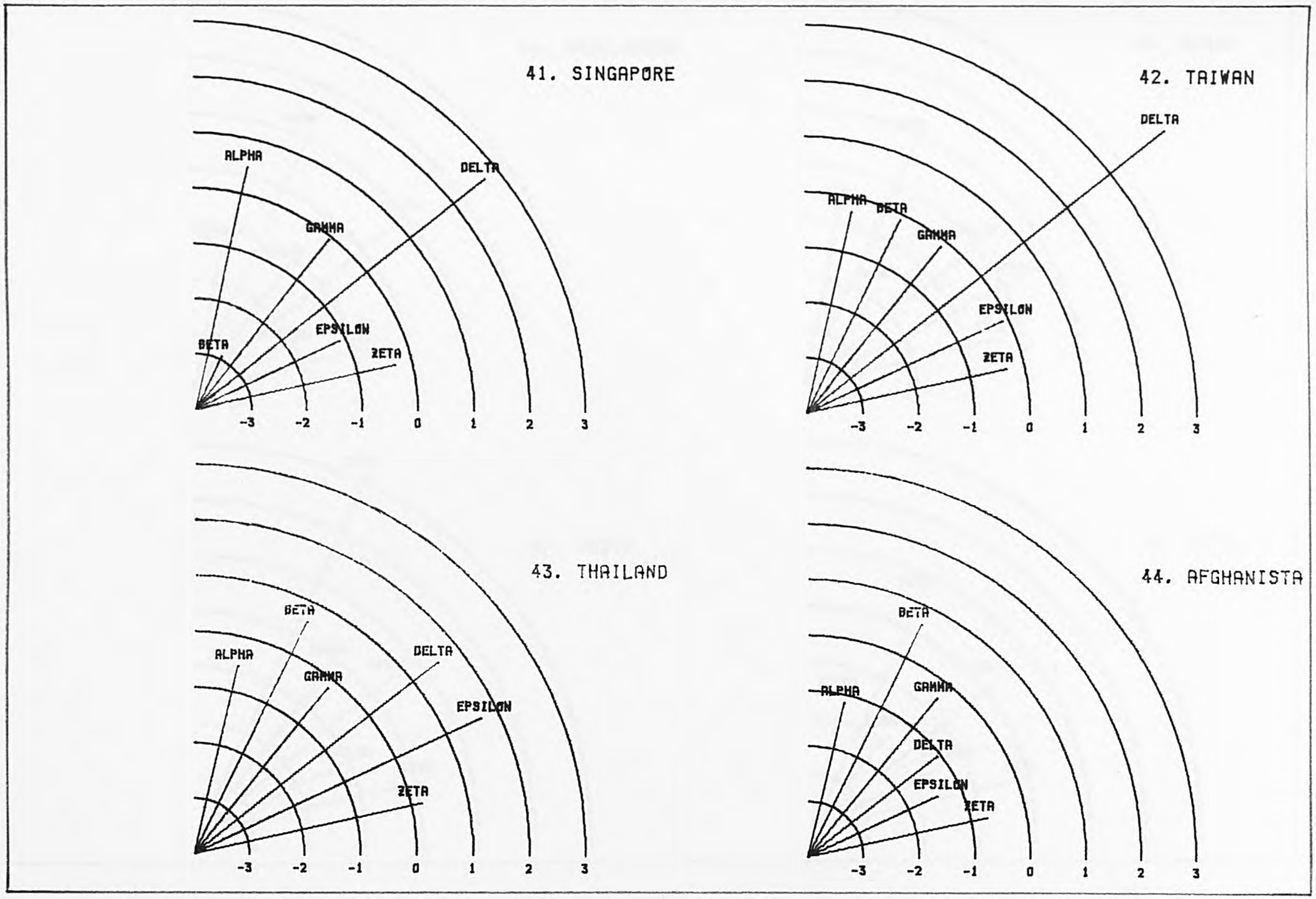
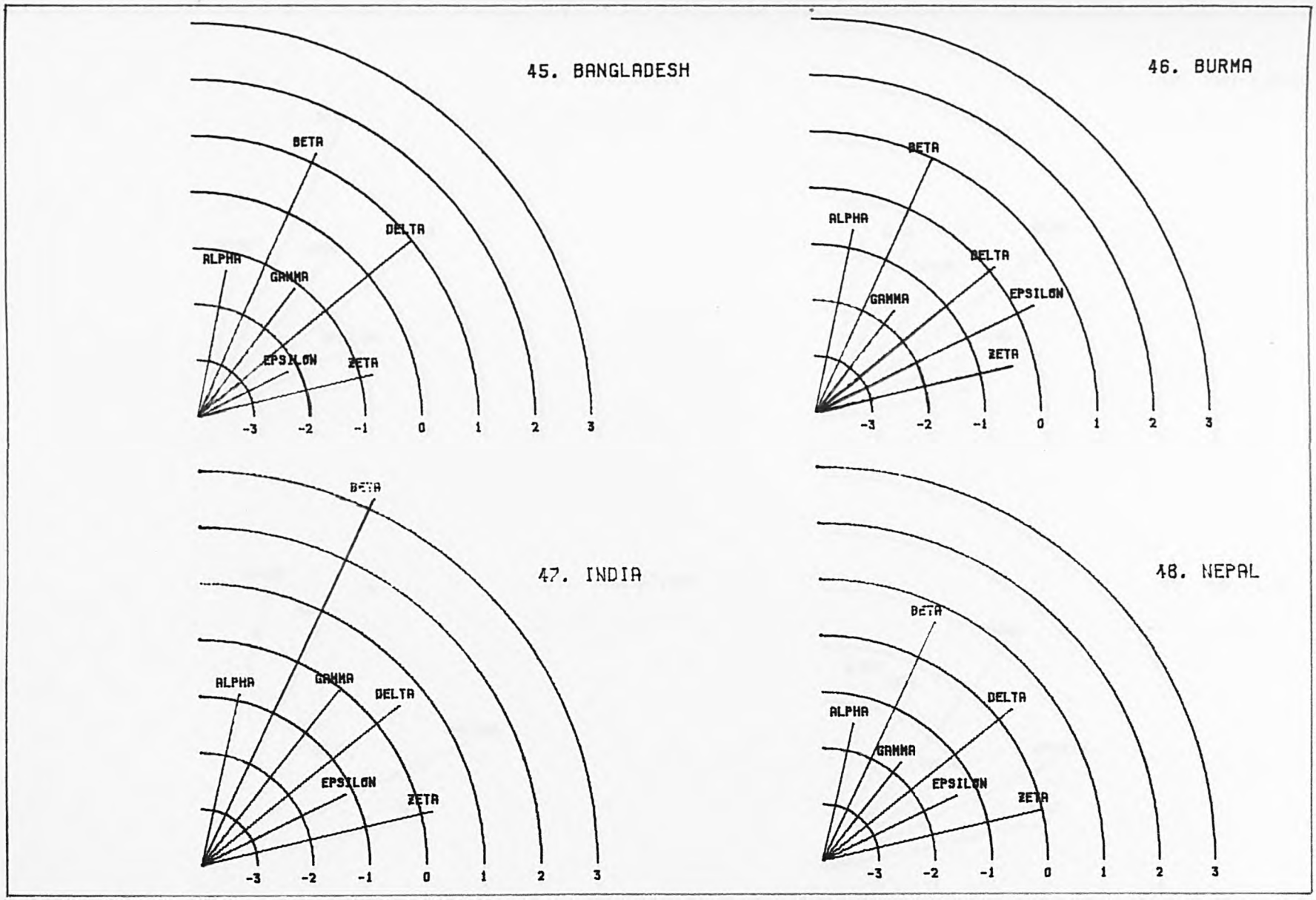
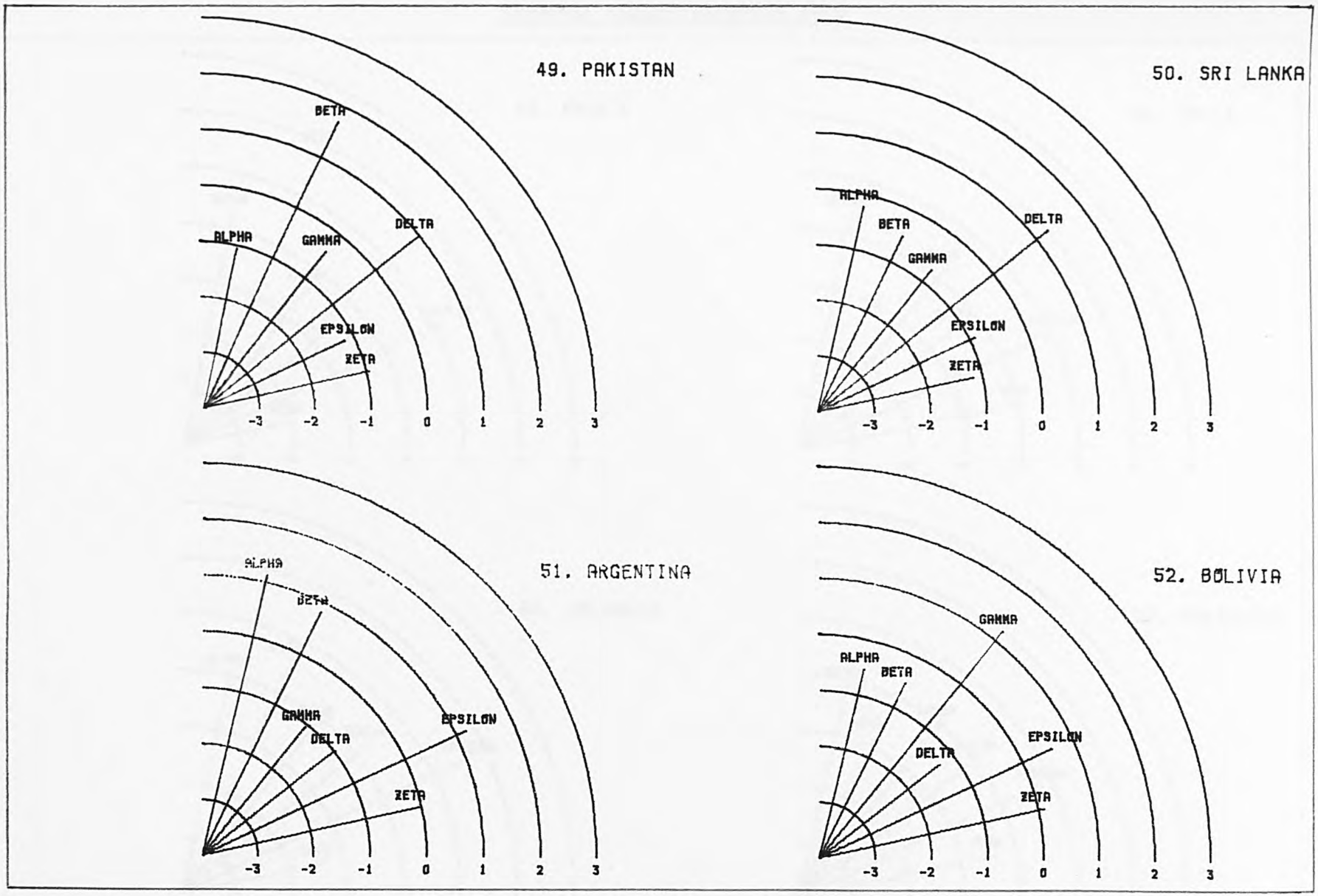
1
2
3

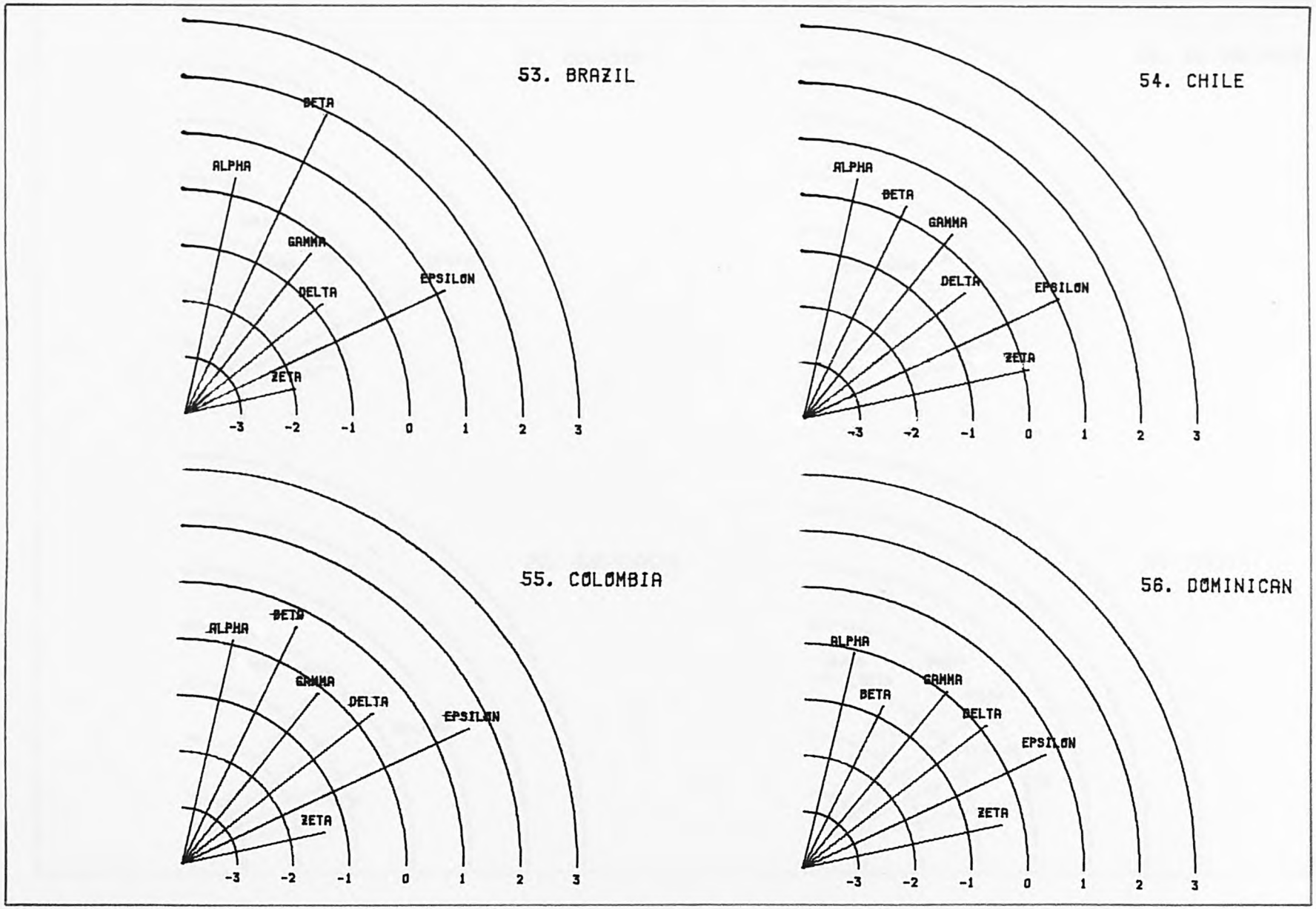
NATIONAL CHARACTERISTICS 1970

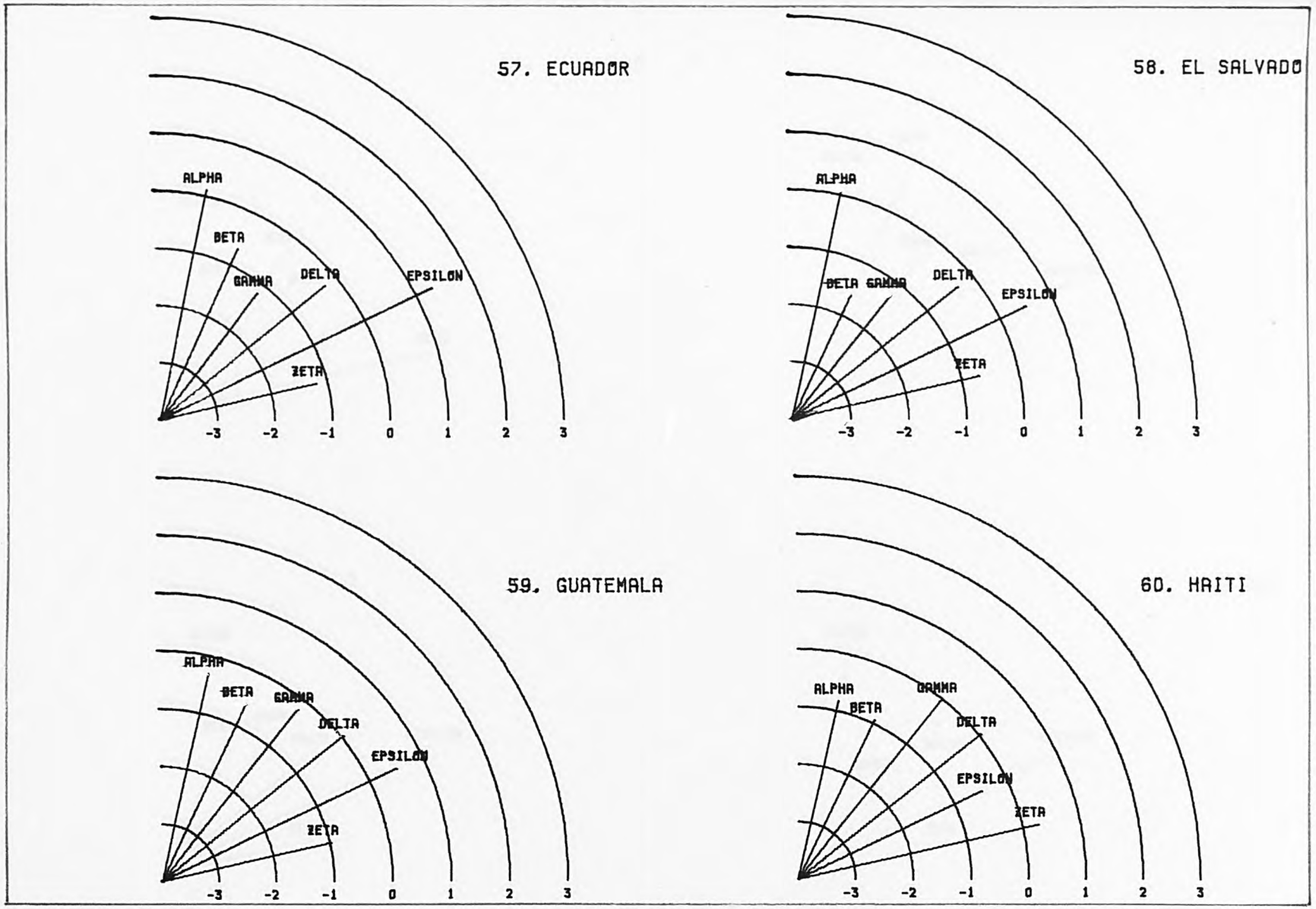



45. BANGLADESH
BETA
DELTA
ALPHA
GAMMA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
46. BURMA
BETA
ALPHA
DELTA
EPSILON
GAMMA
ZETA
-3 -2 -1 0 1 2 3
47. INDIA
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
48. NEPAL
BETA
DELTA
ALPHA
GAMMA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

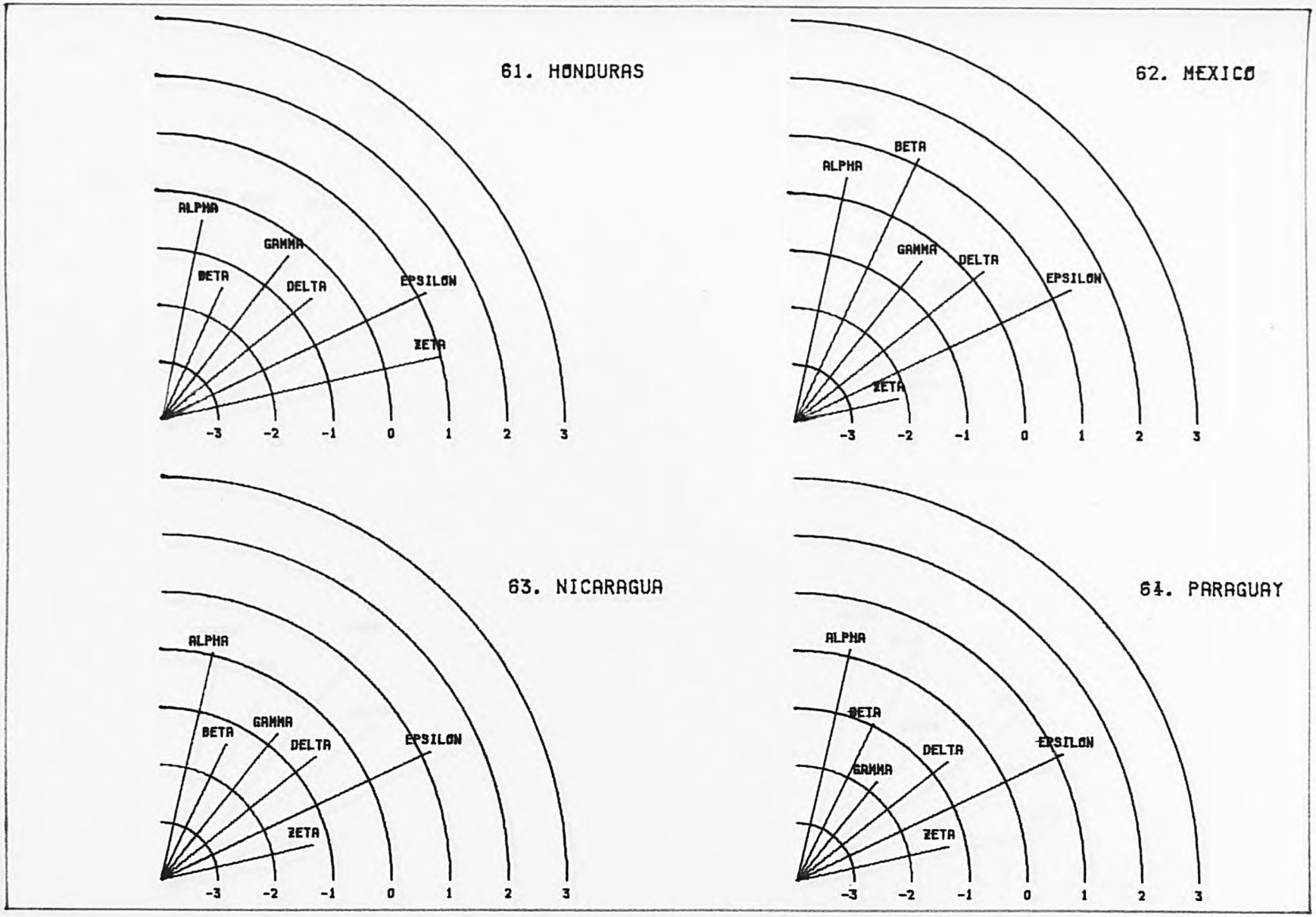

49. PAKISTAN
BETA
ALPHA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
50. SRI LANKA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
51. ARGENTINA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
52. BOLIVIA
GAMMA
ALPHA
BETA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

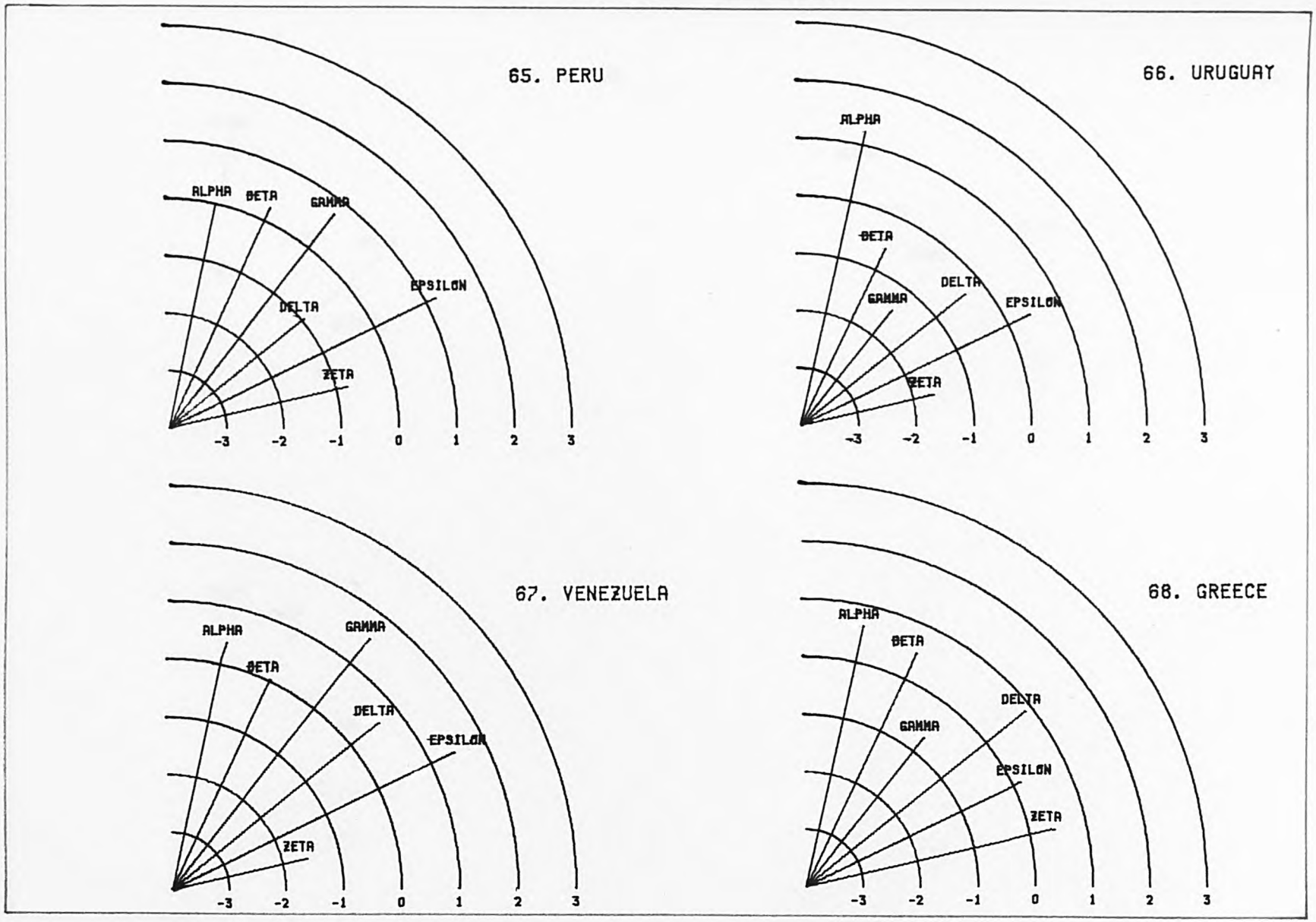
NATIONAL CHARACTERISTICS 1970




57. ECUADOR
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
58. EL SALVADO
ALPHA
BETA GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
59. GUATEMALA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
60. HAITI
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3

NATIONAL CHARACTERISTICS 1970




65. PERU
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
66. URUGUAY
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
67. VENEZUELA
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3
-2
-1
0
1
2
3
68. GREECE
ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
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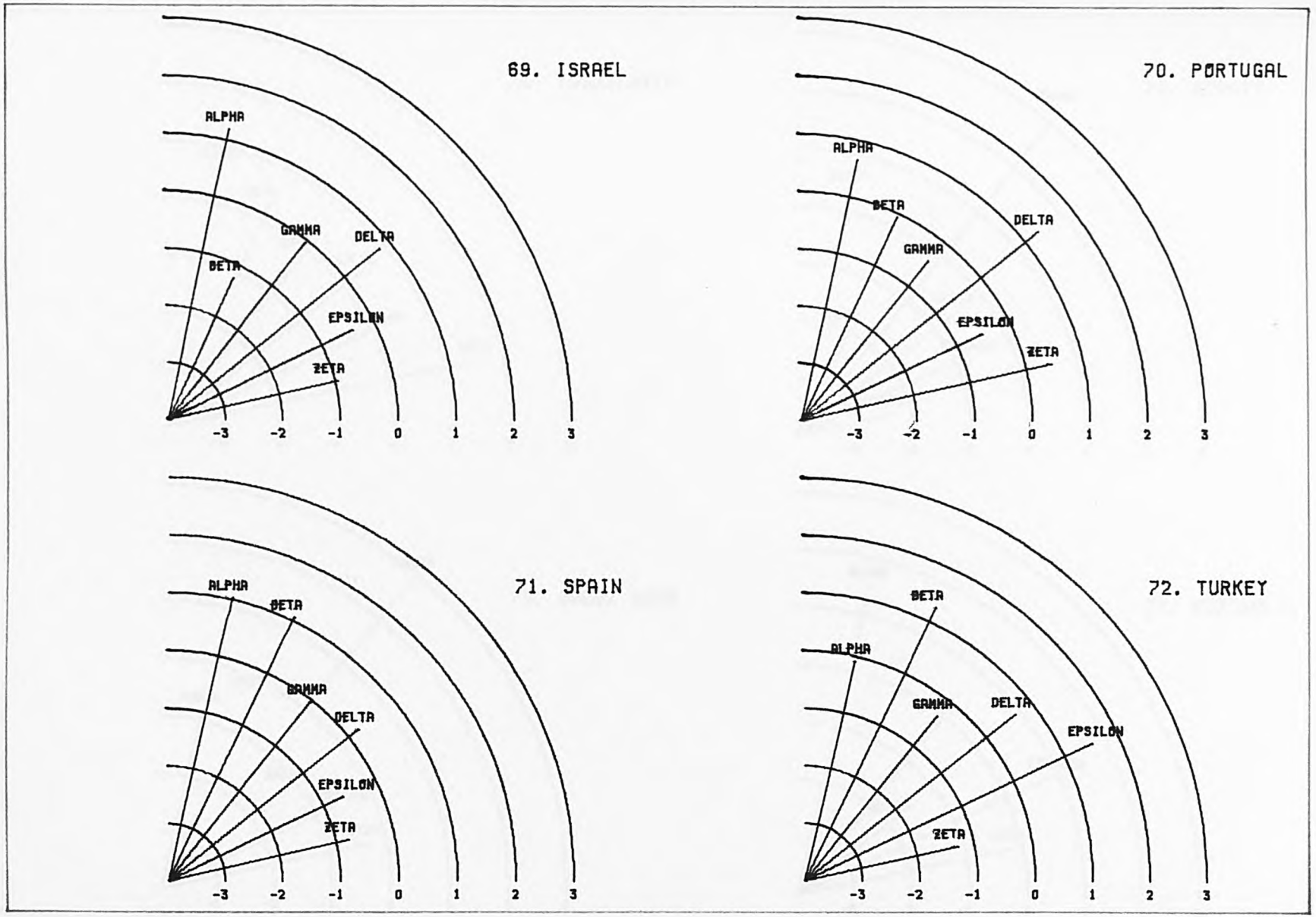
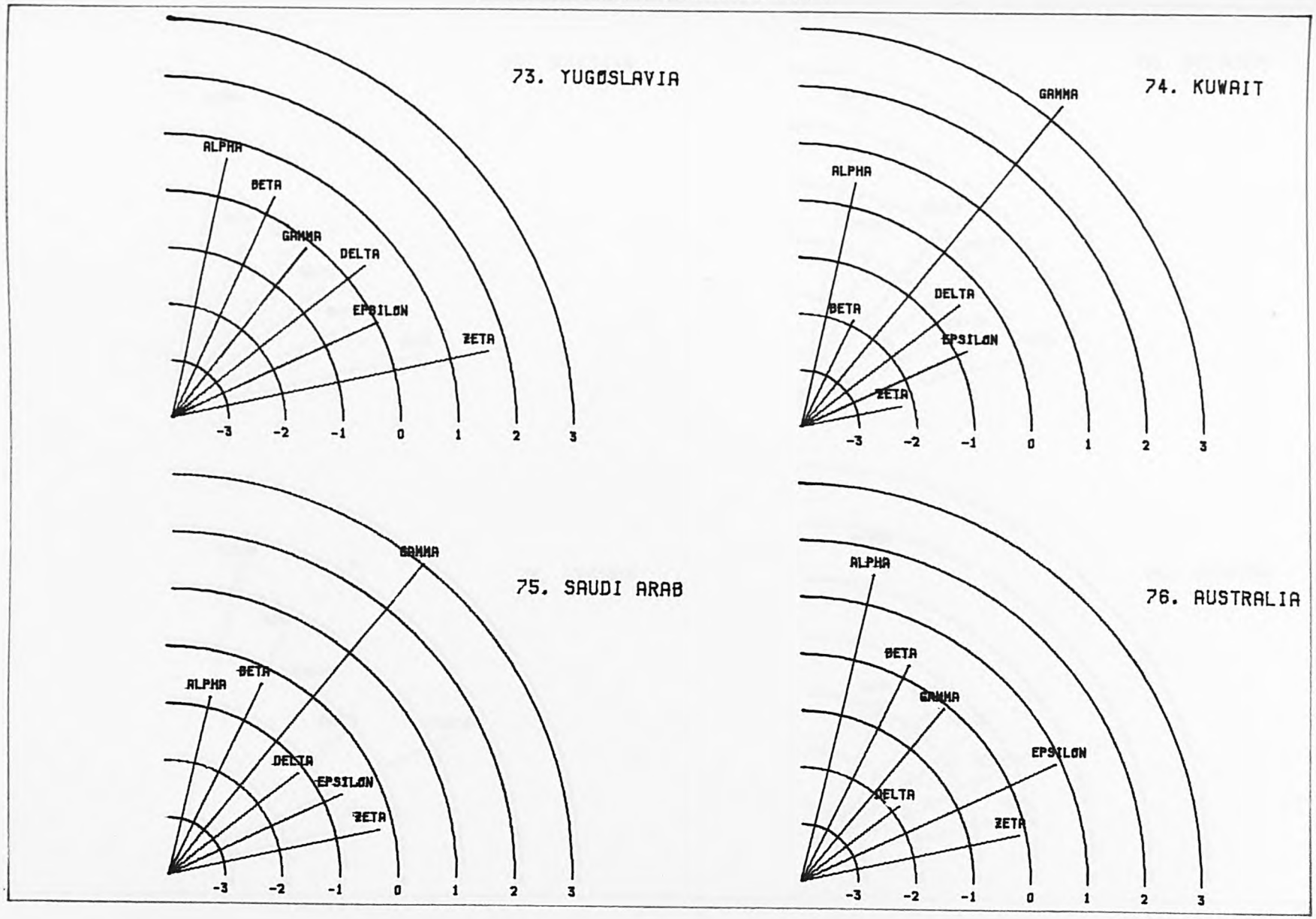
3

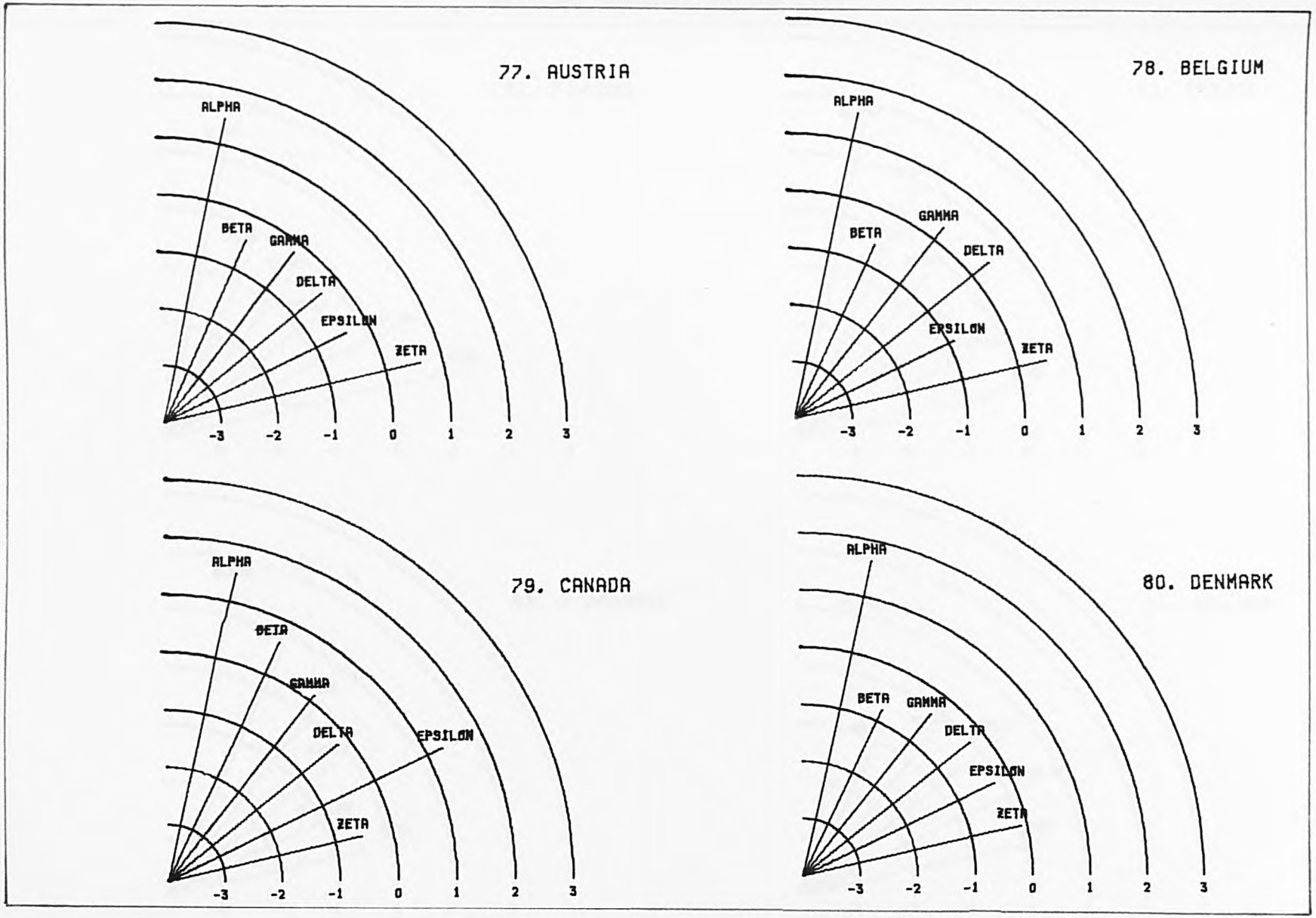
NATIONAL CHARACTERISTICS 1970



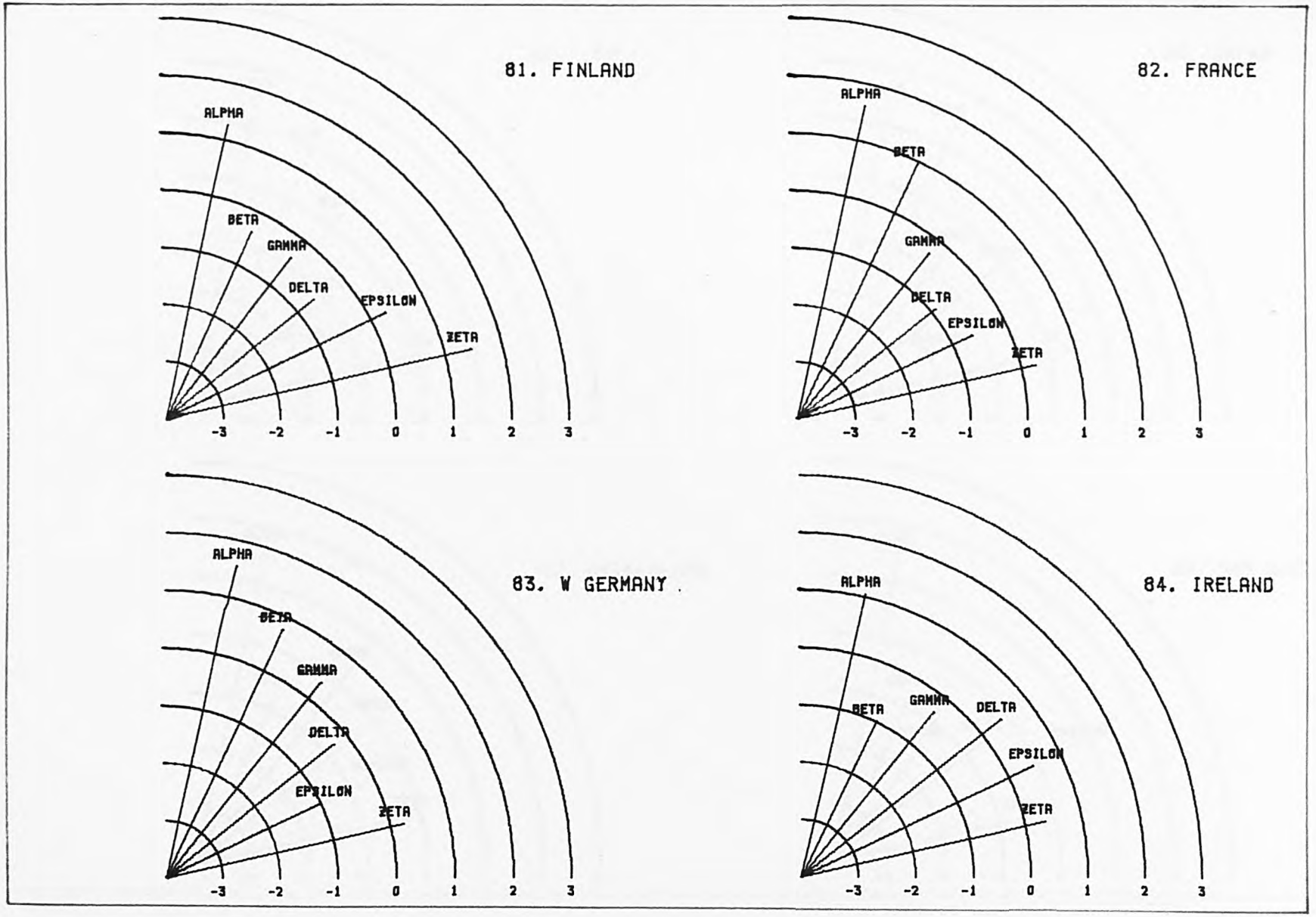
NATIONAL CHARACTERISTICS 1970



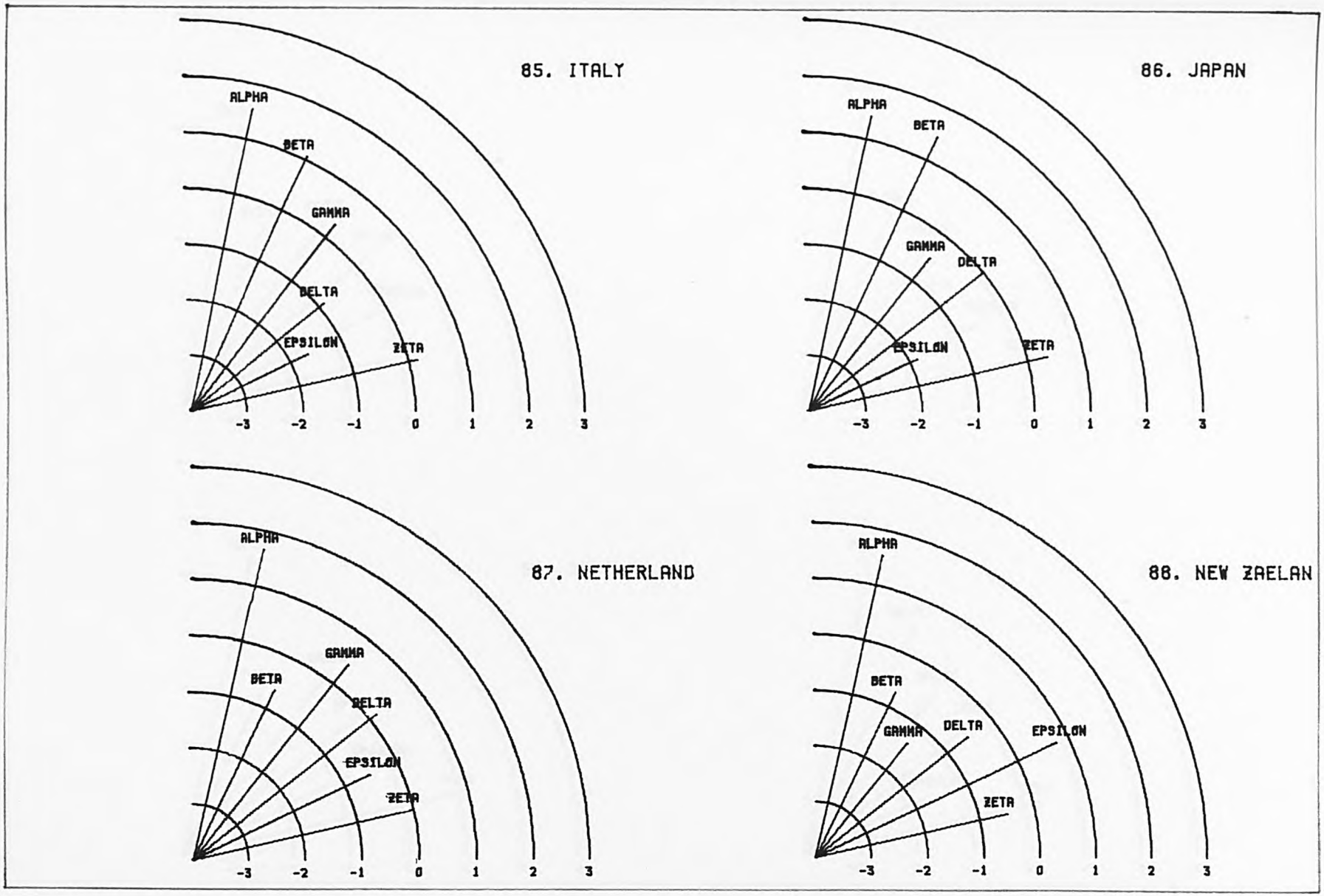
NATIONAL CHARACTERISTICS 1970



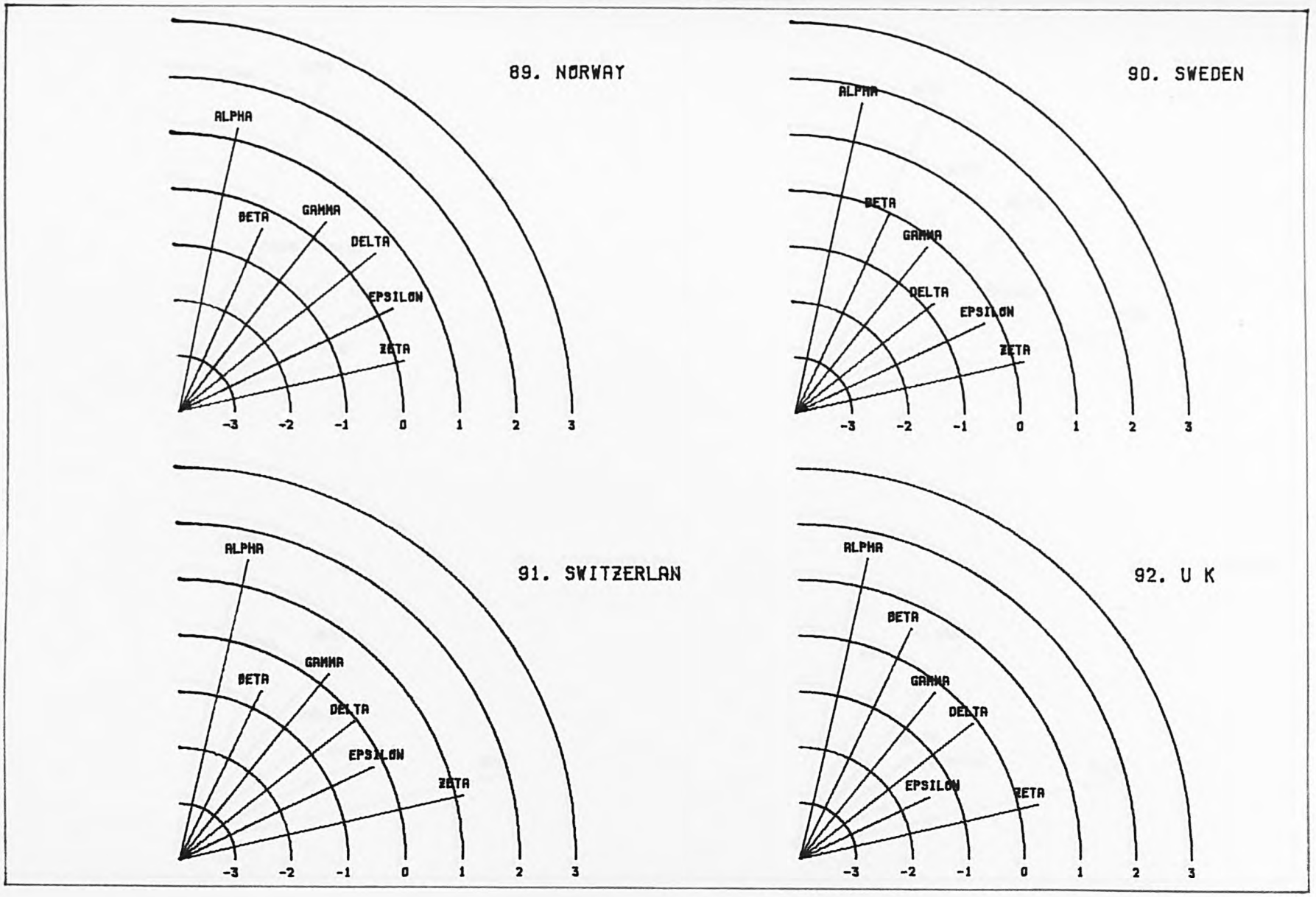
NATIONAL CHARACTERISTICS 1970



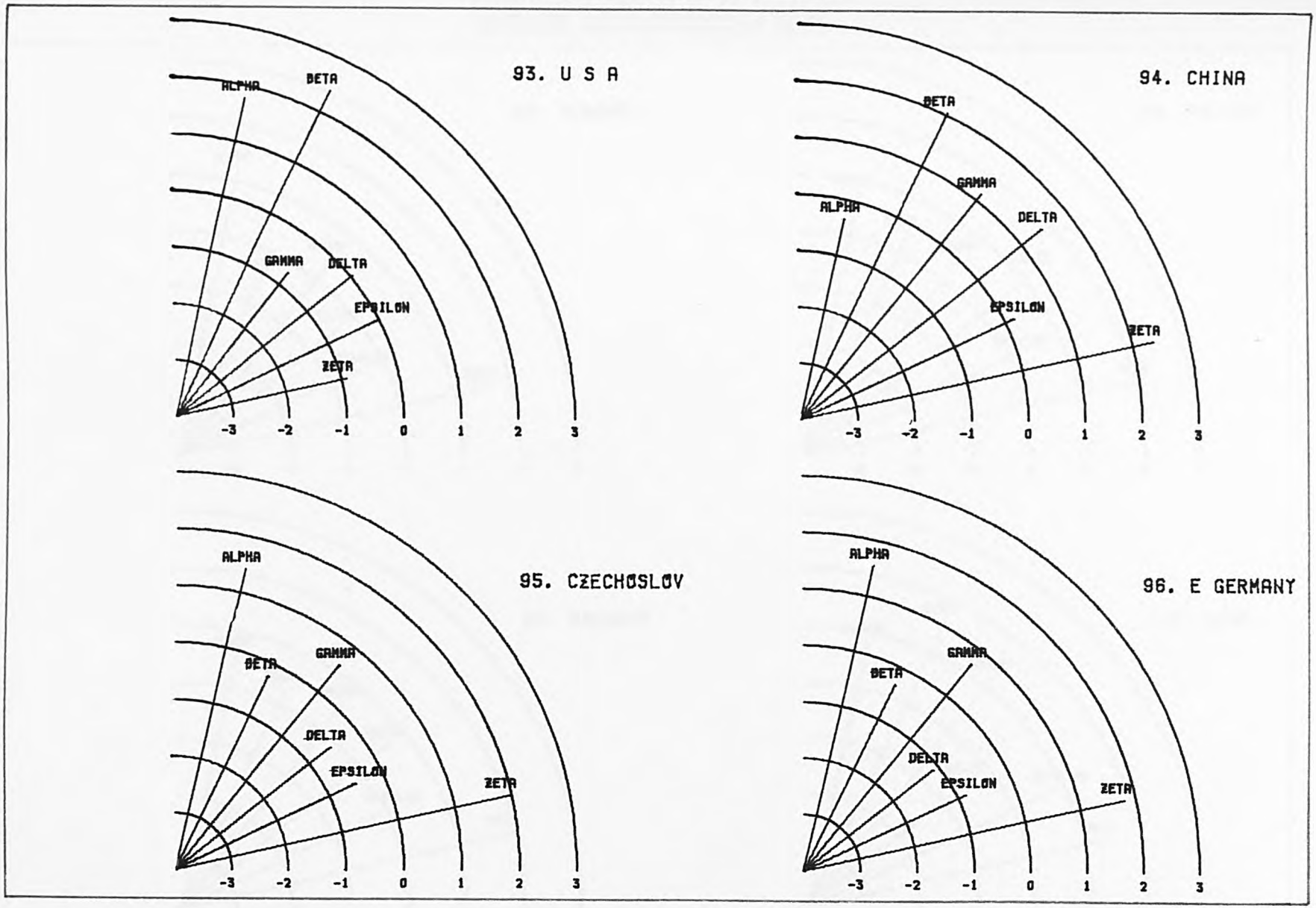
NATIONAL CHARACTERISTICS 1970



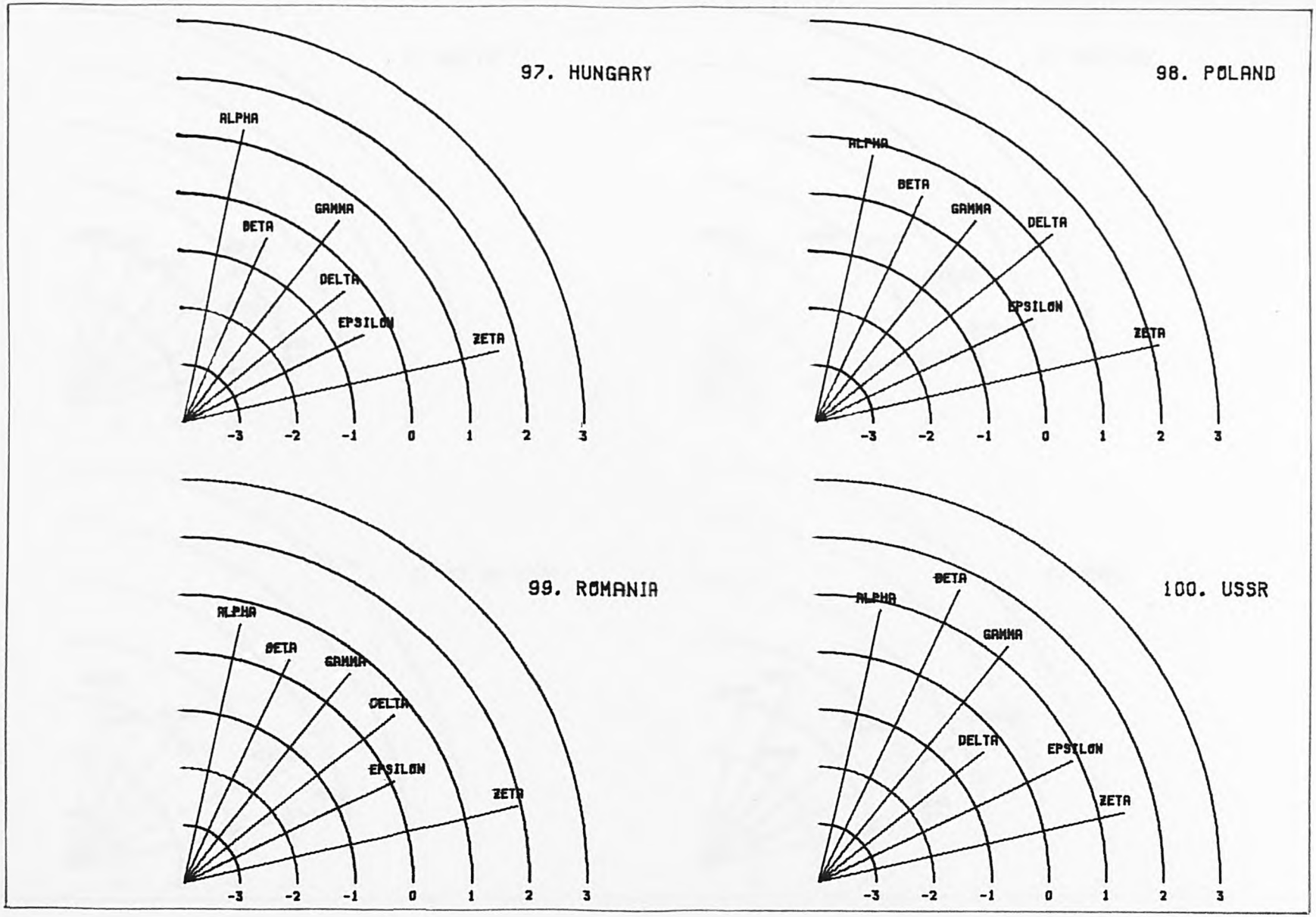
NATIONAL CHARACTERISTICS 1970



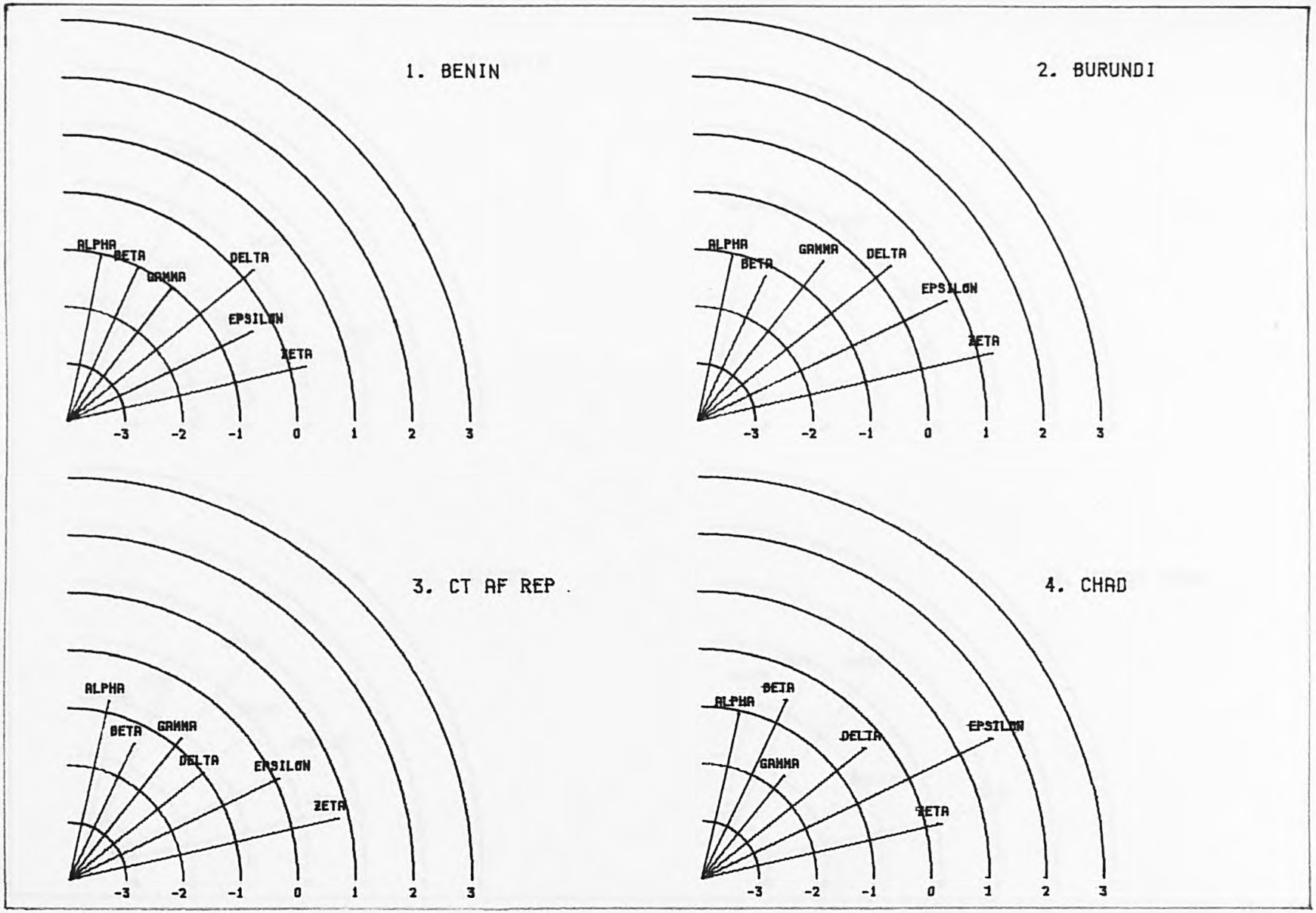
NATIONAL CHARACTERISTICS 1970



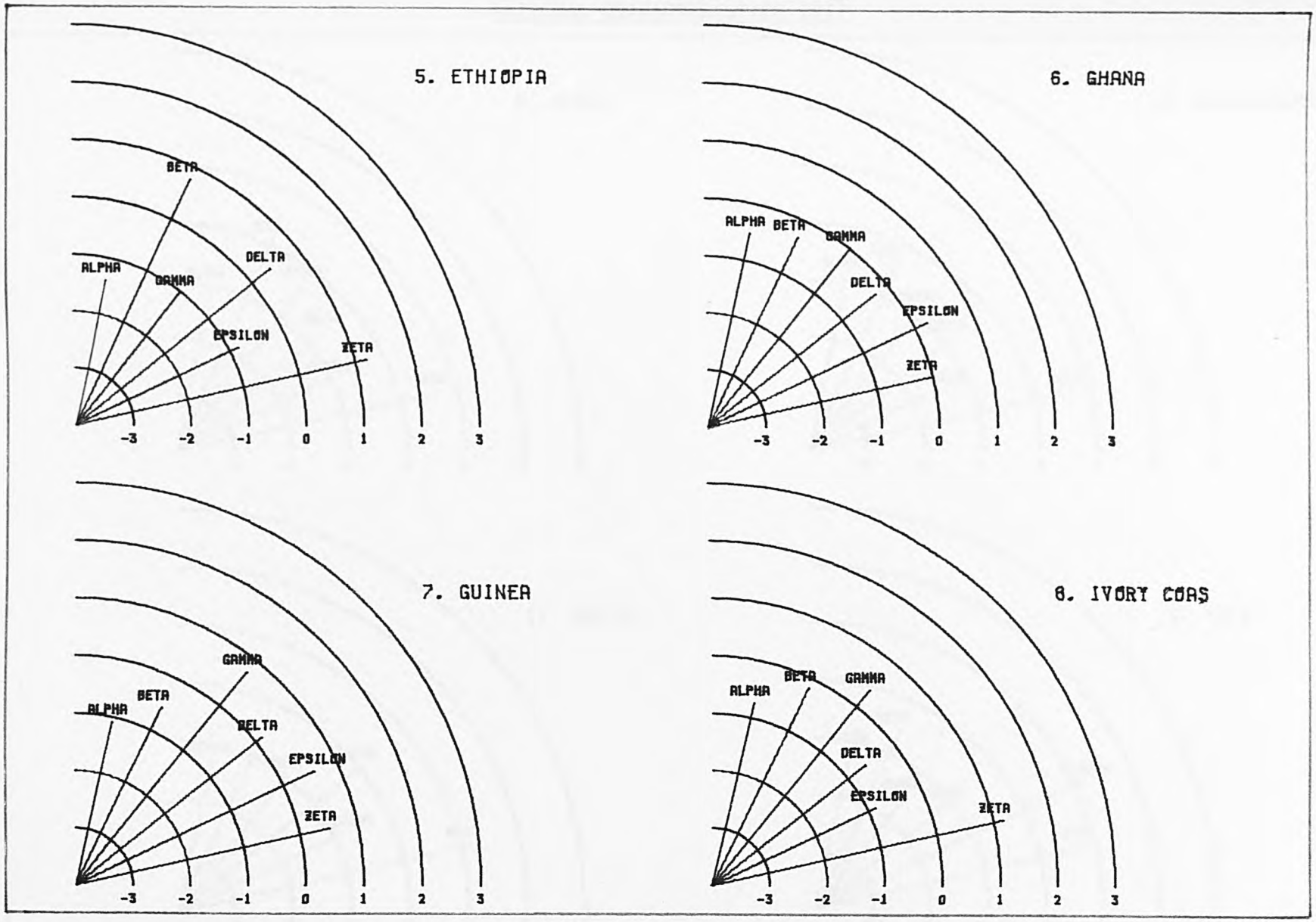
NATIONAL CHARACTERISTICS 1970



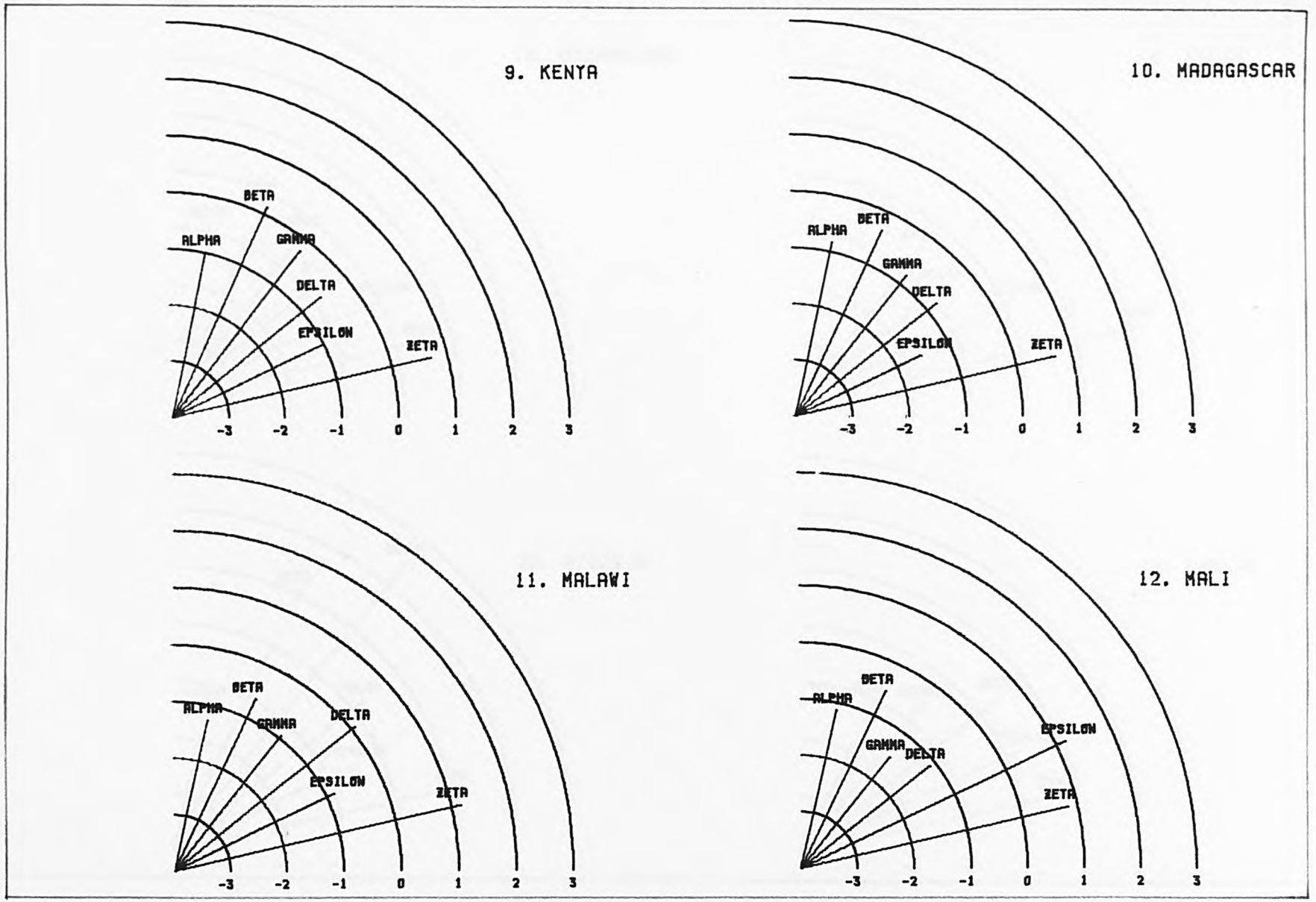
NATIONAL CHARACTERISTICS 1977



NATIONAL CHARACTERISTICS 1977



NATIONAL CHARACTERISTICS 1977



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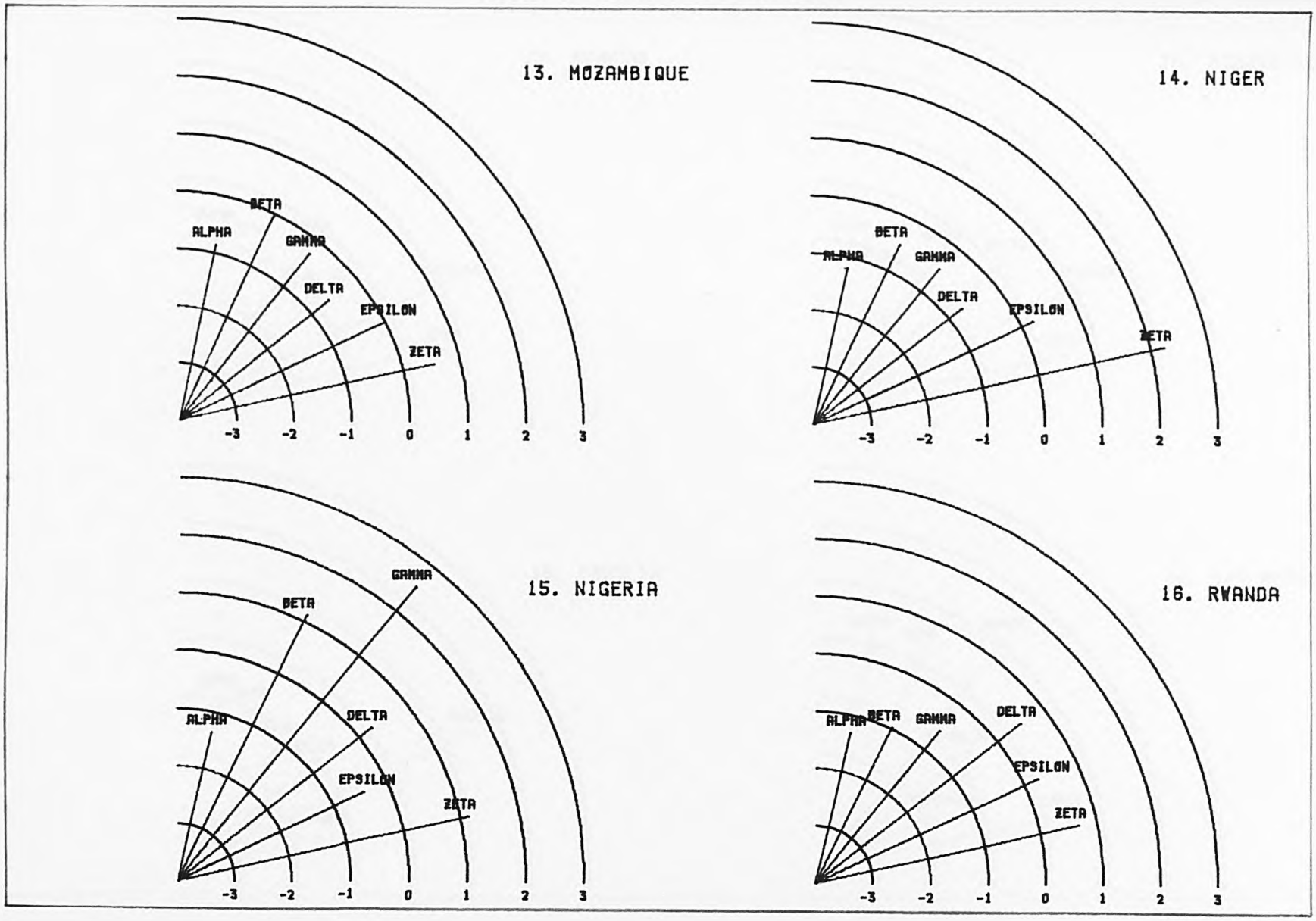
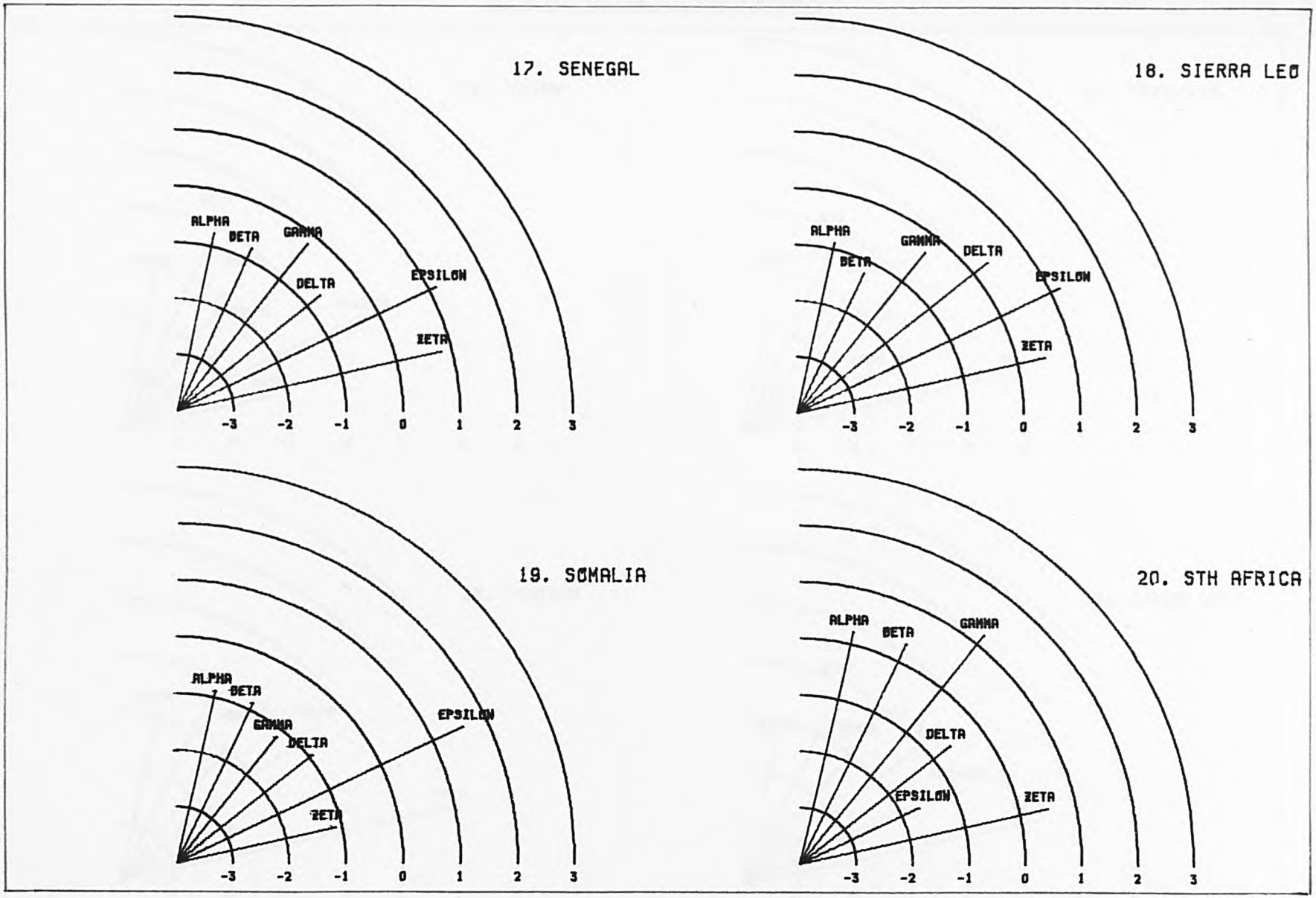
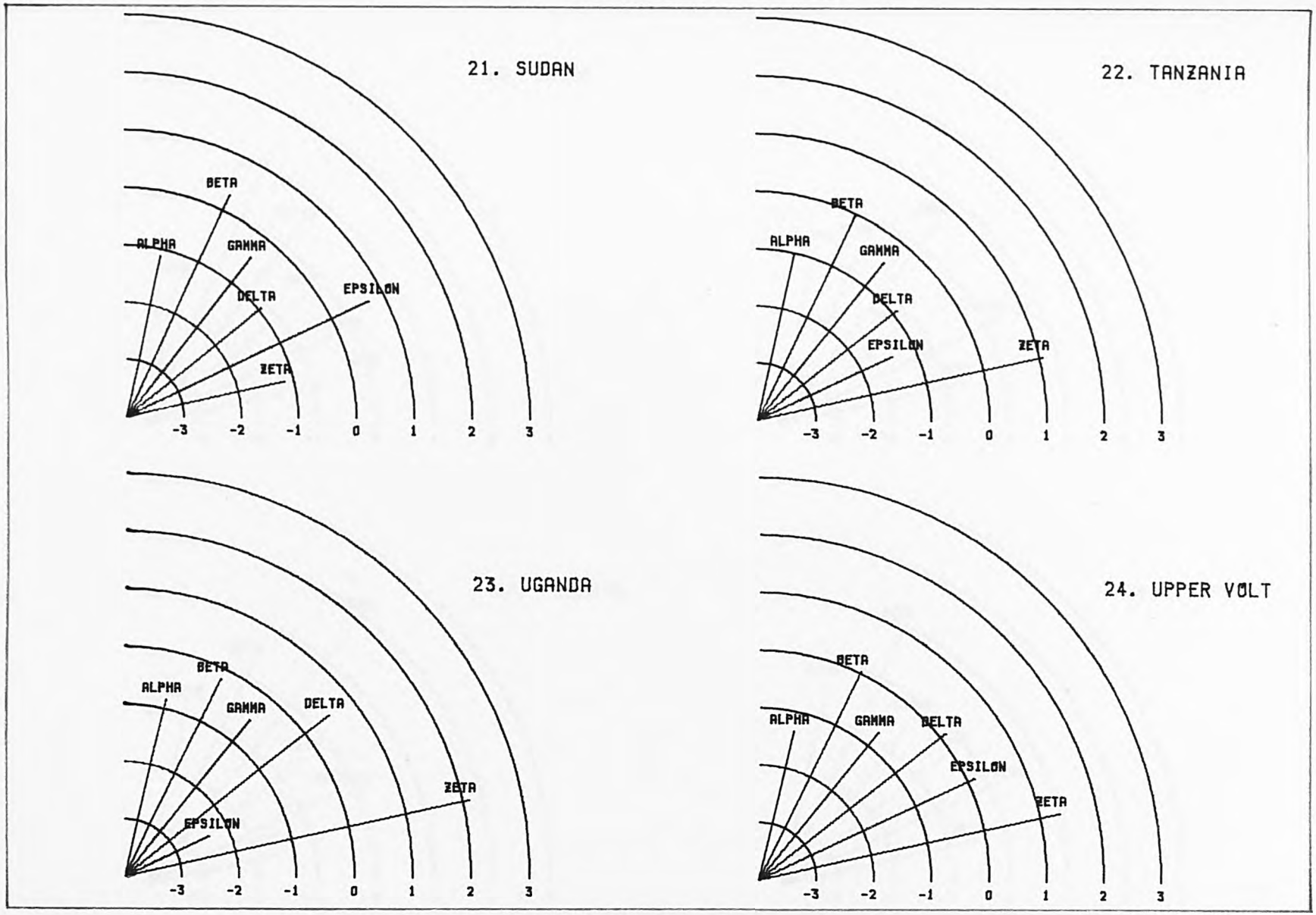


NATIONAL CHARACTERISTICS 1977



NATIONAL CHARACTERISTICS 1977



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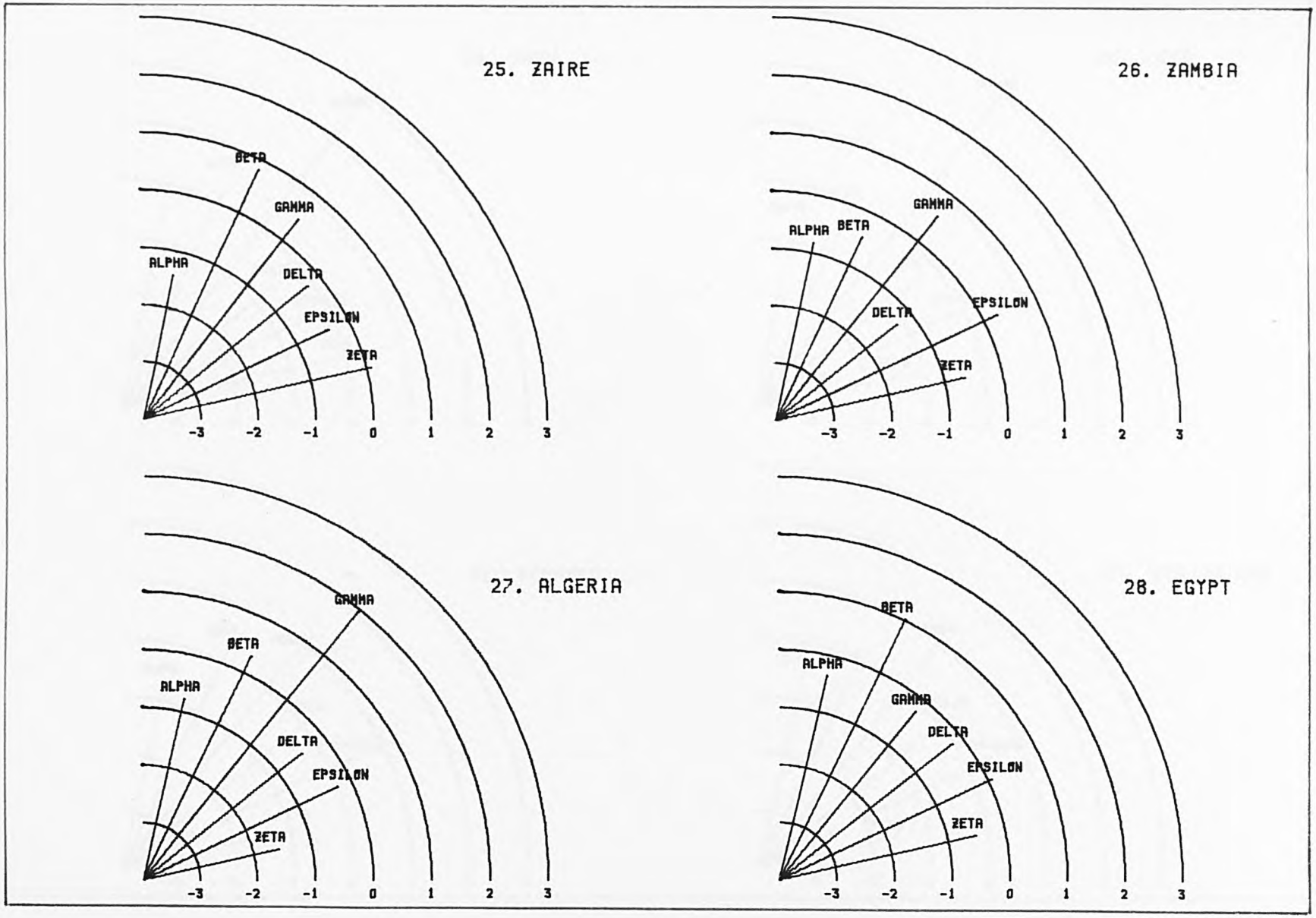

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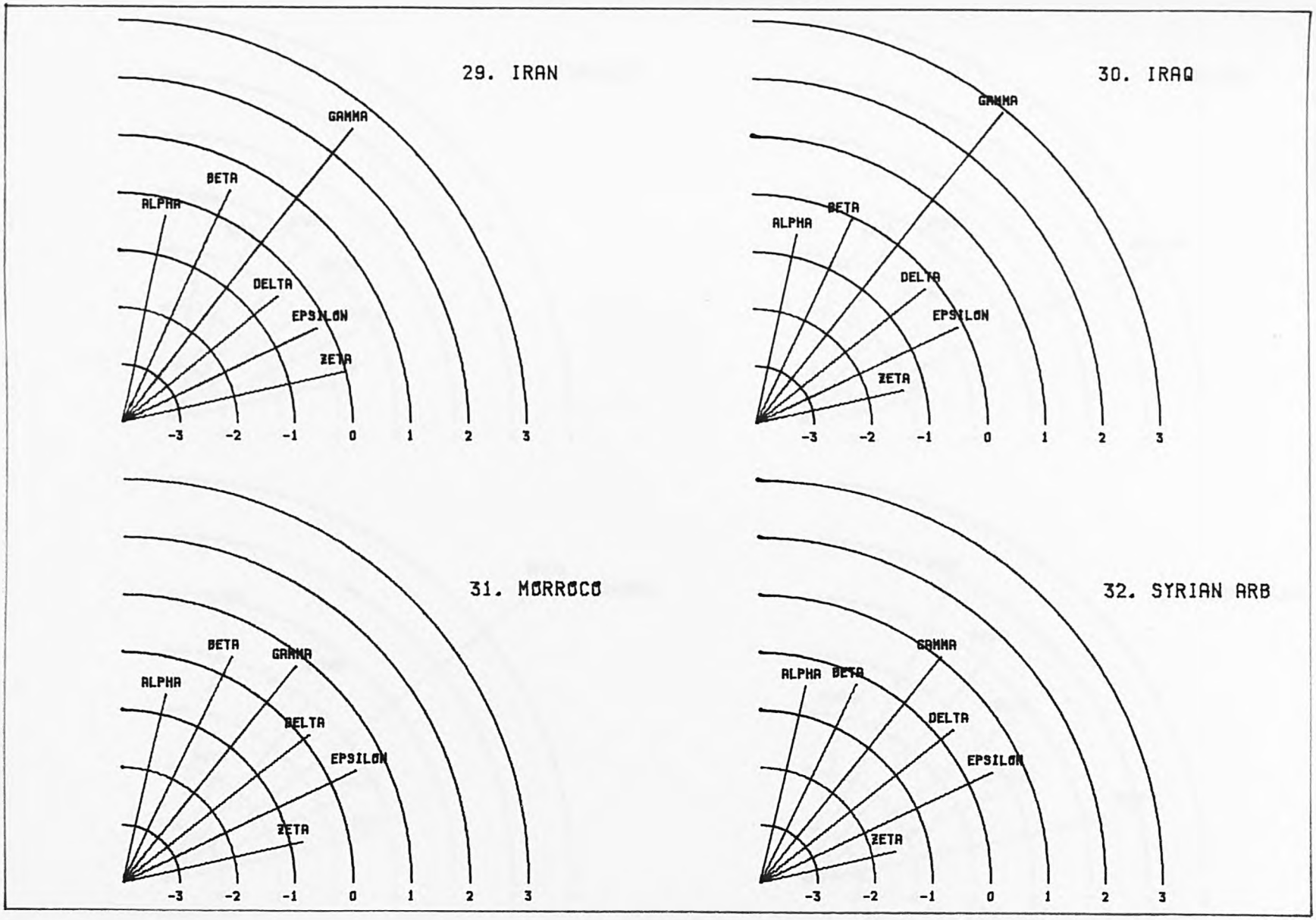

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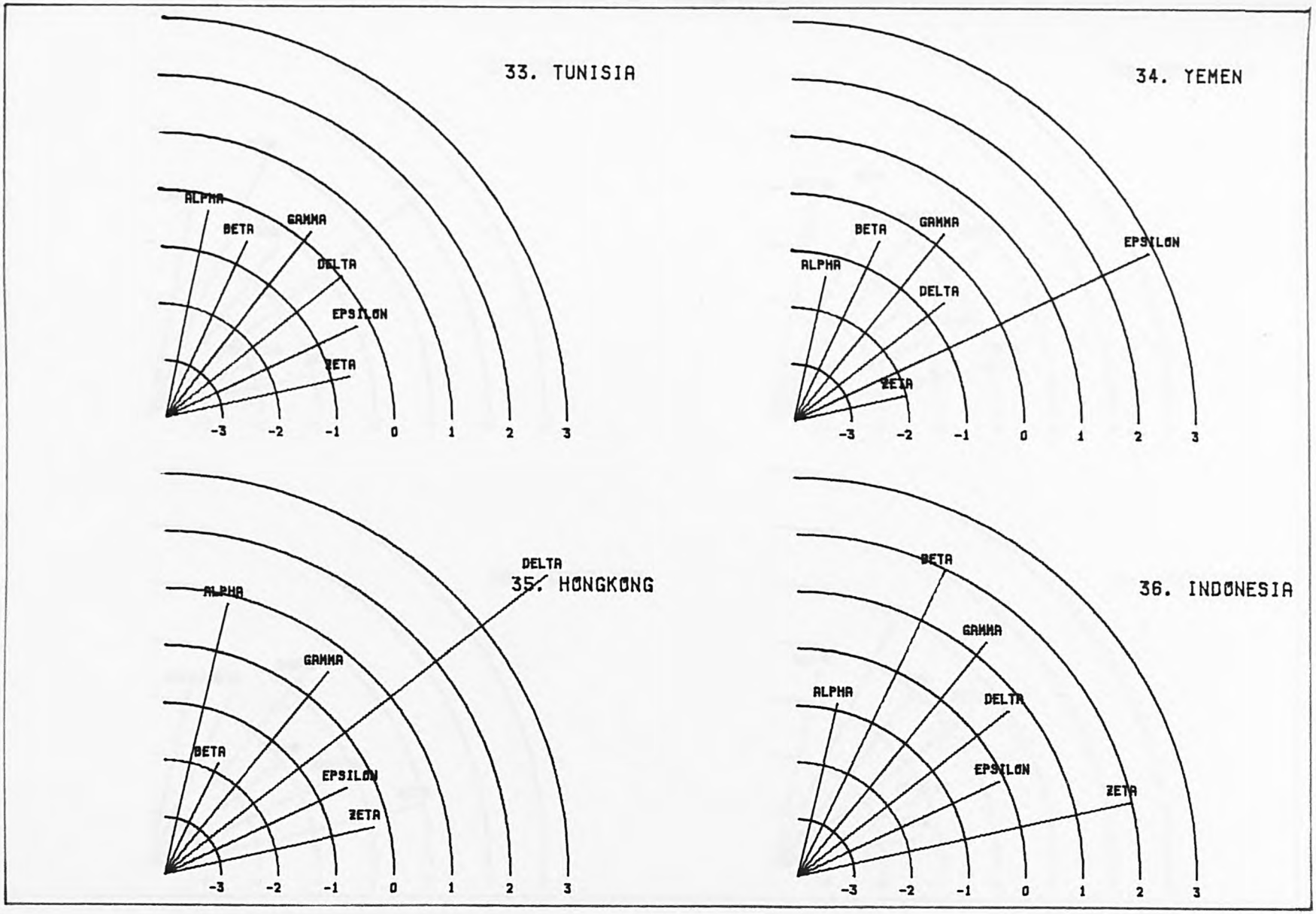

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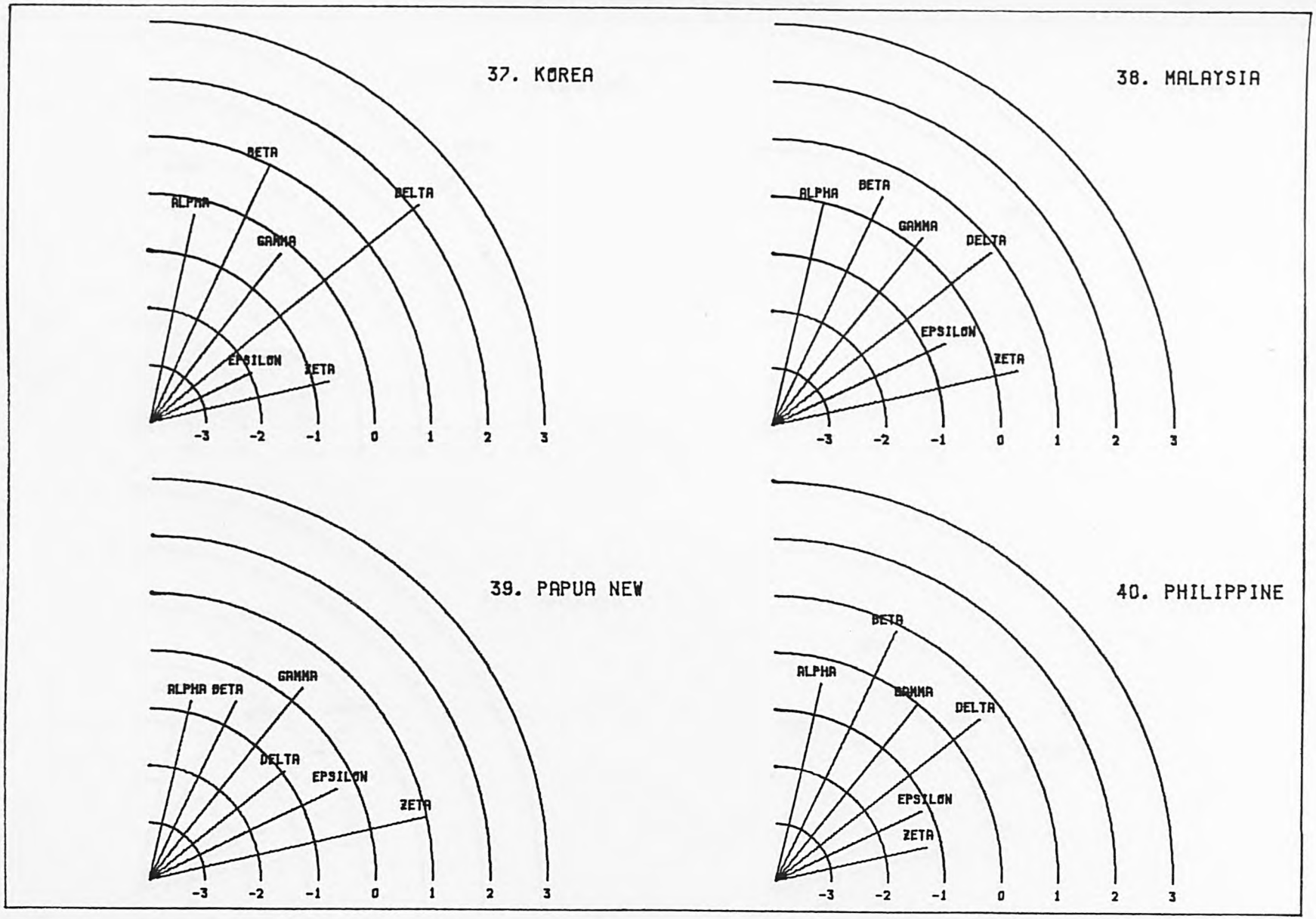

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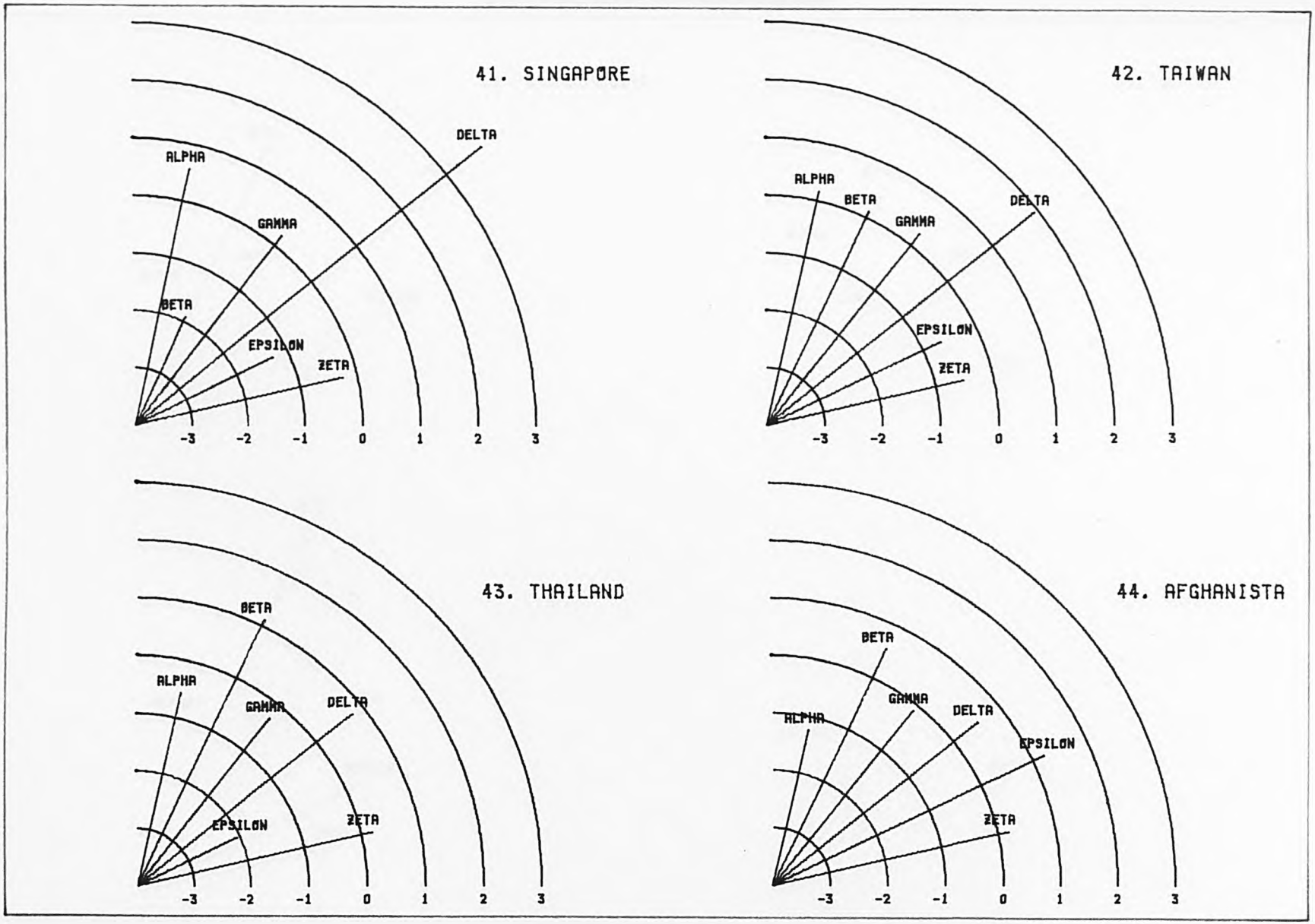

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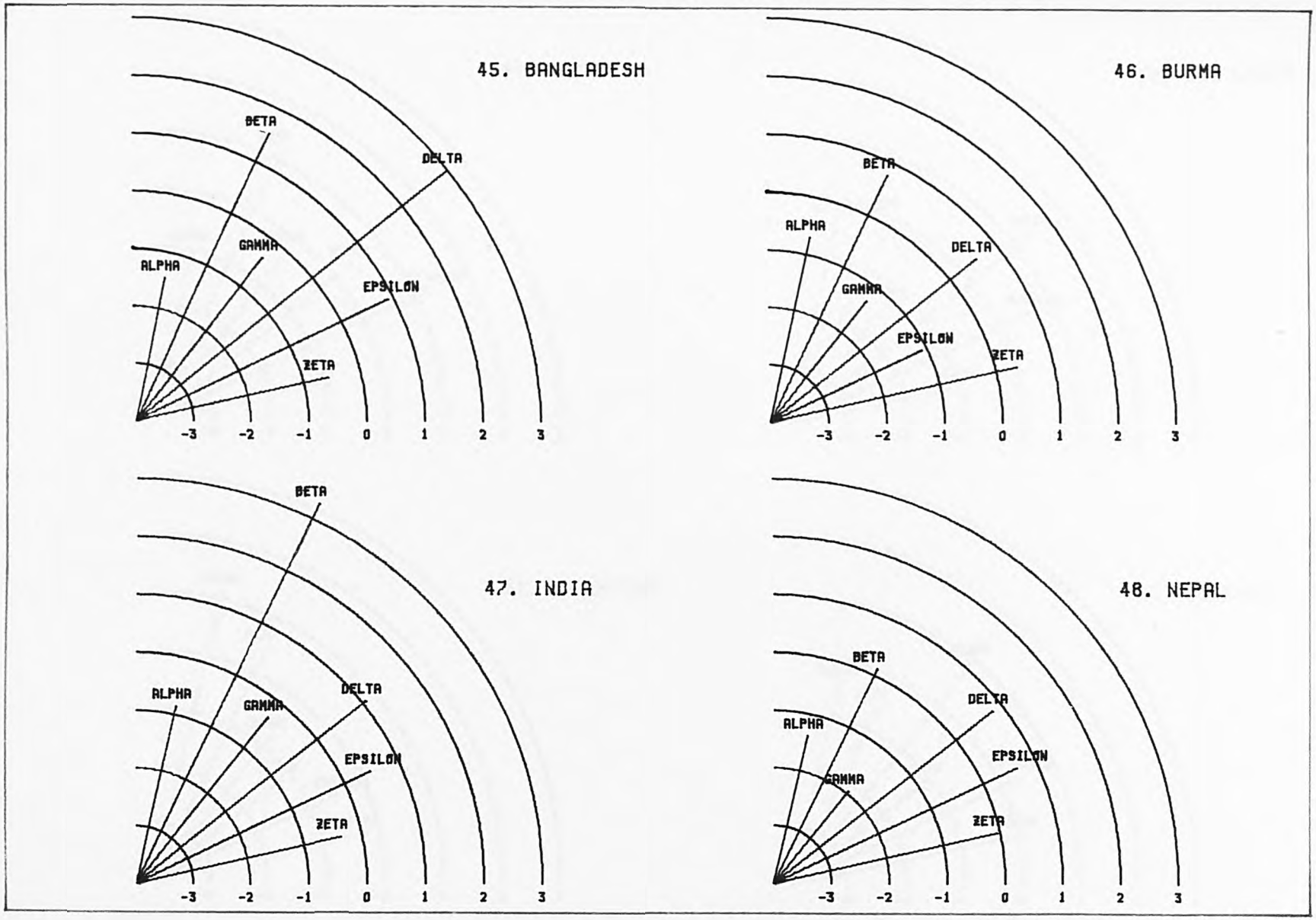

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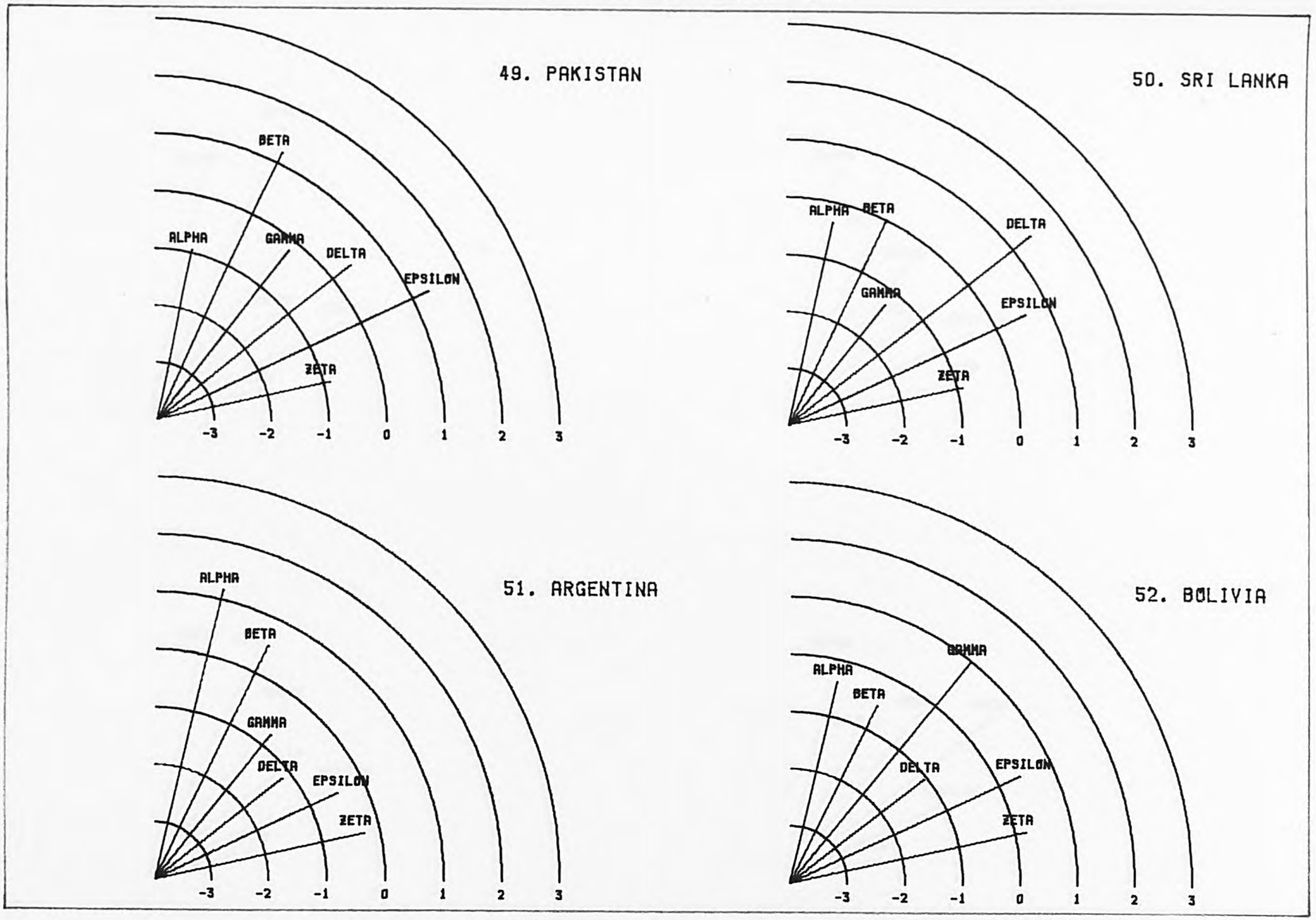

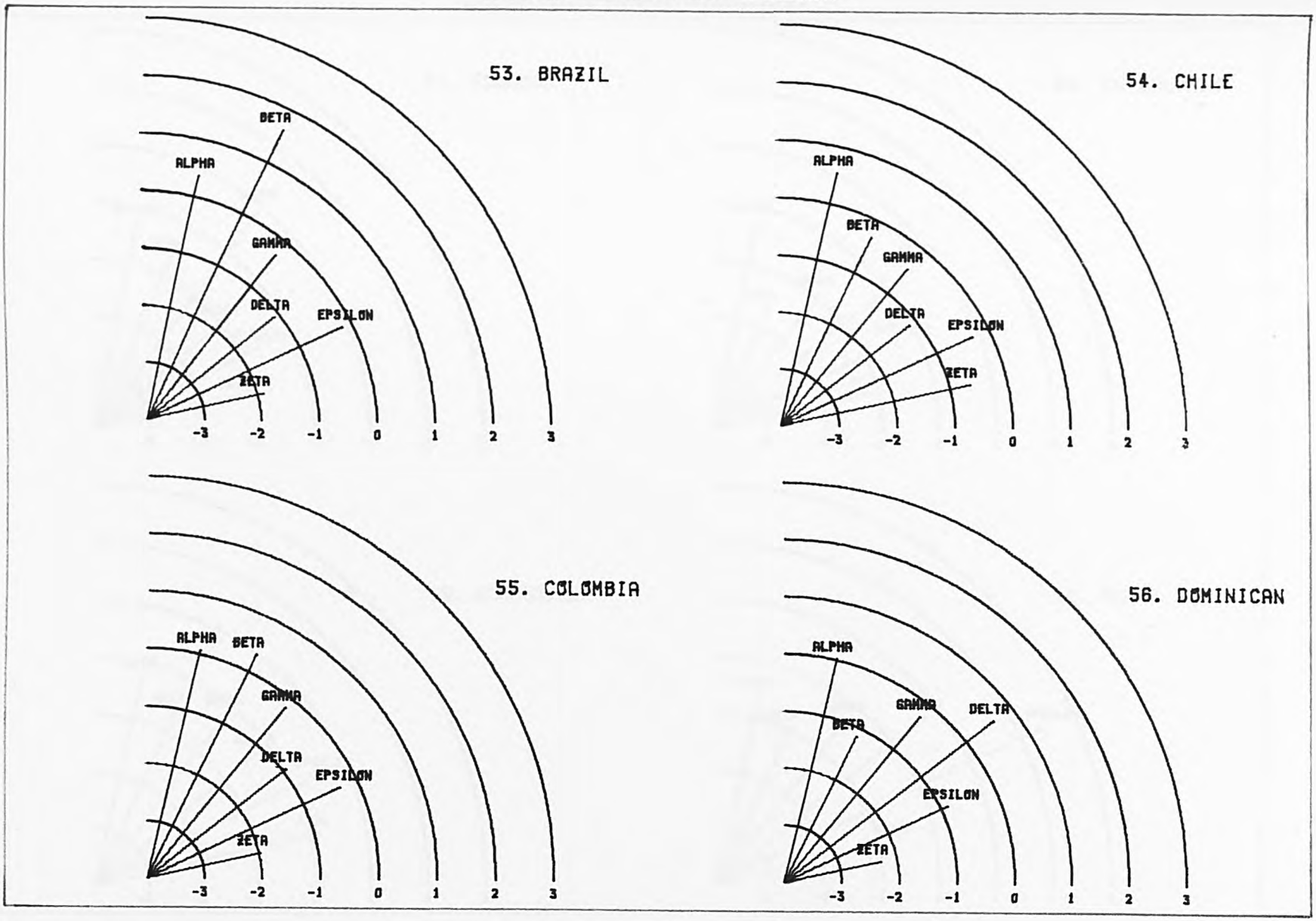
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ZETA
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ALPHA
BETA
GAMMA
DELTA
EPSILON
ZETA
-3 -2 -1 0 1 2 3
55. COLOMBIA
ALPHA
BETA
GAMMA
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EPSILON
ZETA
-3 -2 -1 0 1 2 3
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ALPHA
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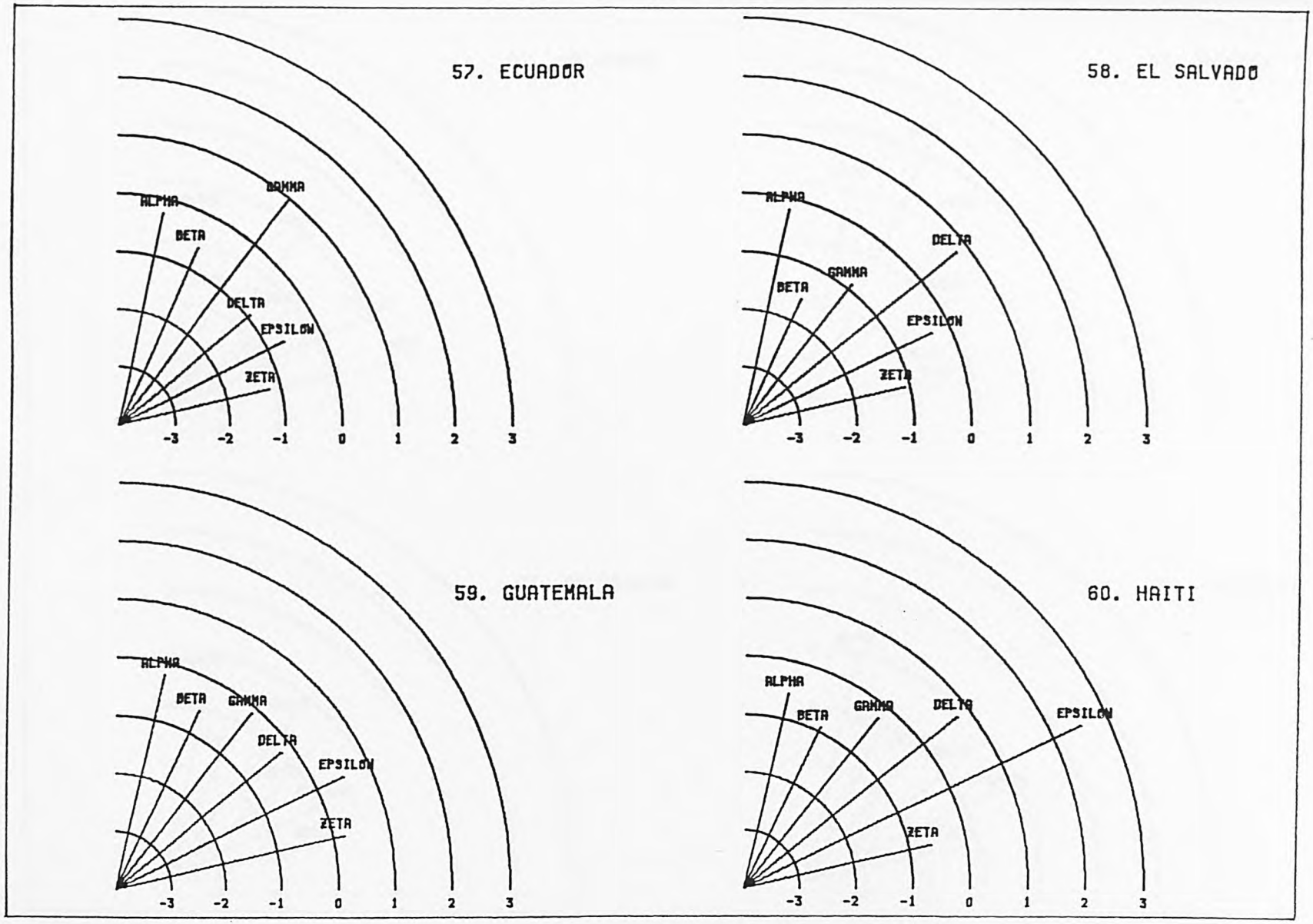
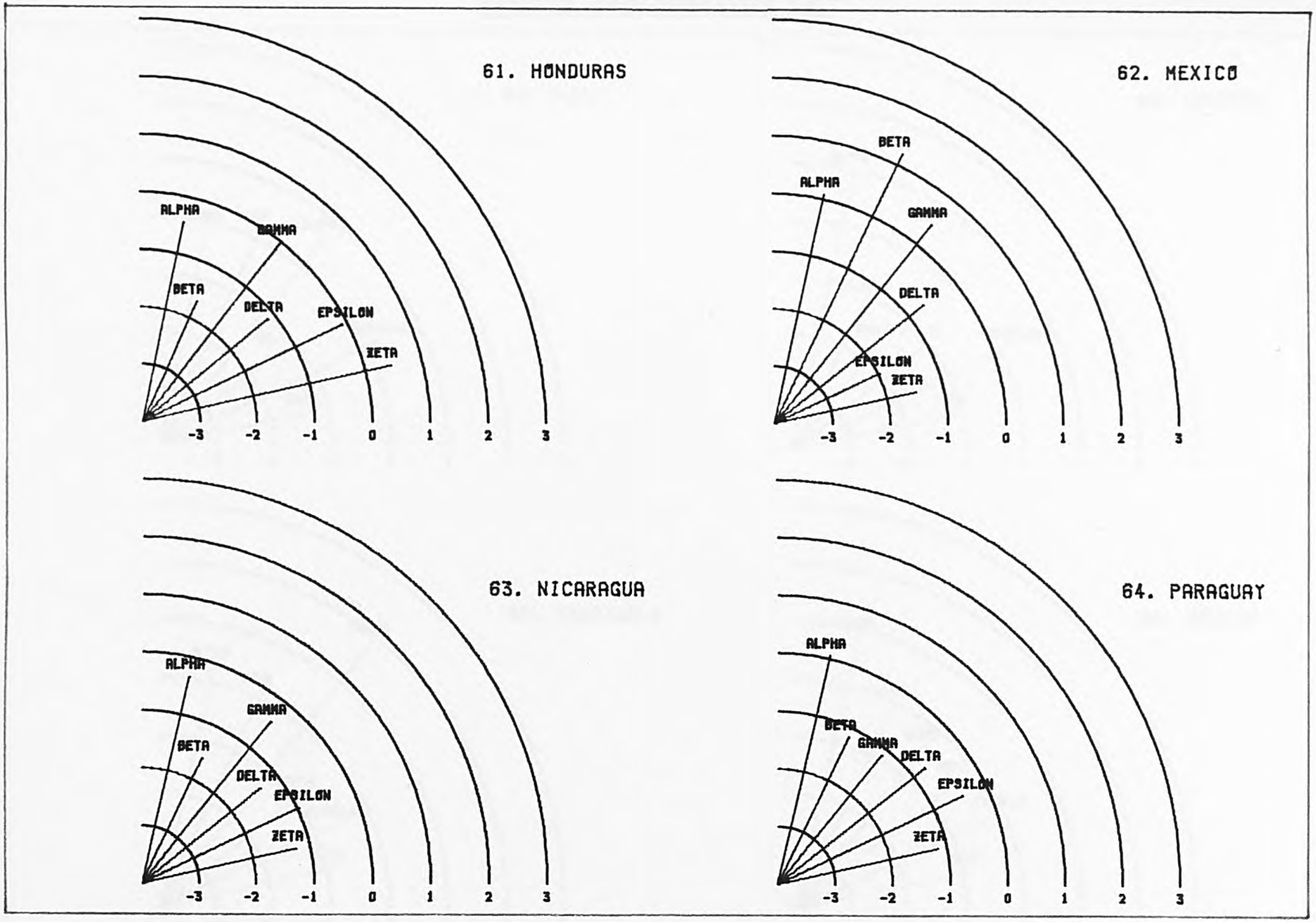
NATIONAL CHARACTERISTICS 1977

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GAMMA
DELTA
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62. MEXICO
BETA
ALPHA
GAMMA
DELTA
EPSILON
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63. NICARAGUA
ALPHA
GAMMA
BETA
DELTA
EPSILON
ZETA
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64. PARAGUAY
ALPHA
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EPSILON
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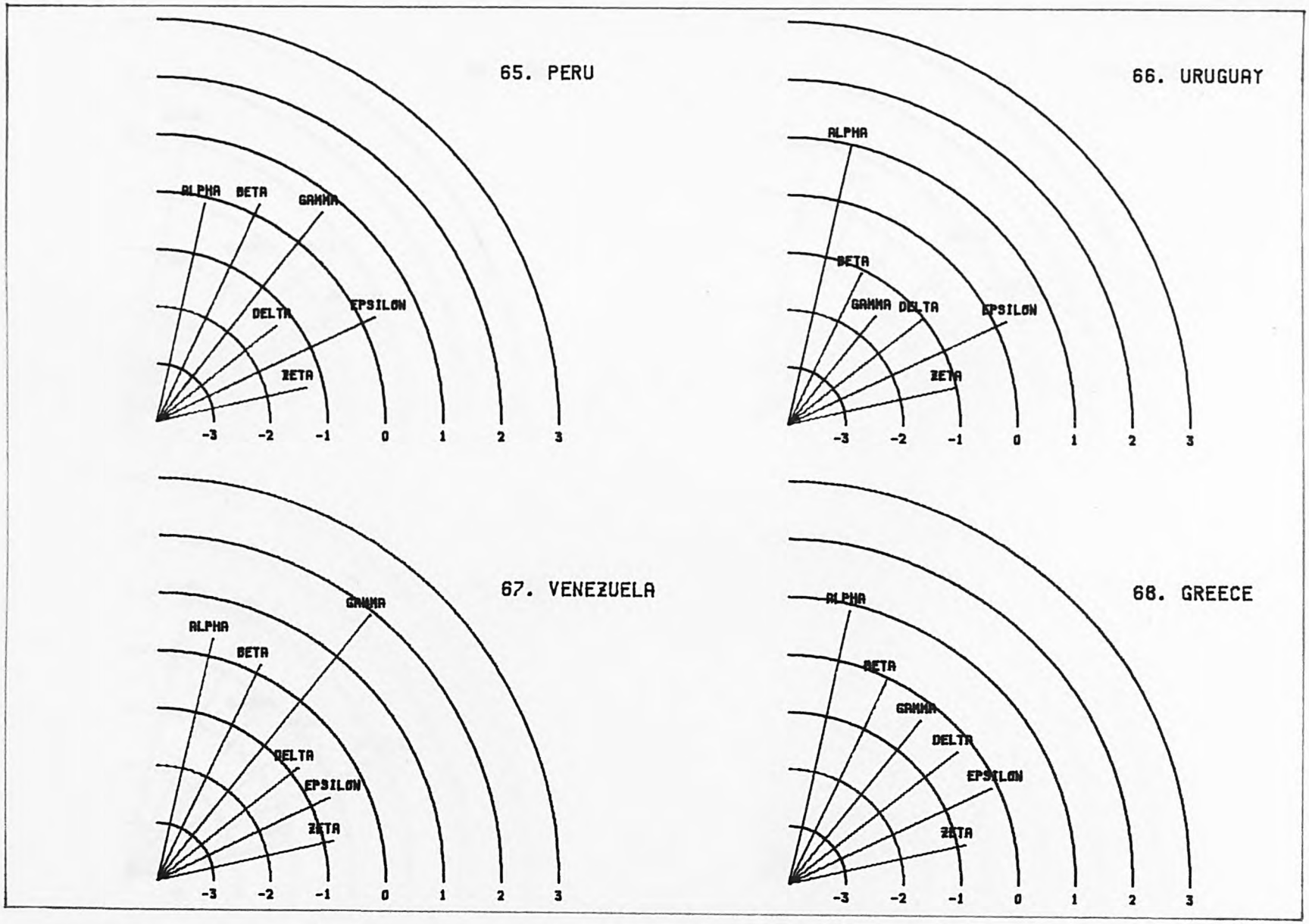
NATIONAL CHARACTERISTICS 1977



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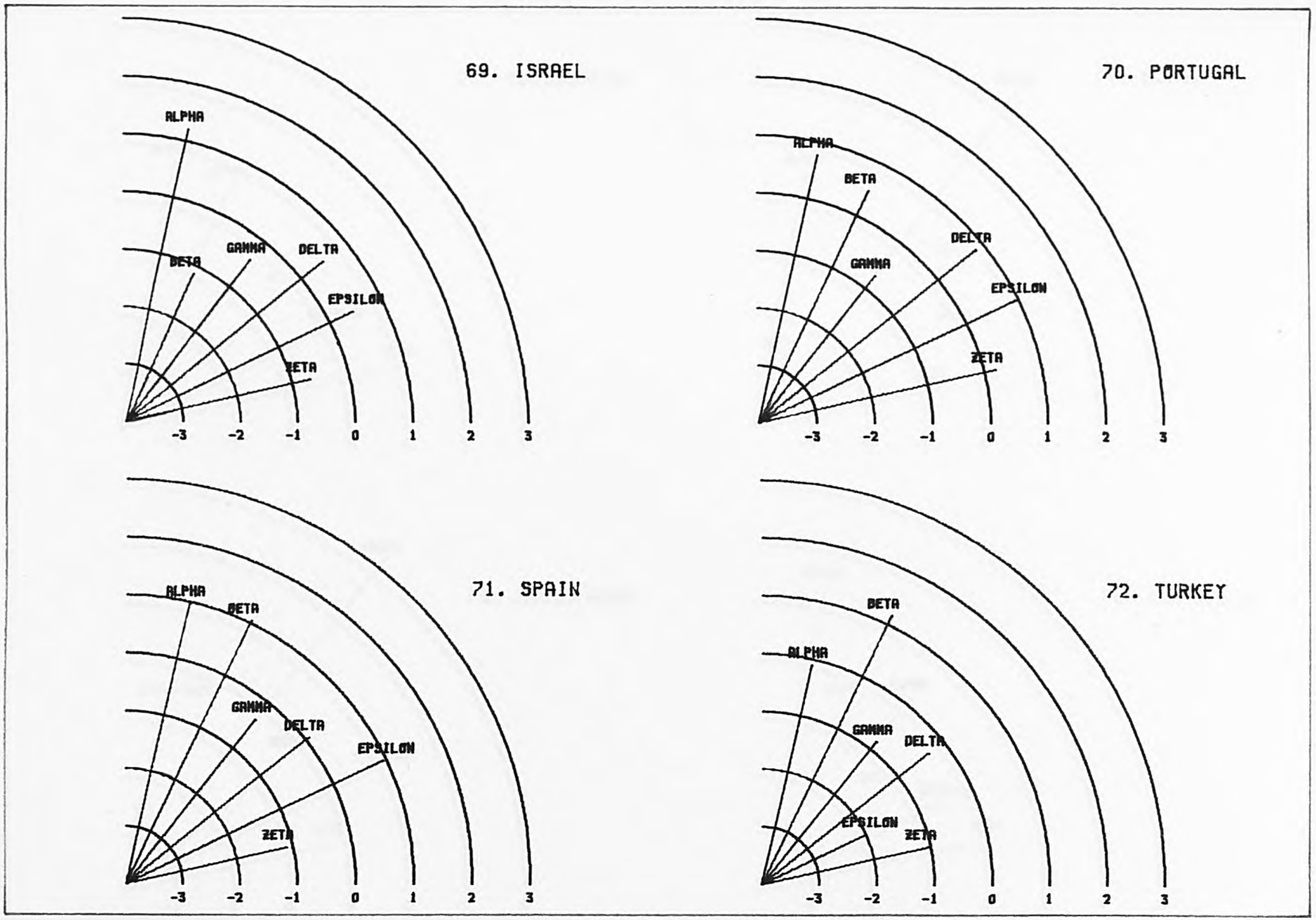

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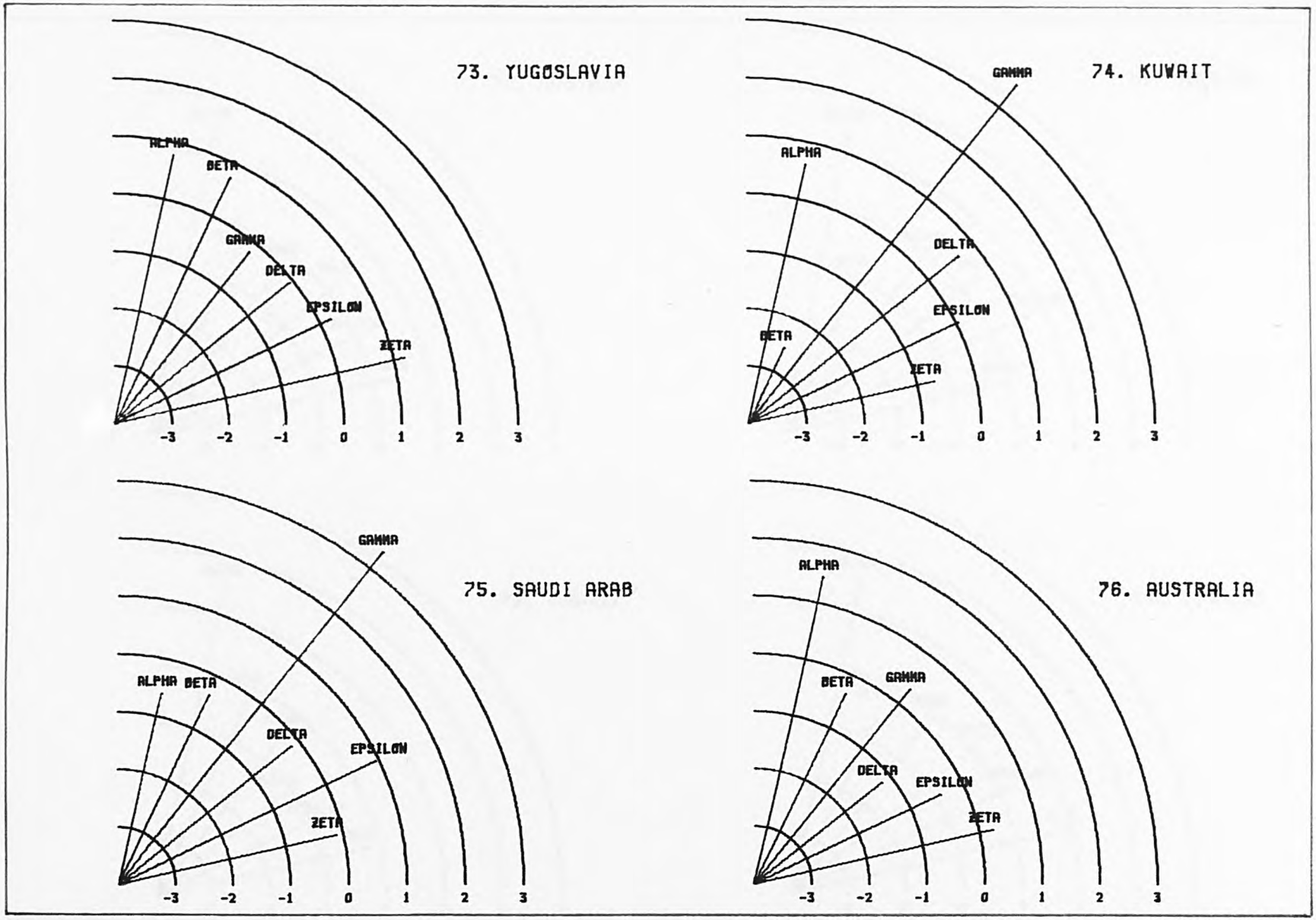

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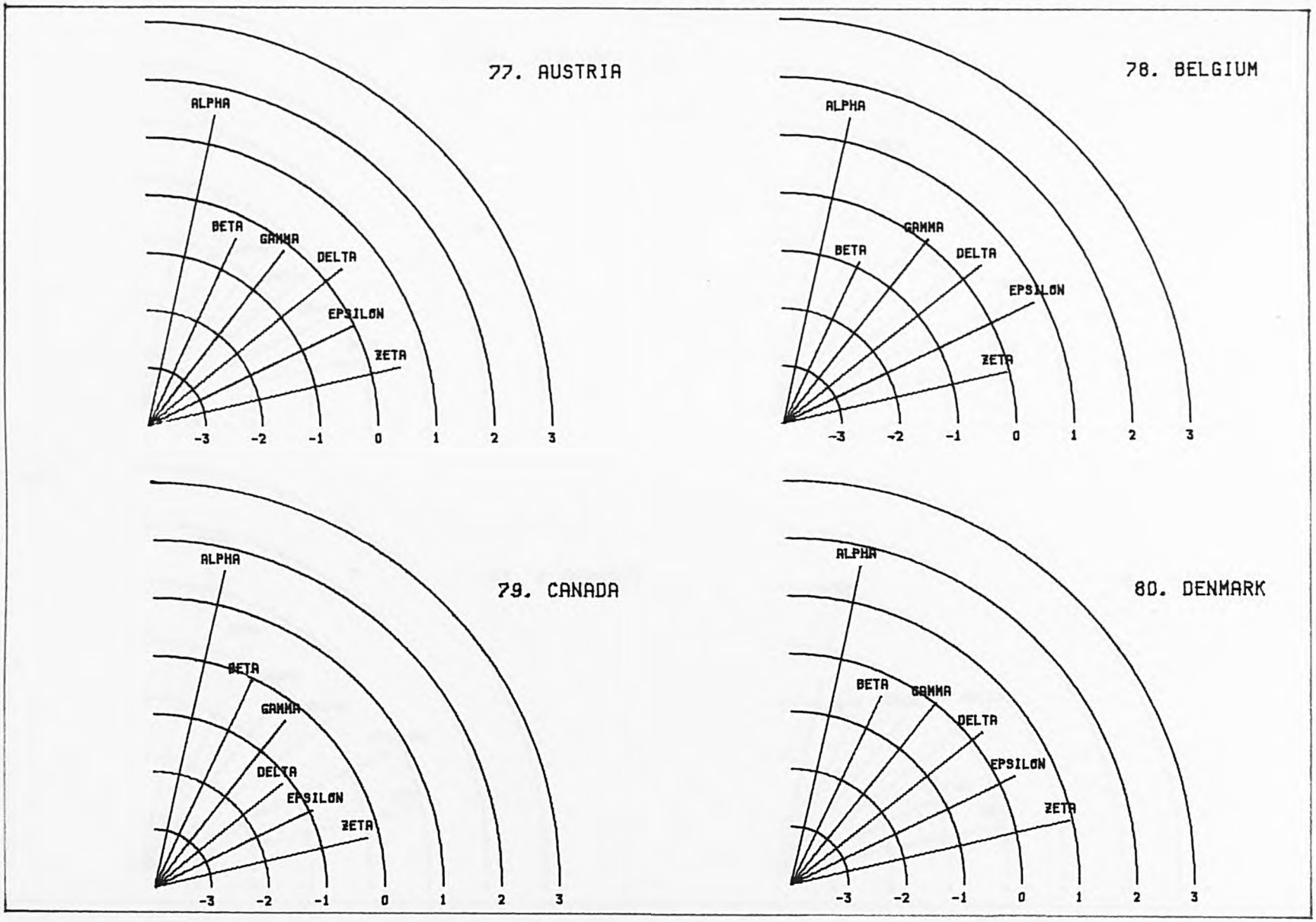

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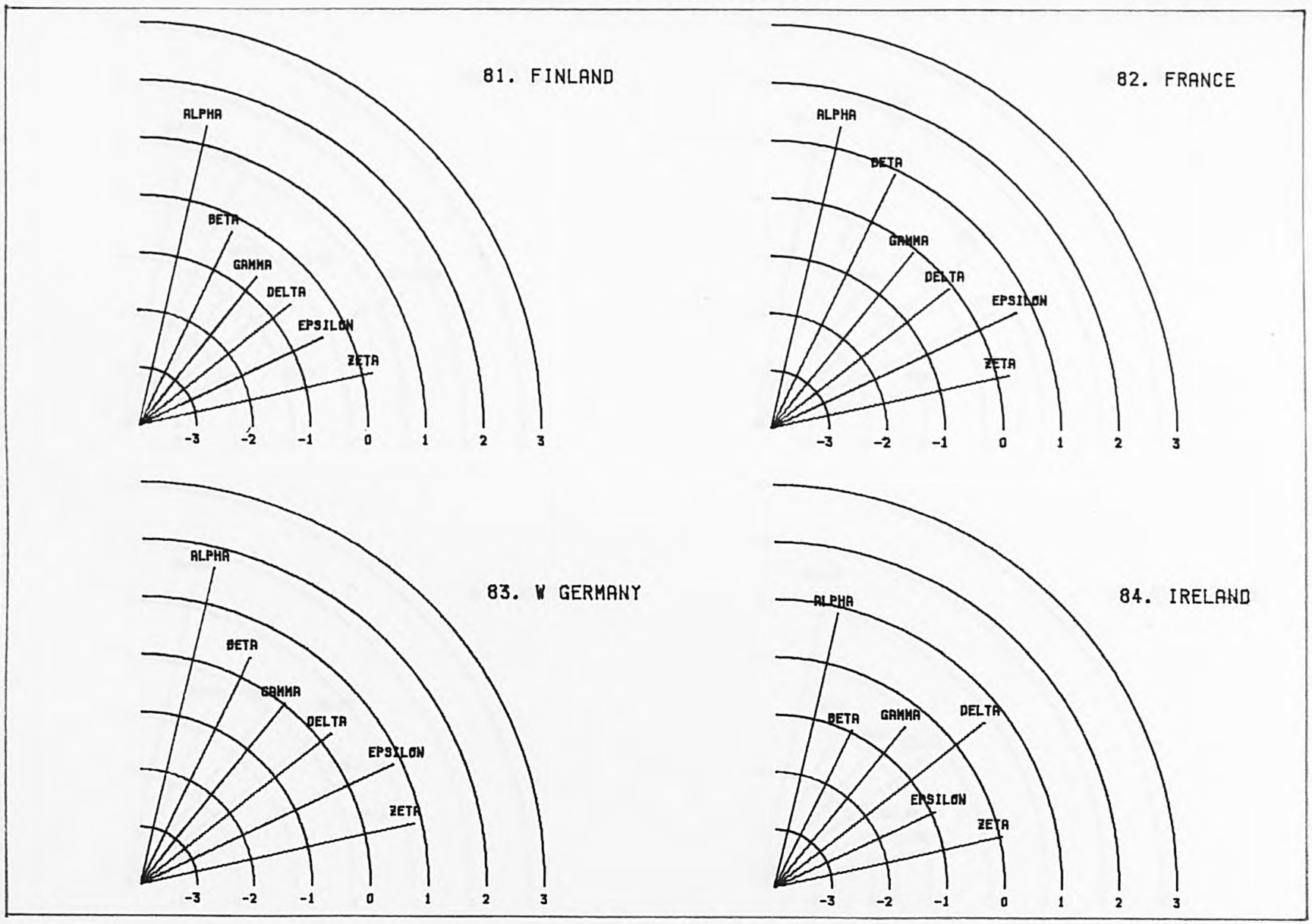

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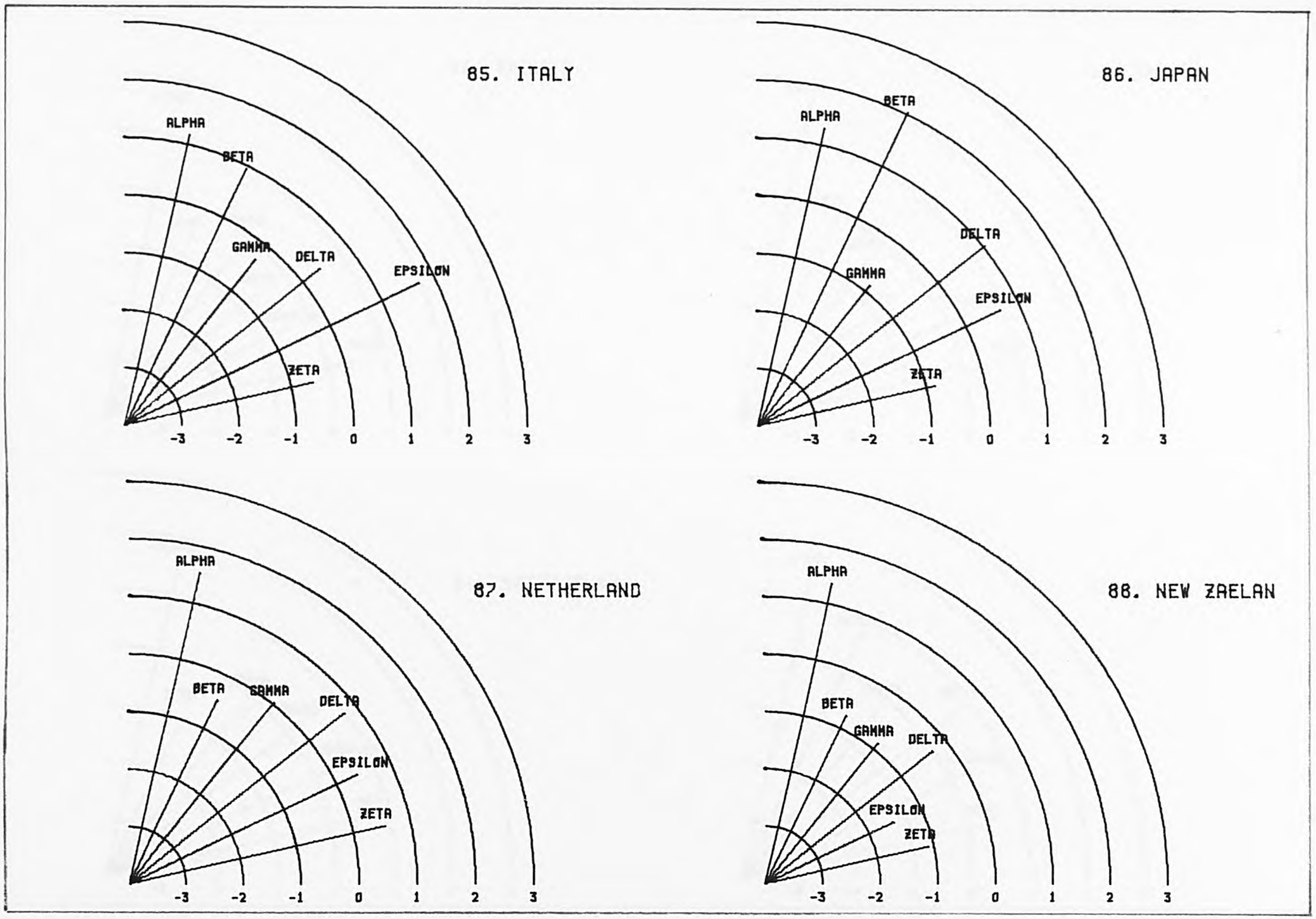

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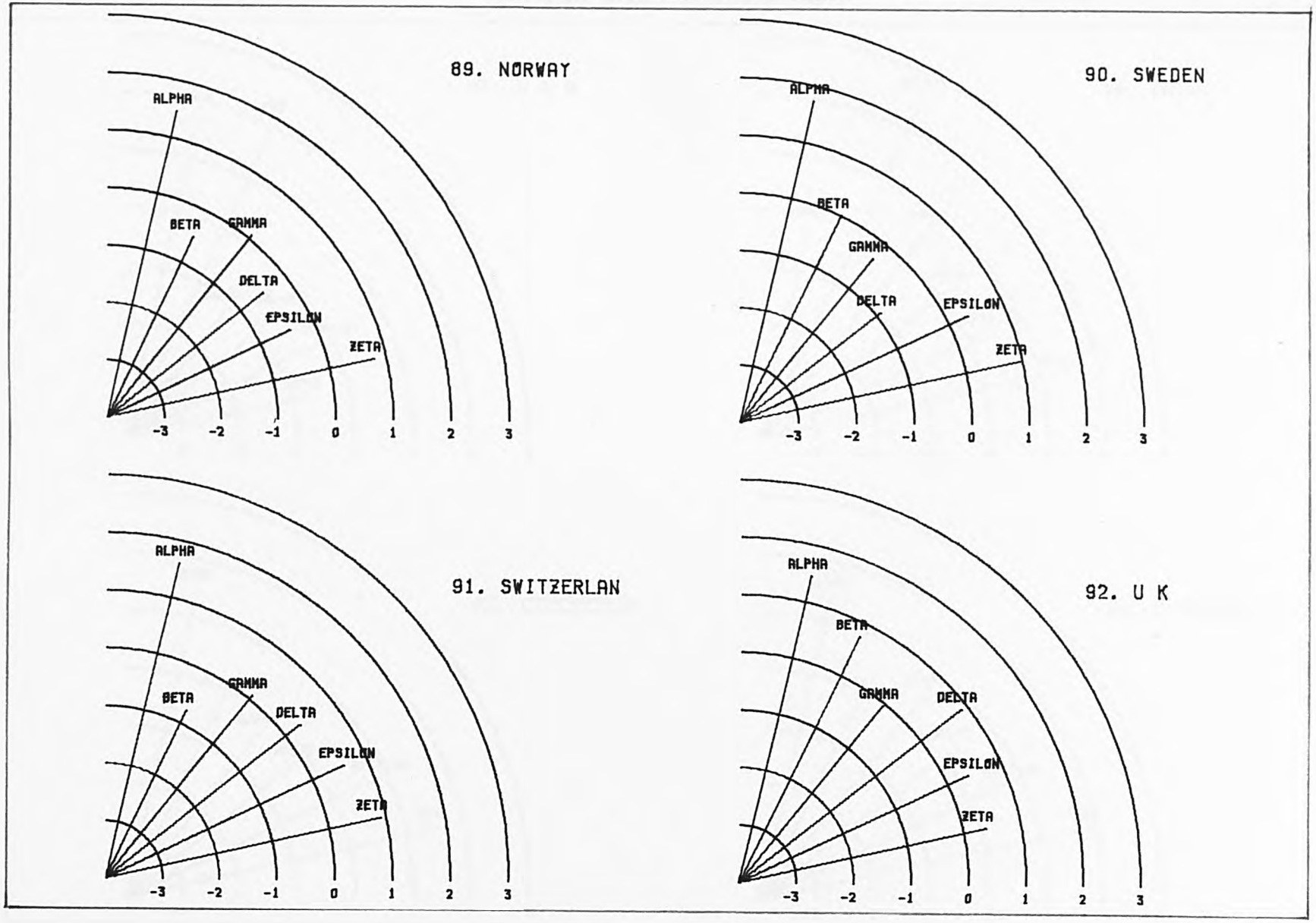

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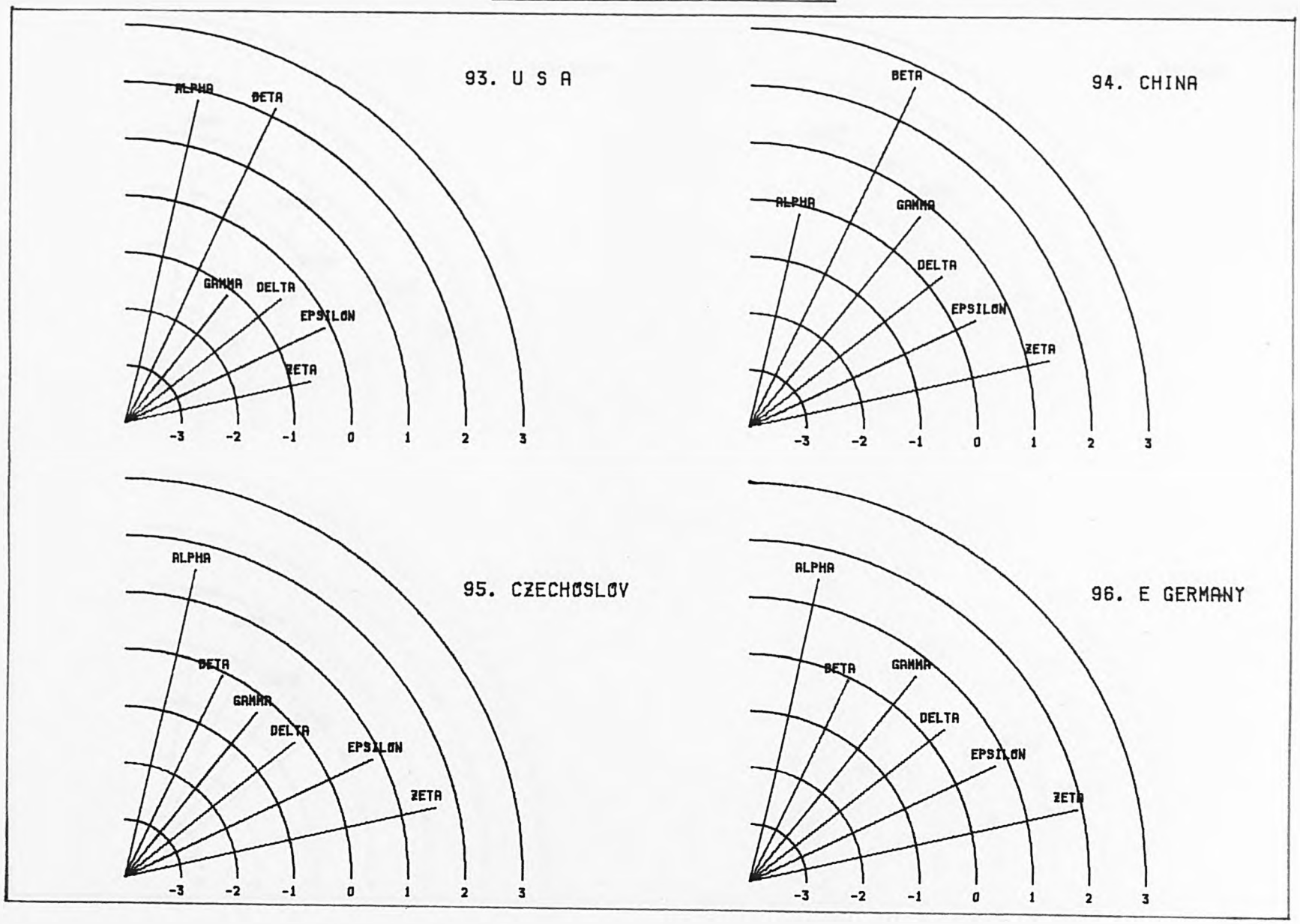

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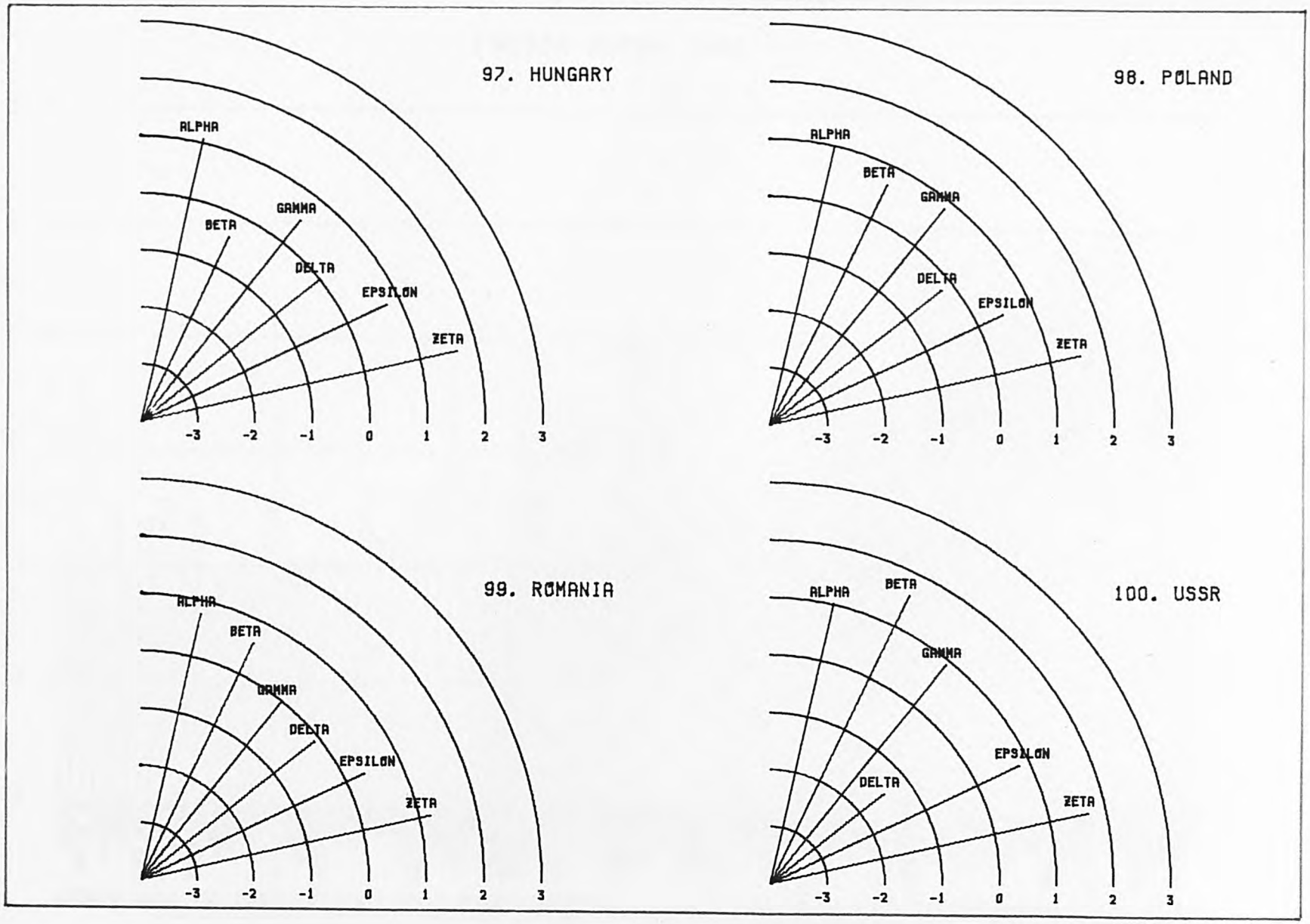

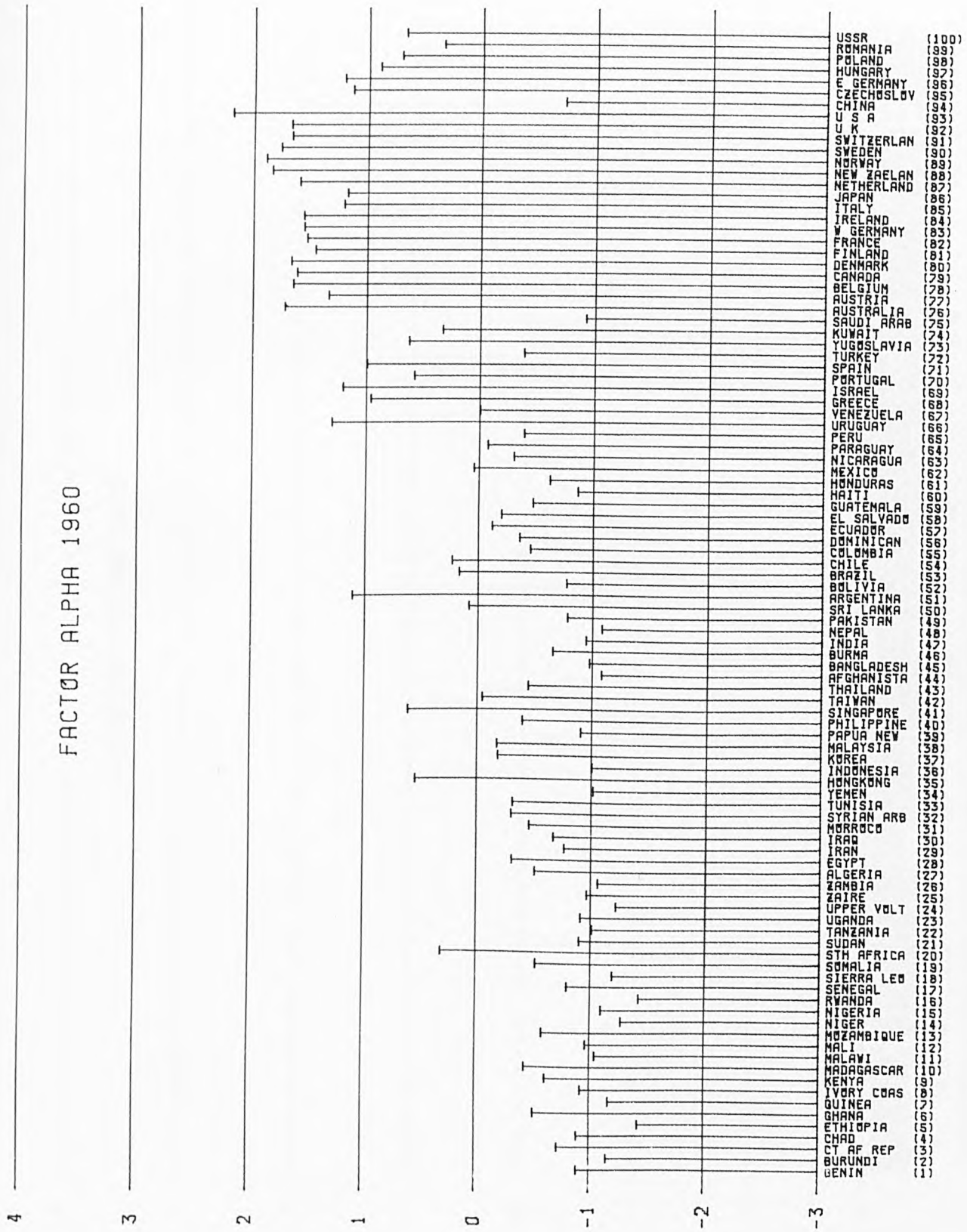
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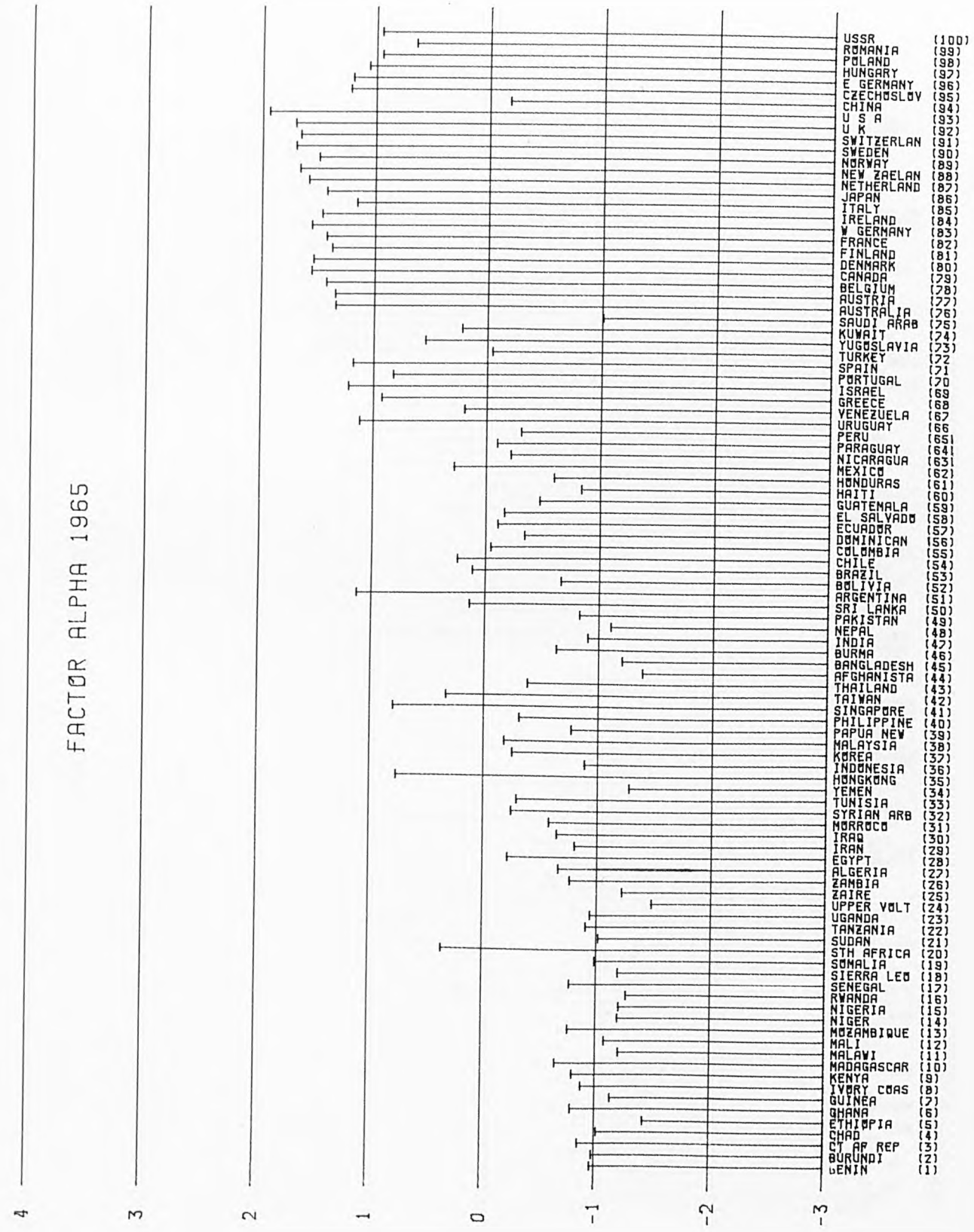
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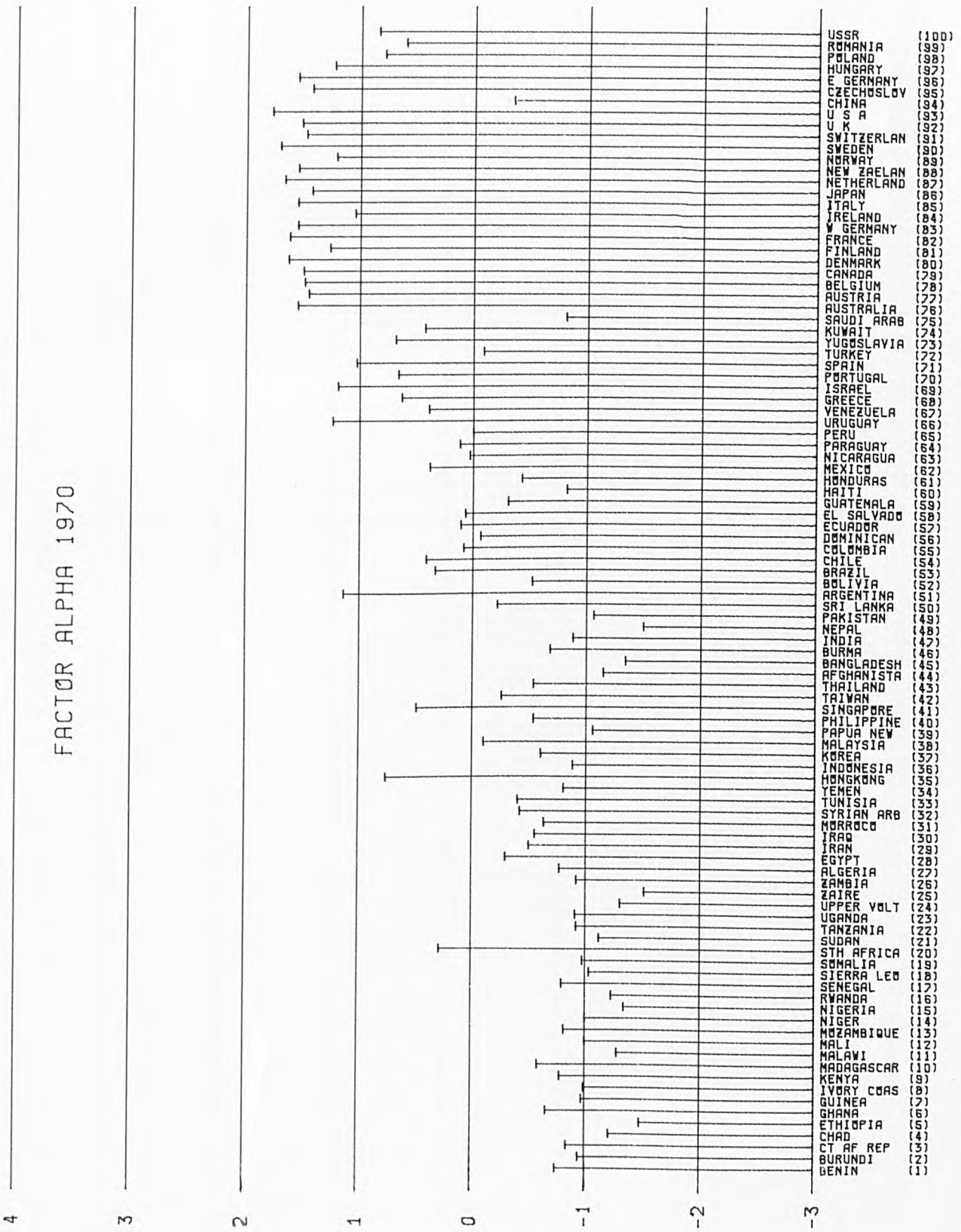
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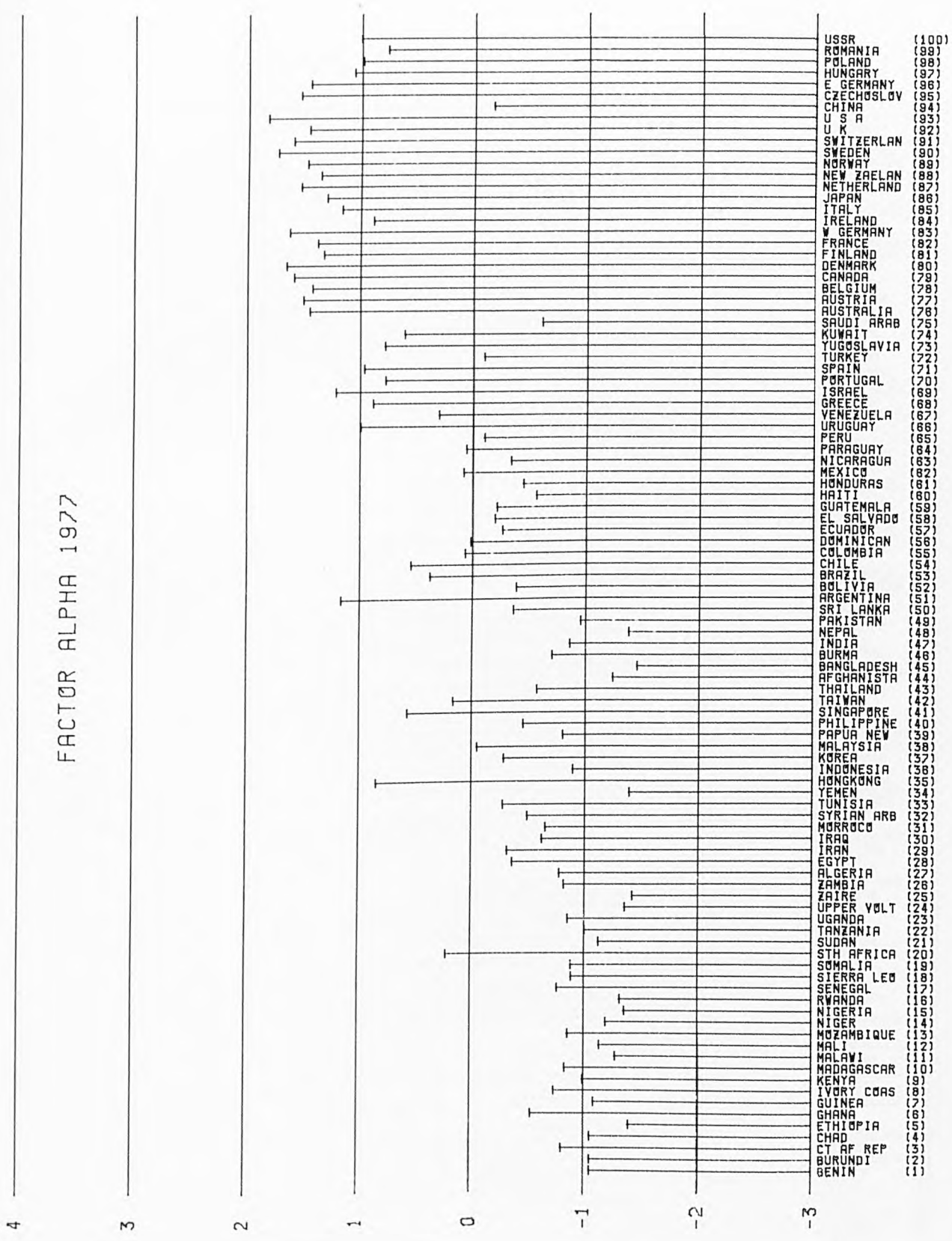
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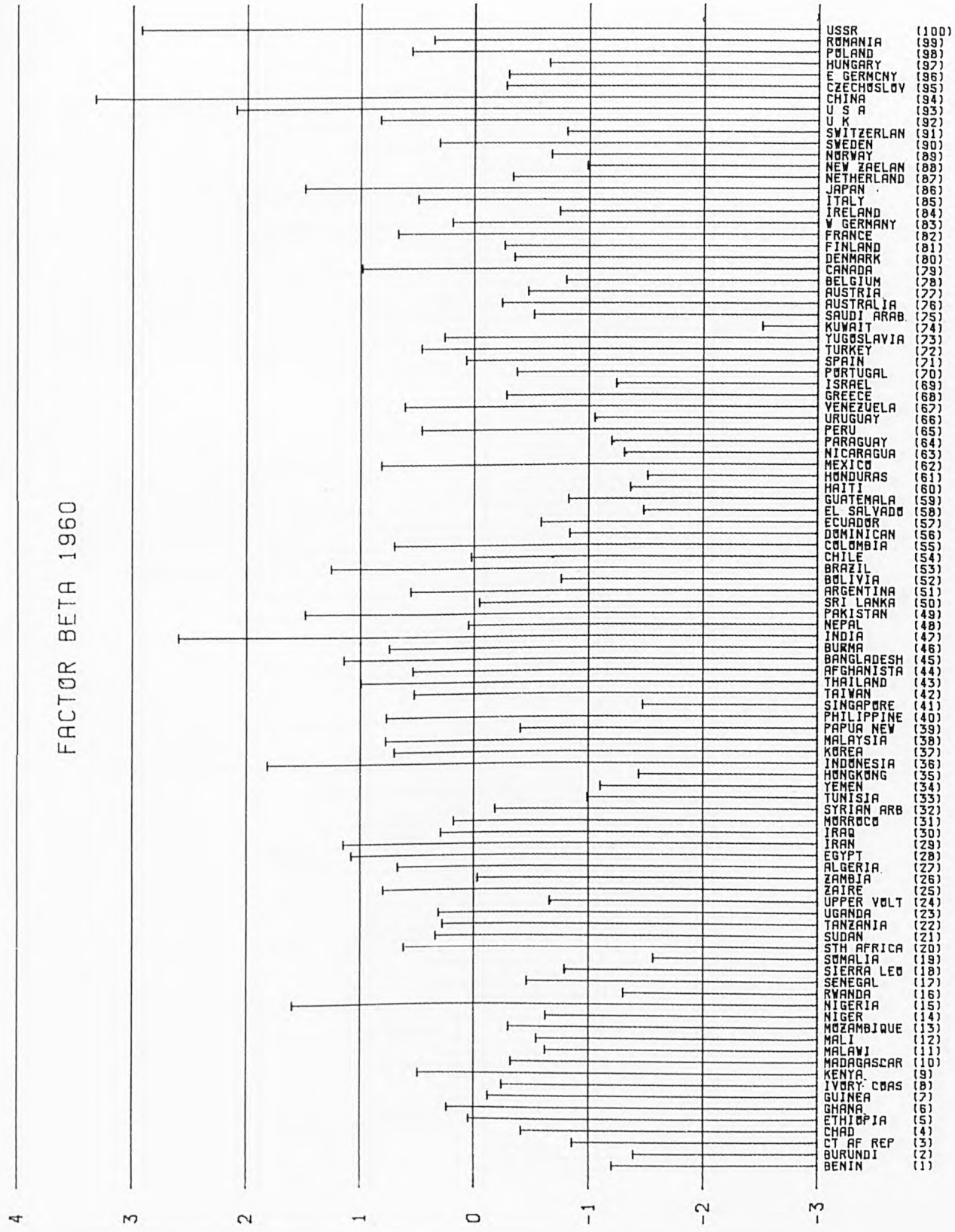
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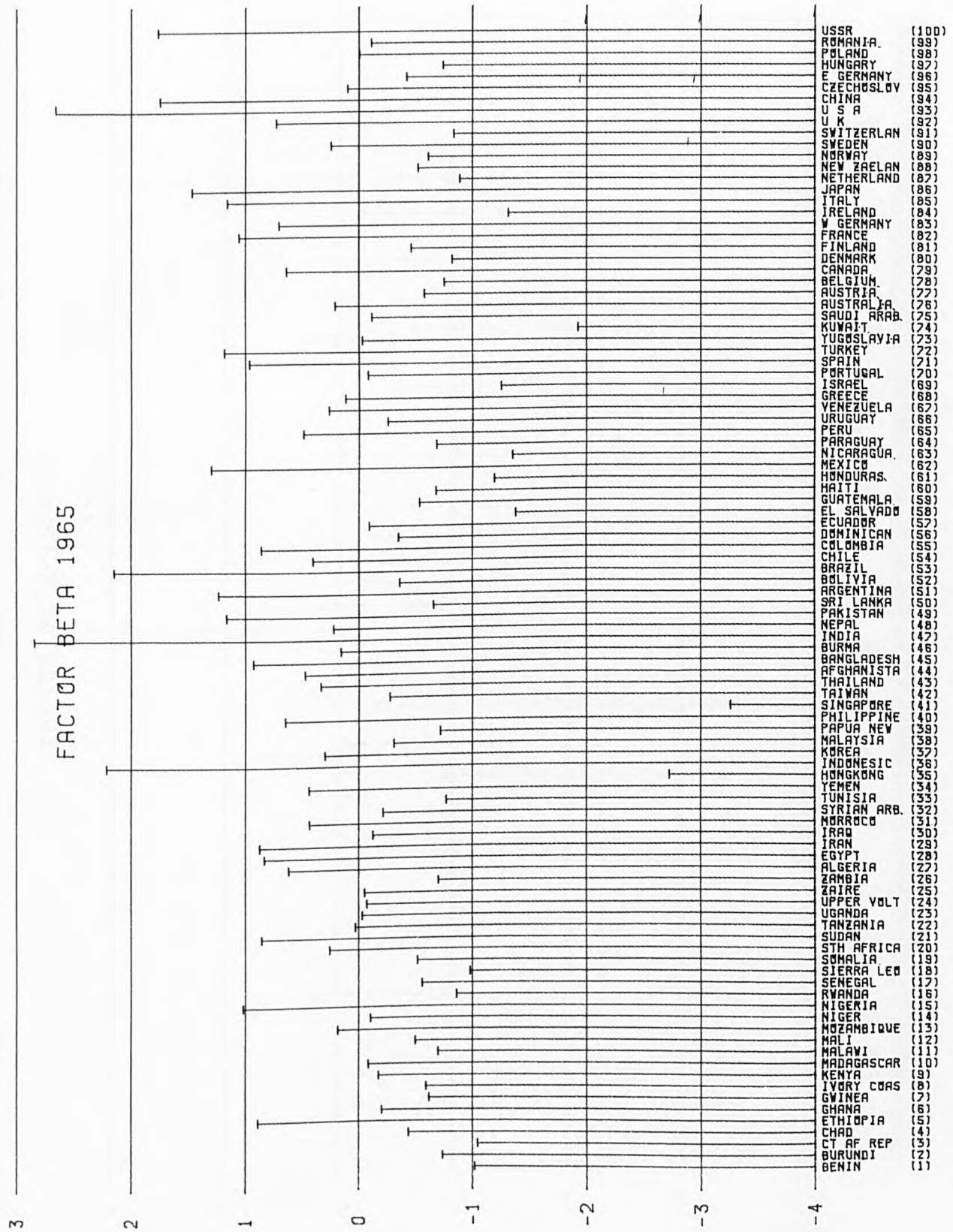
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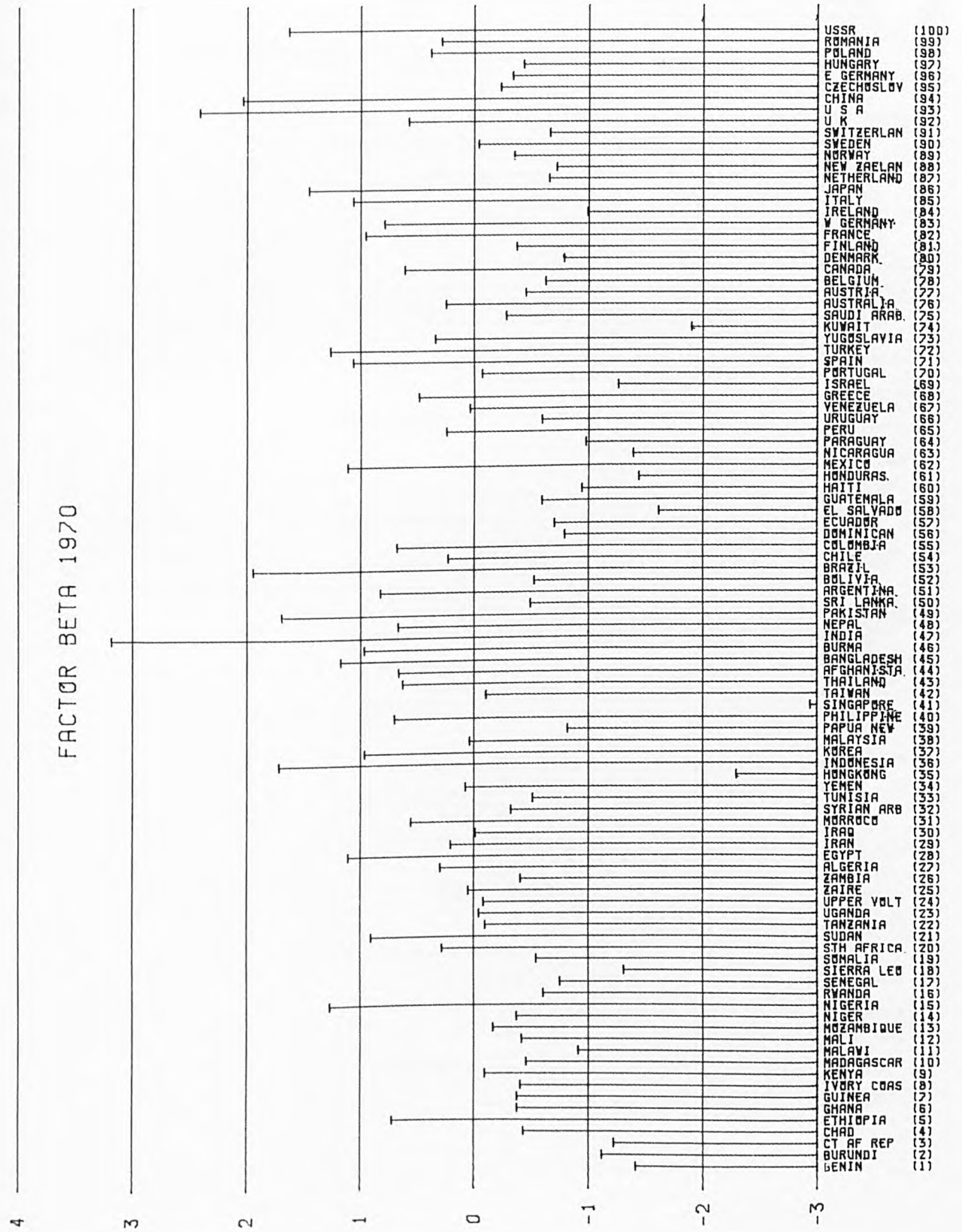
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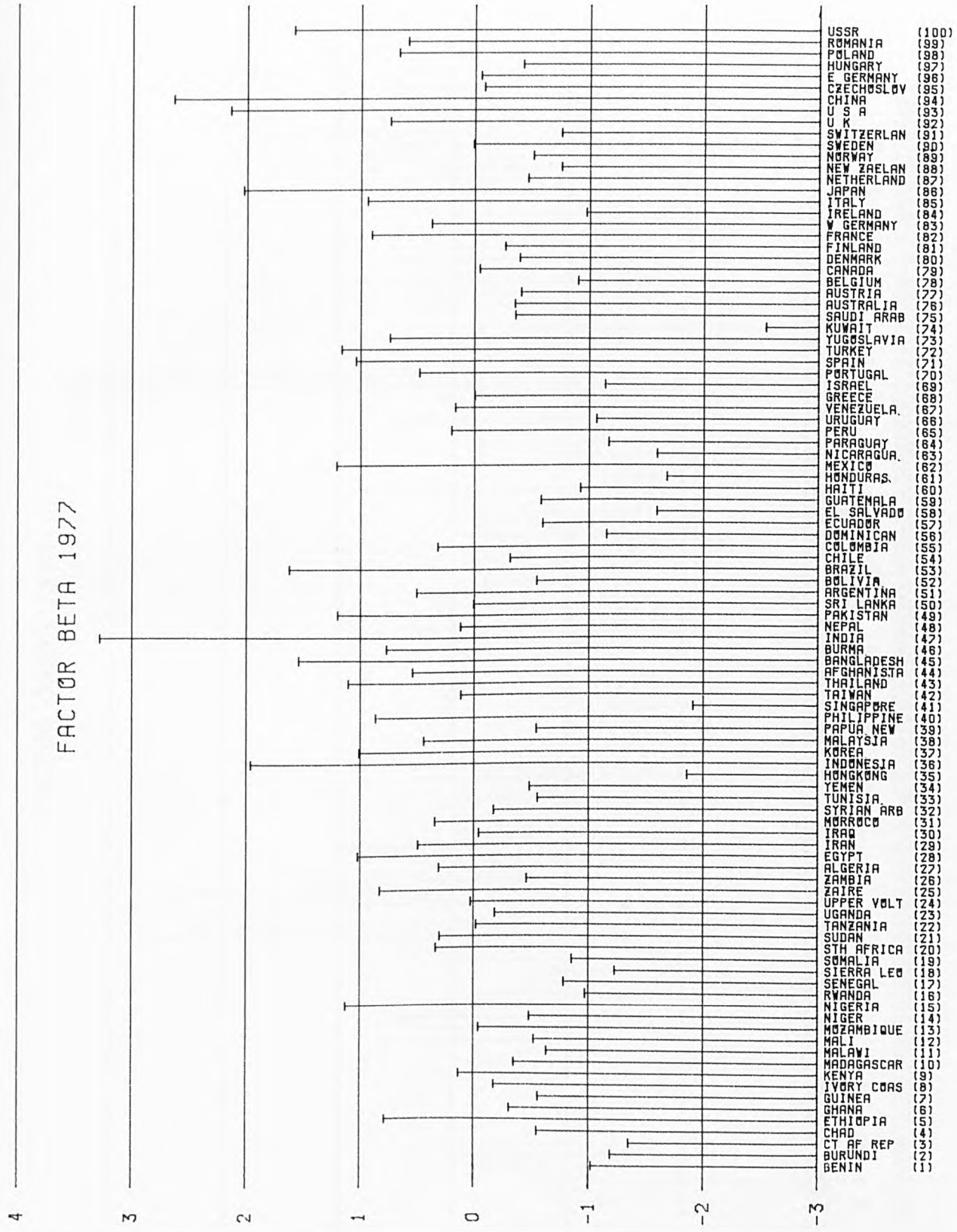
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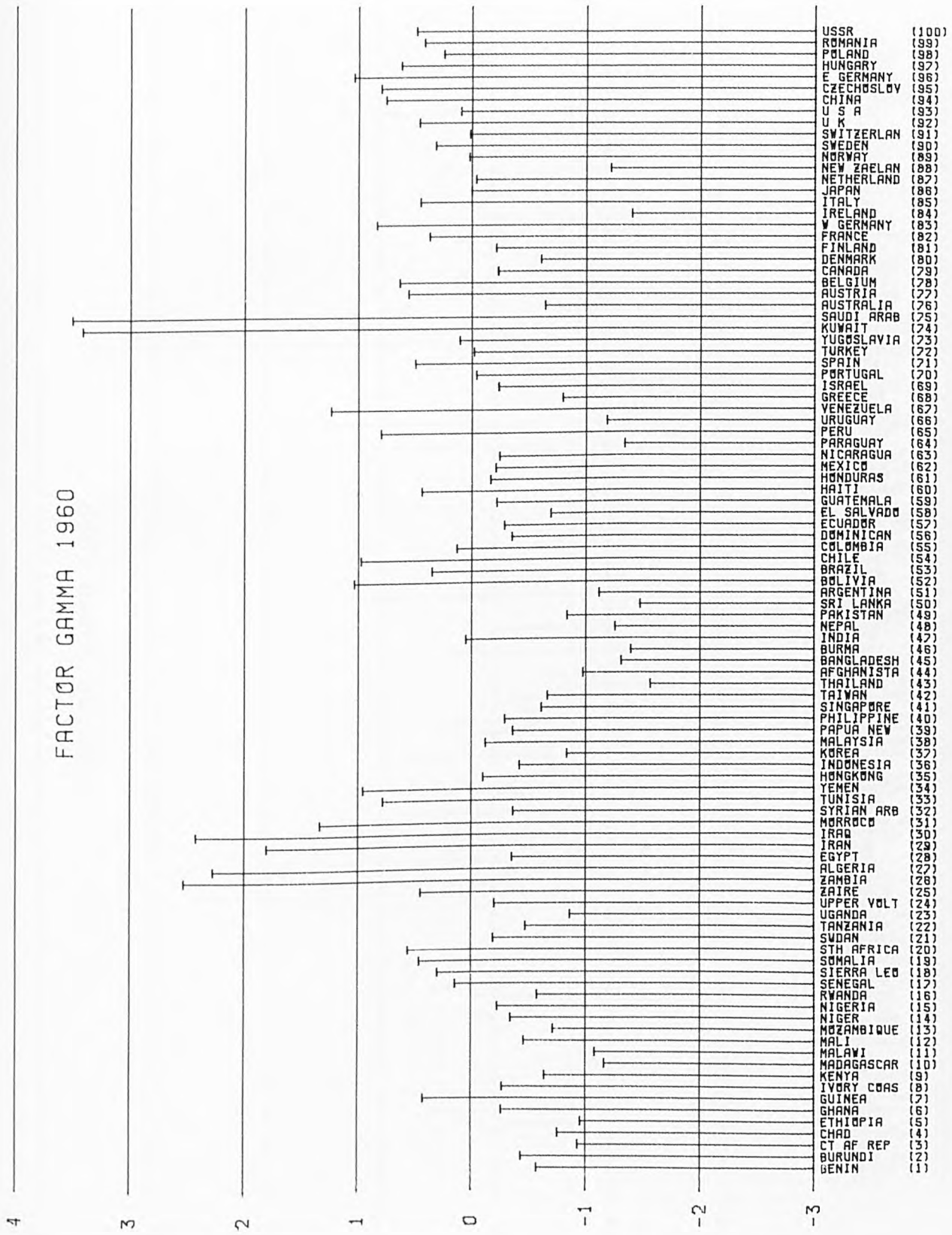
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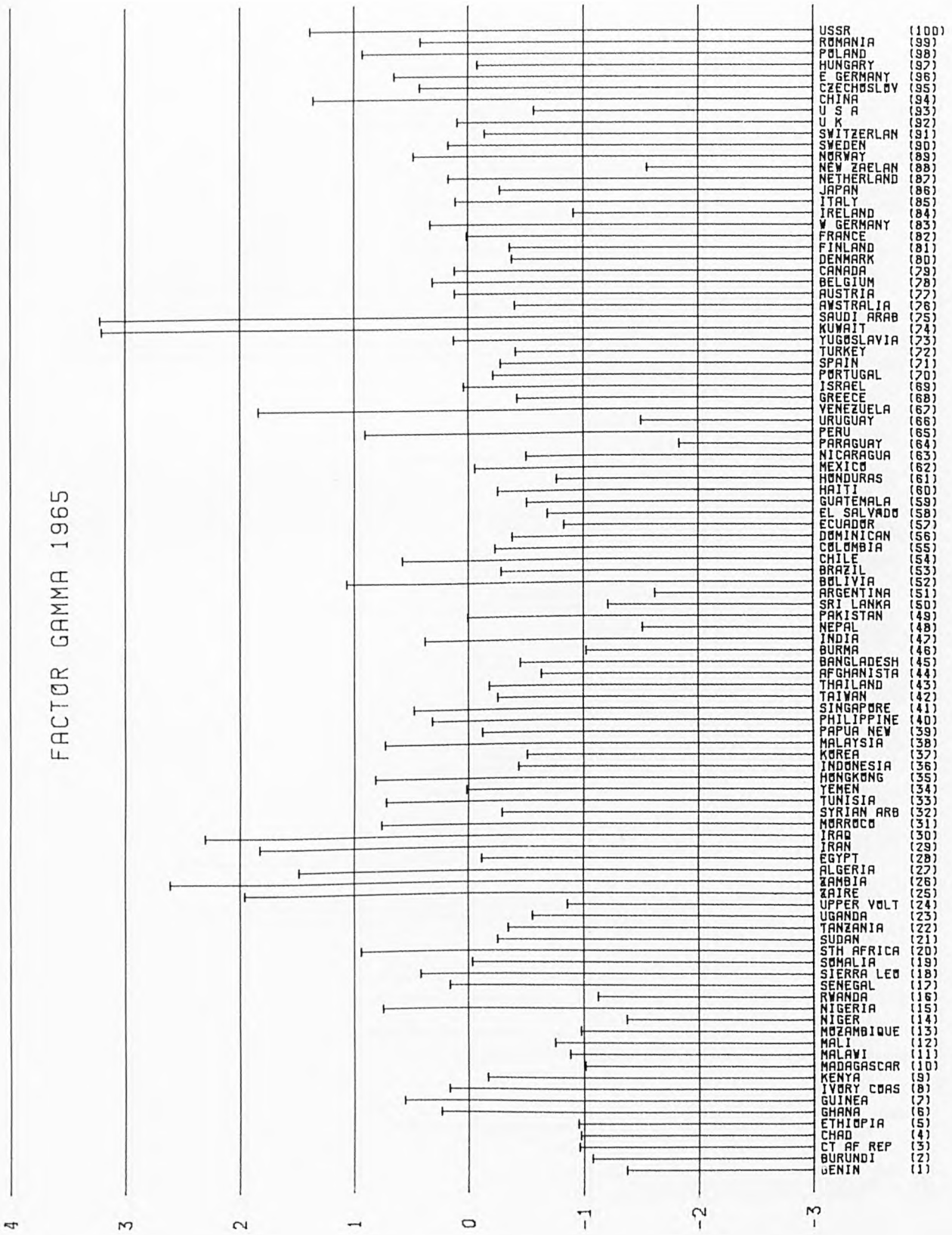
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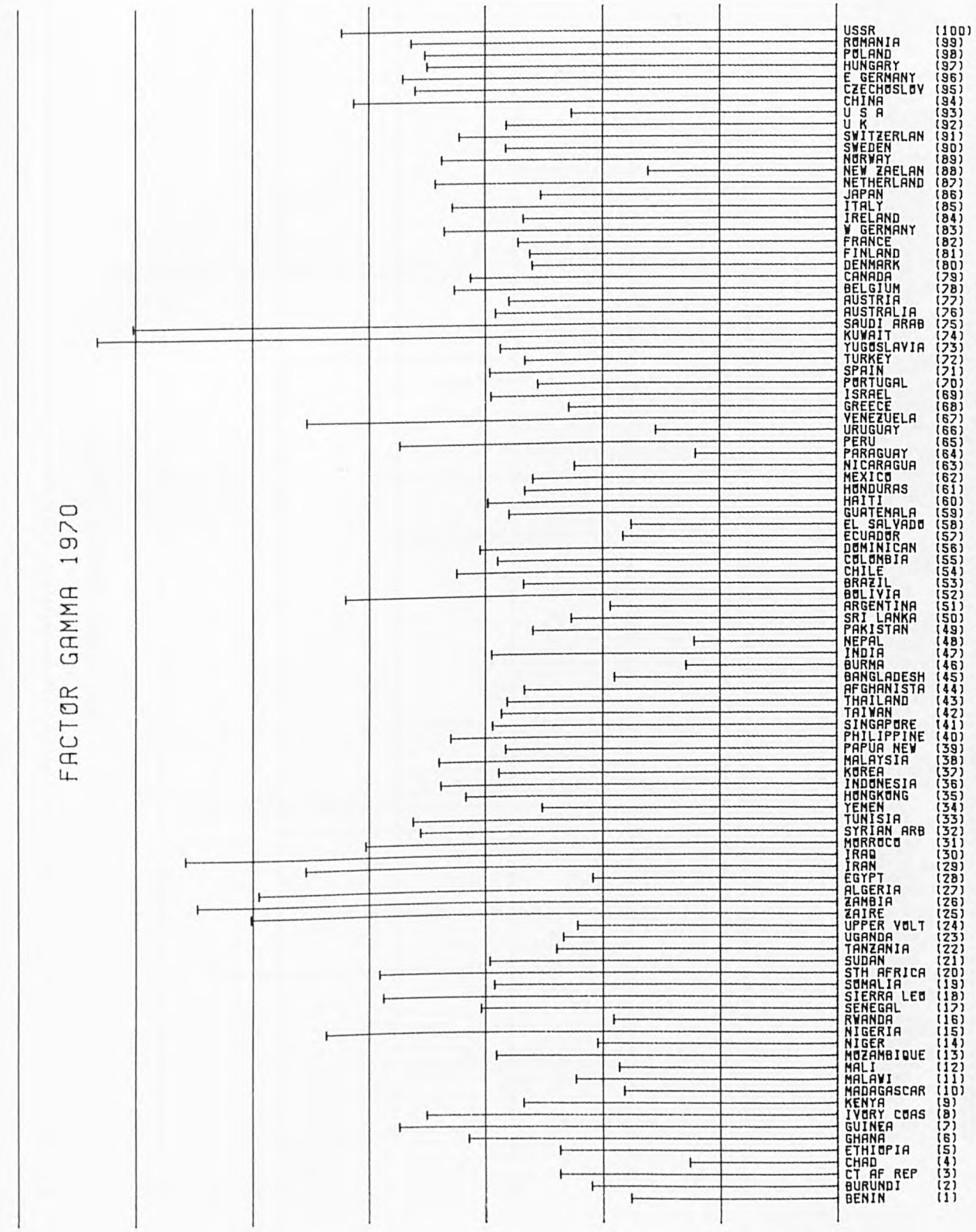
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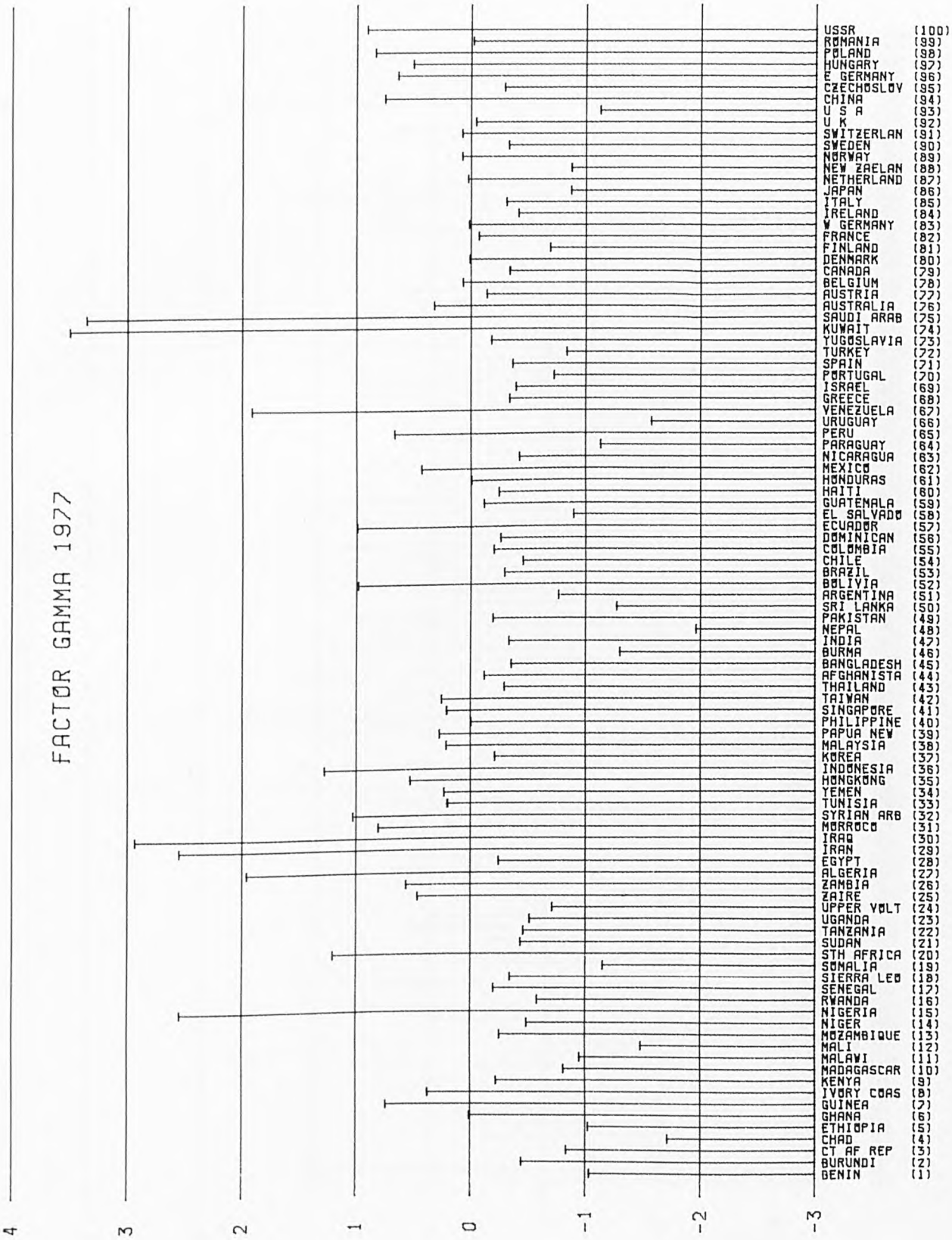
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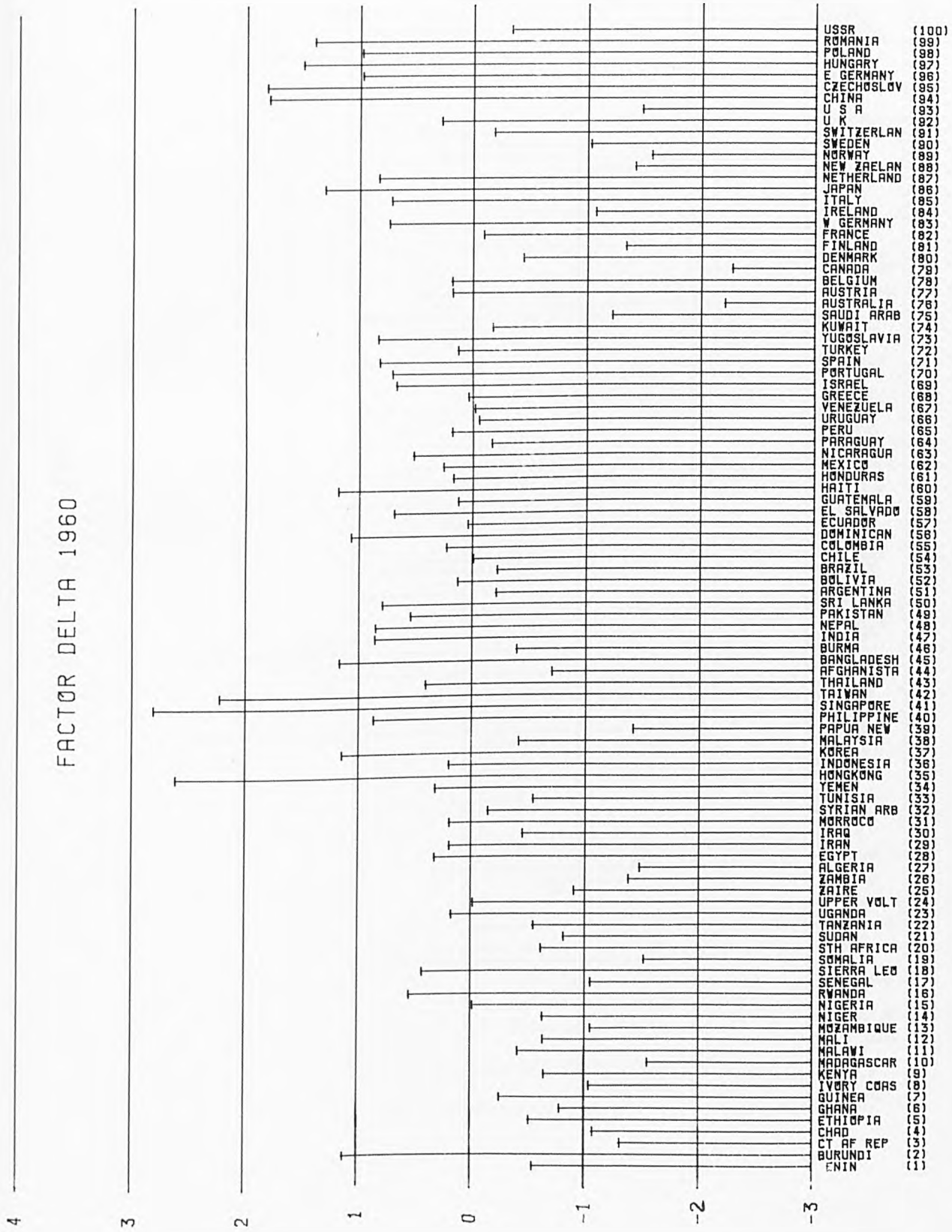
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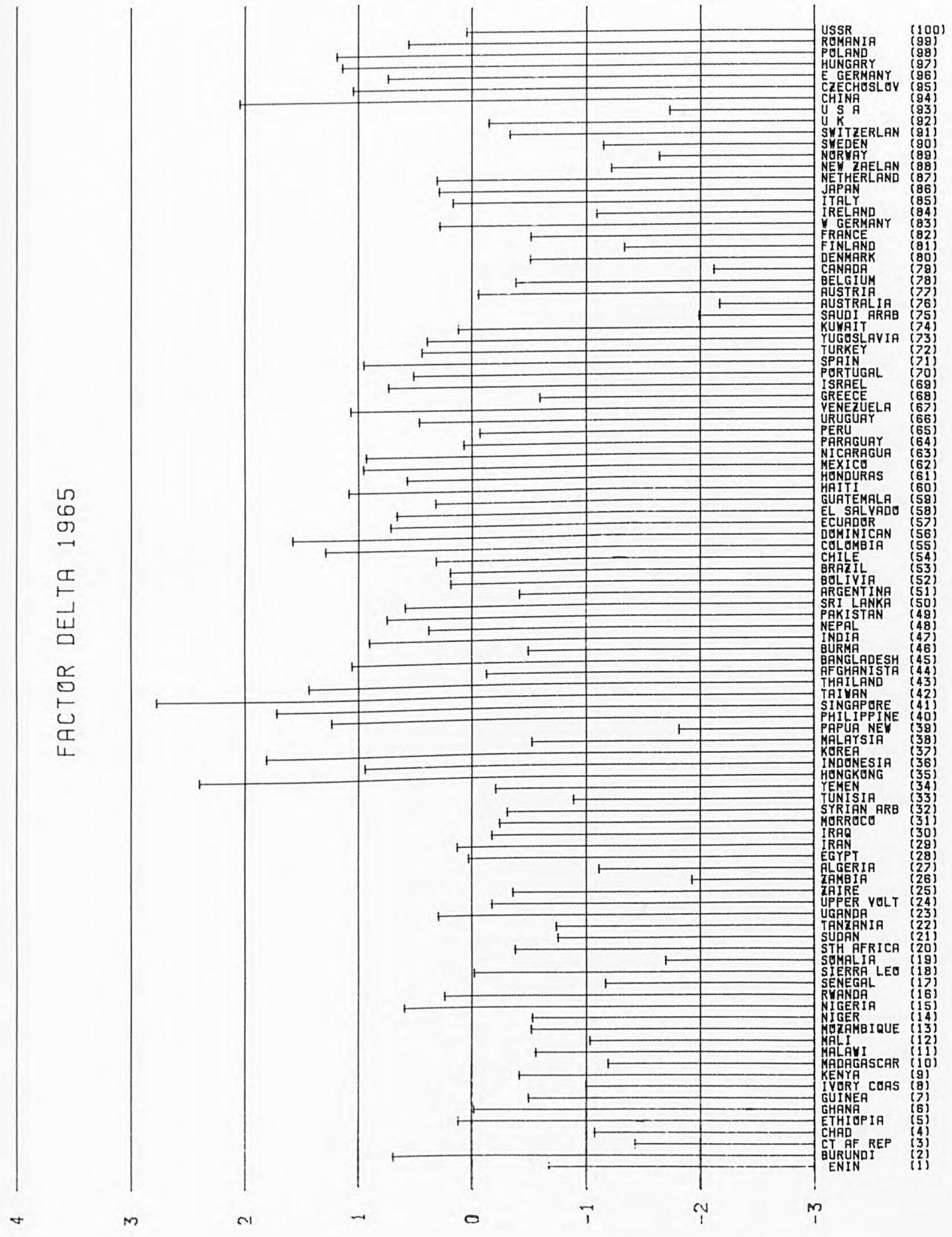
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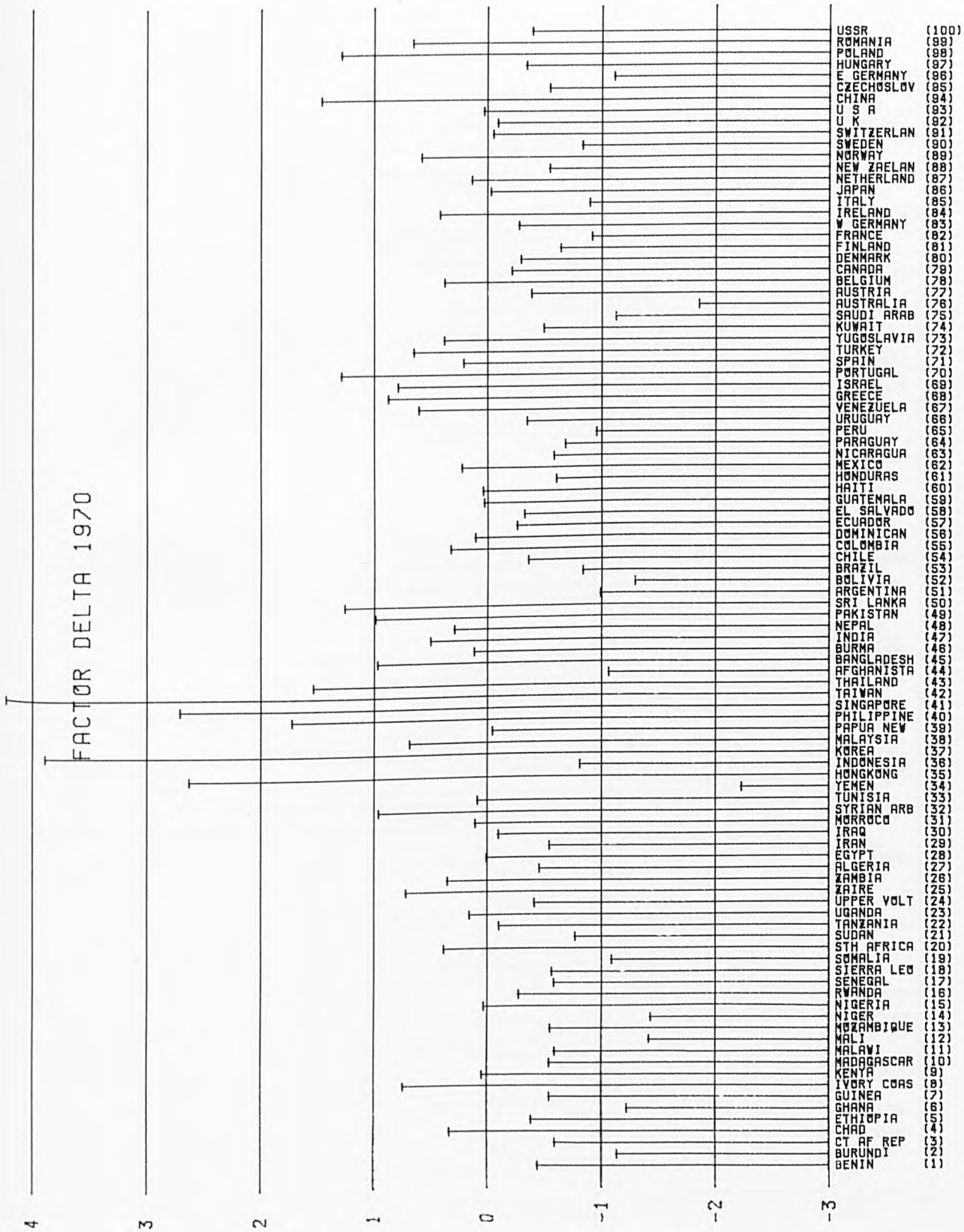
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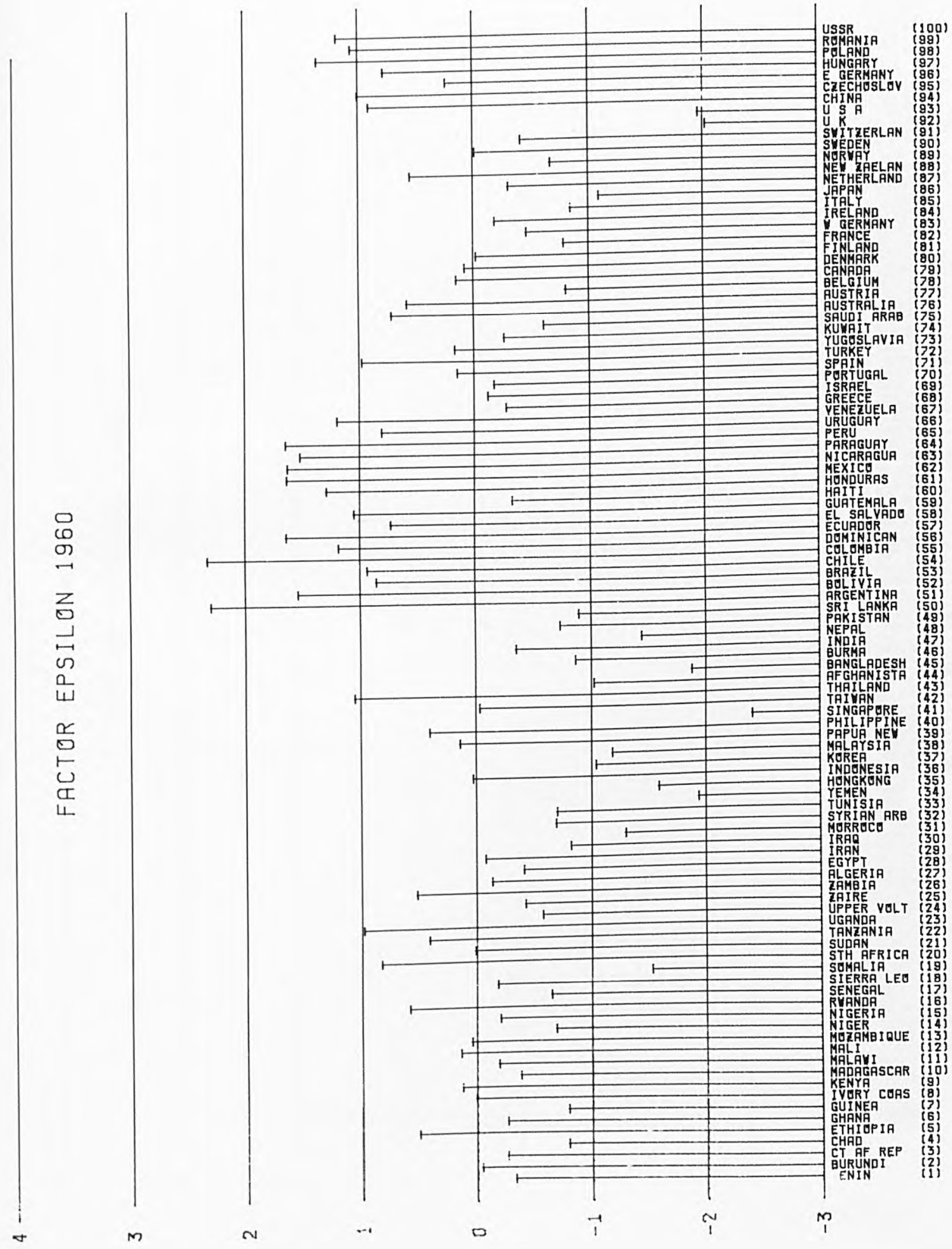
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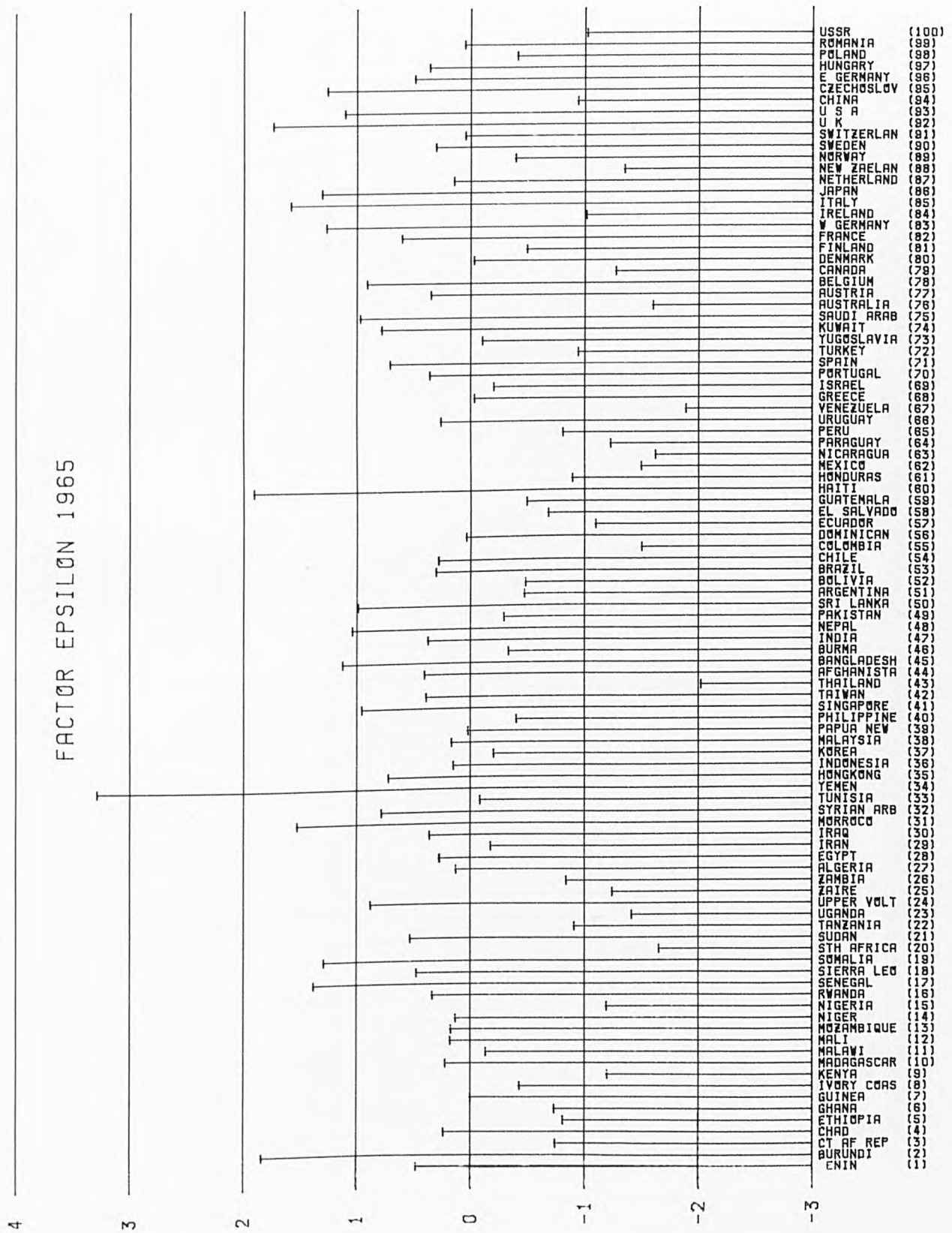
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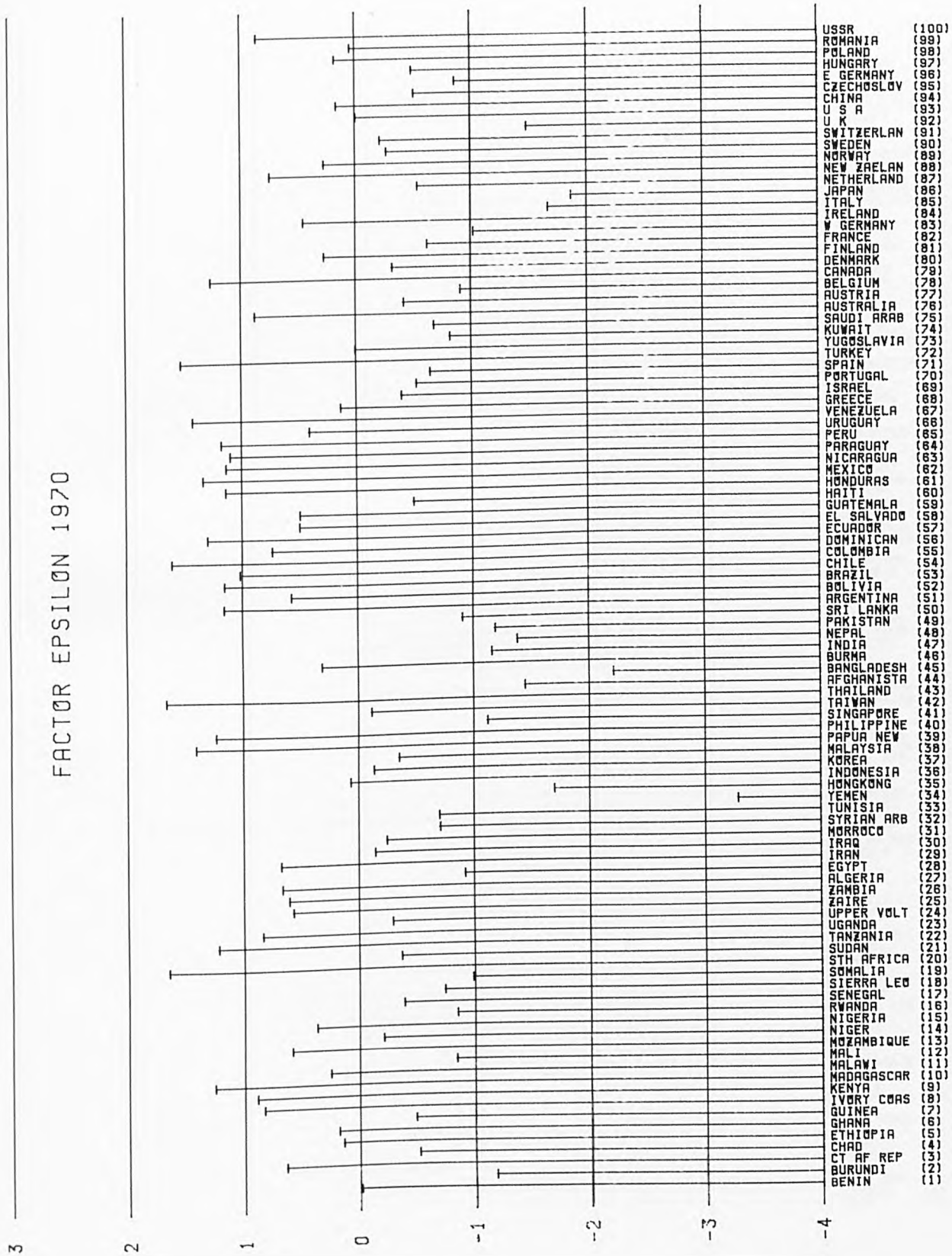
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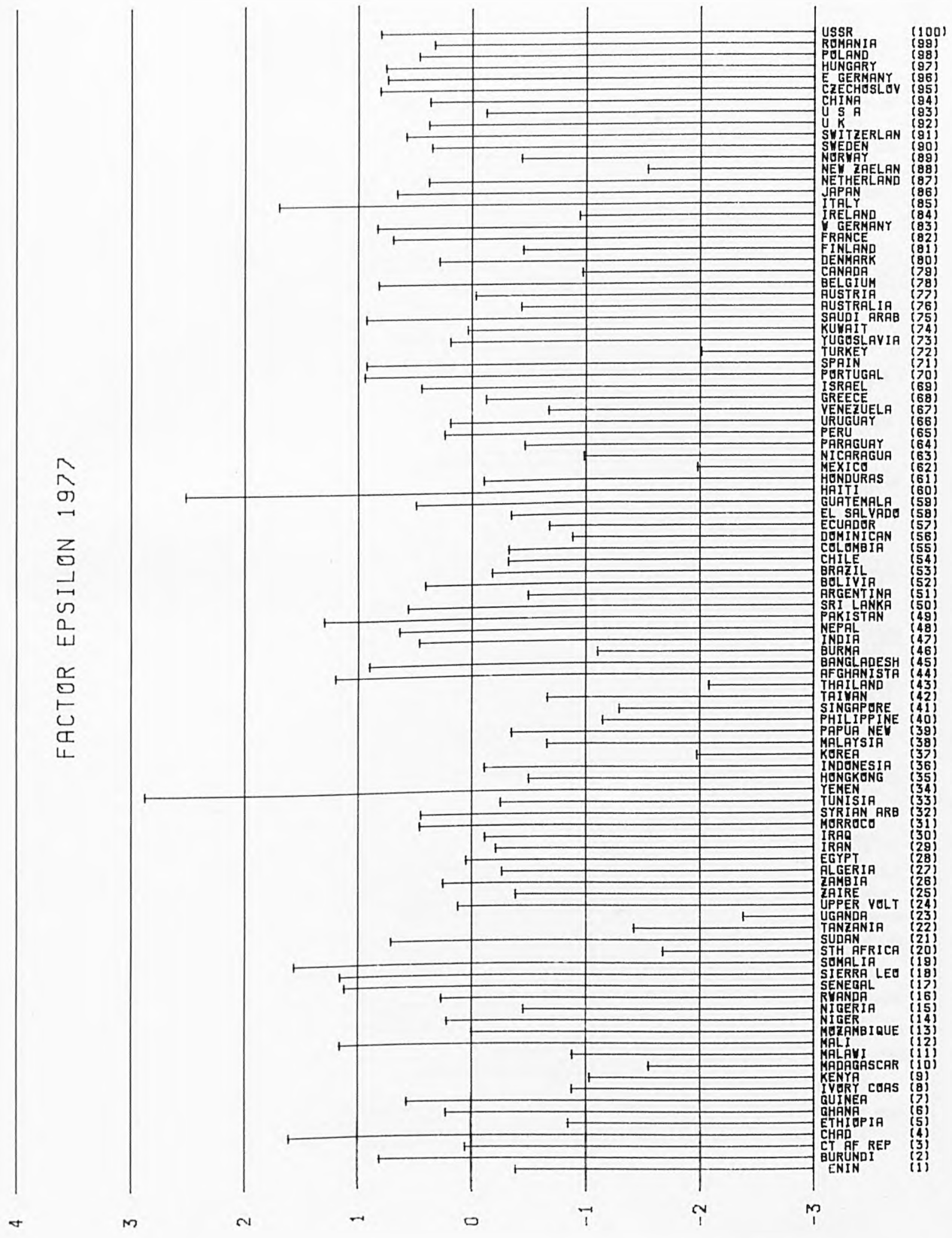
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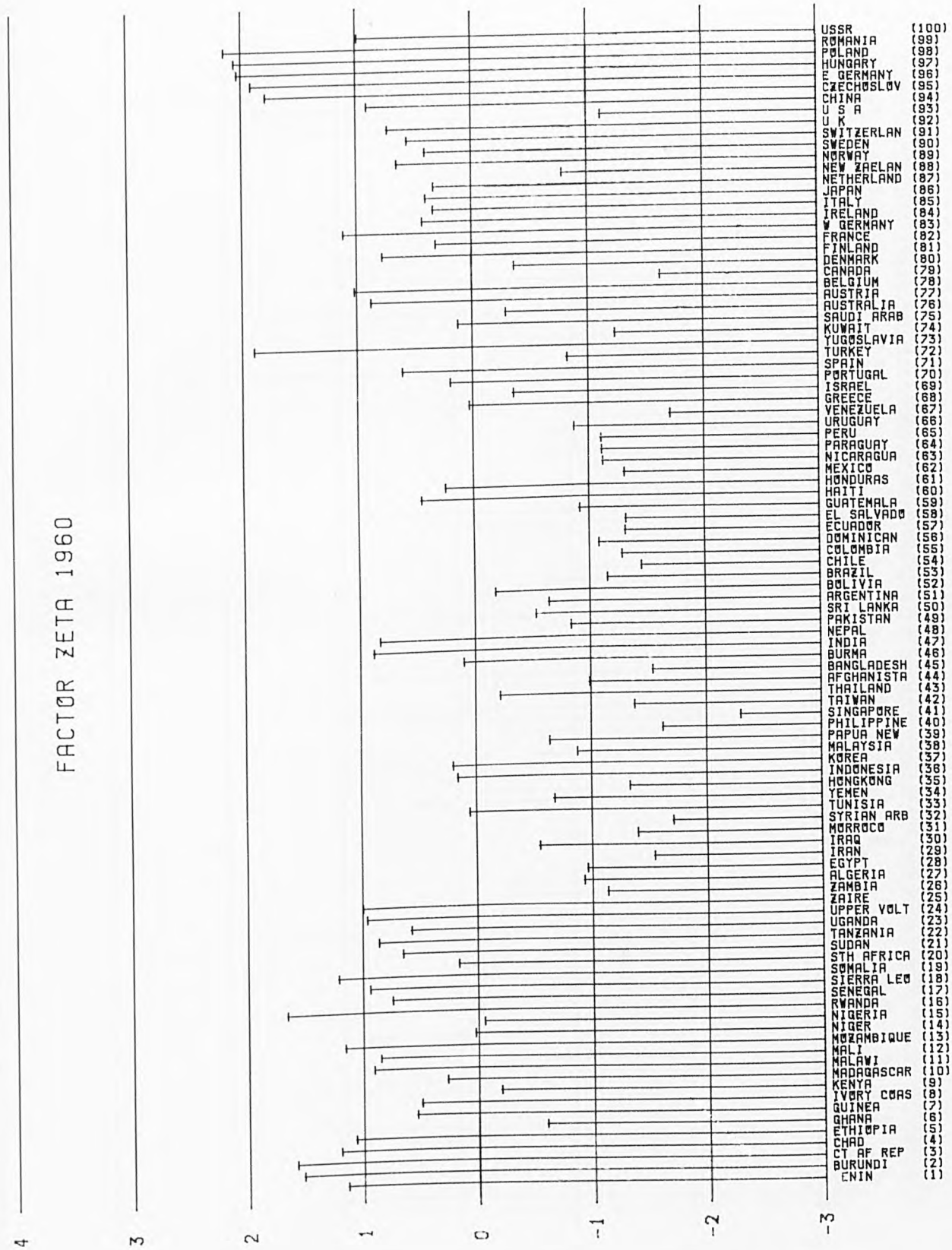
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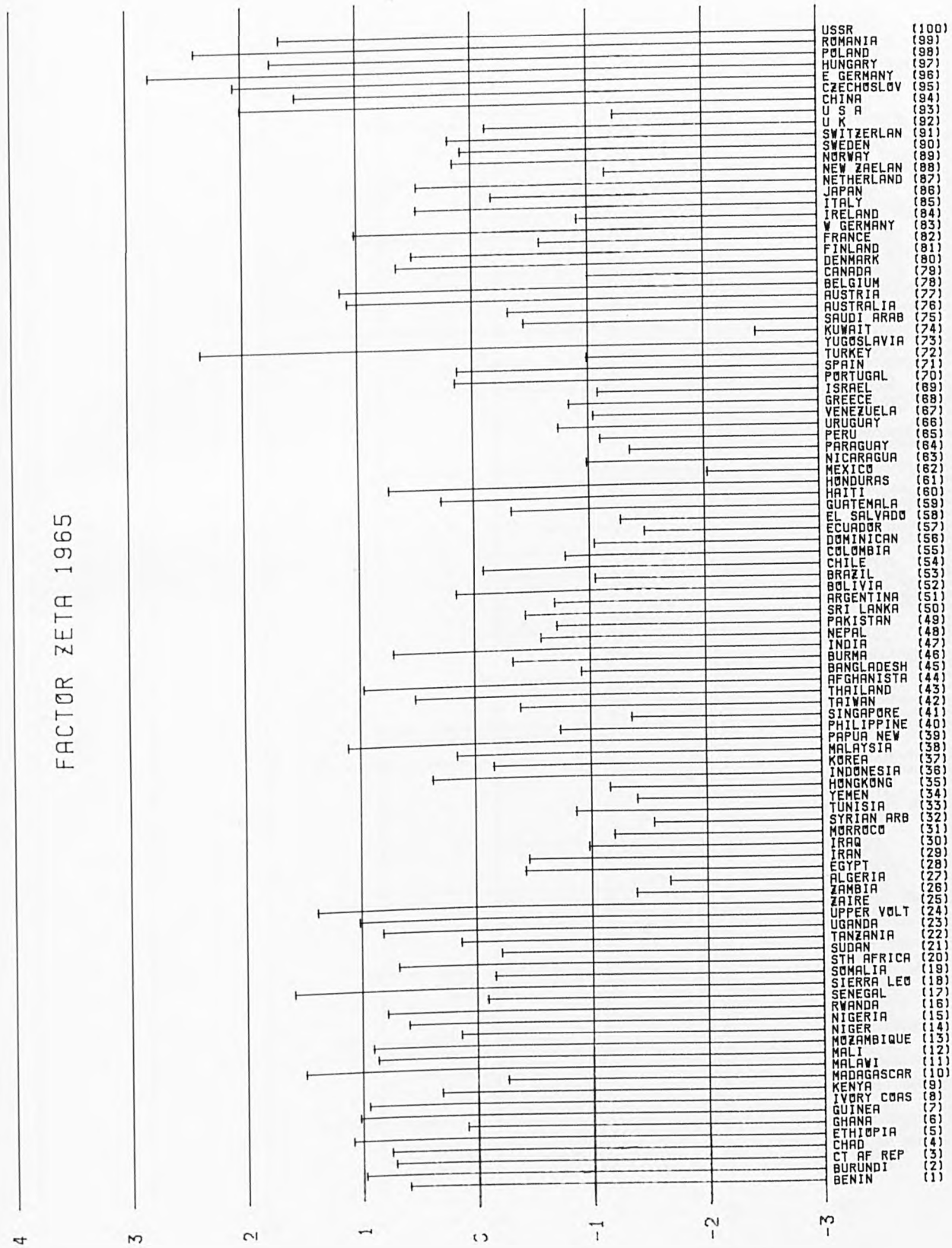
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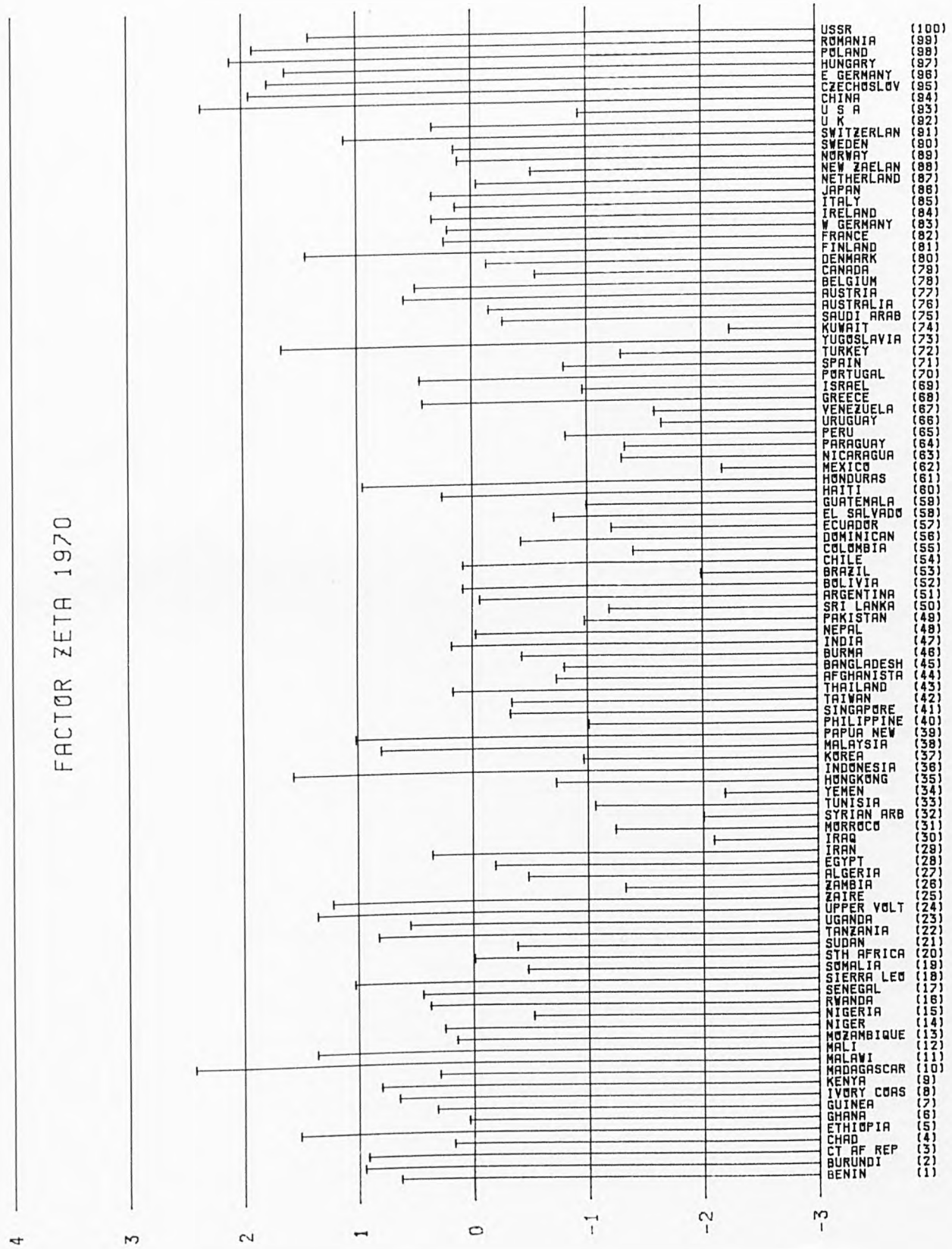
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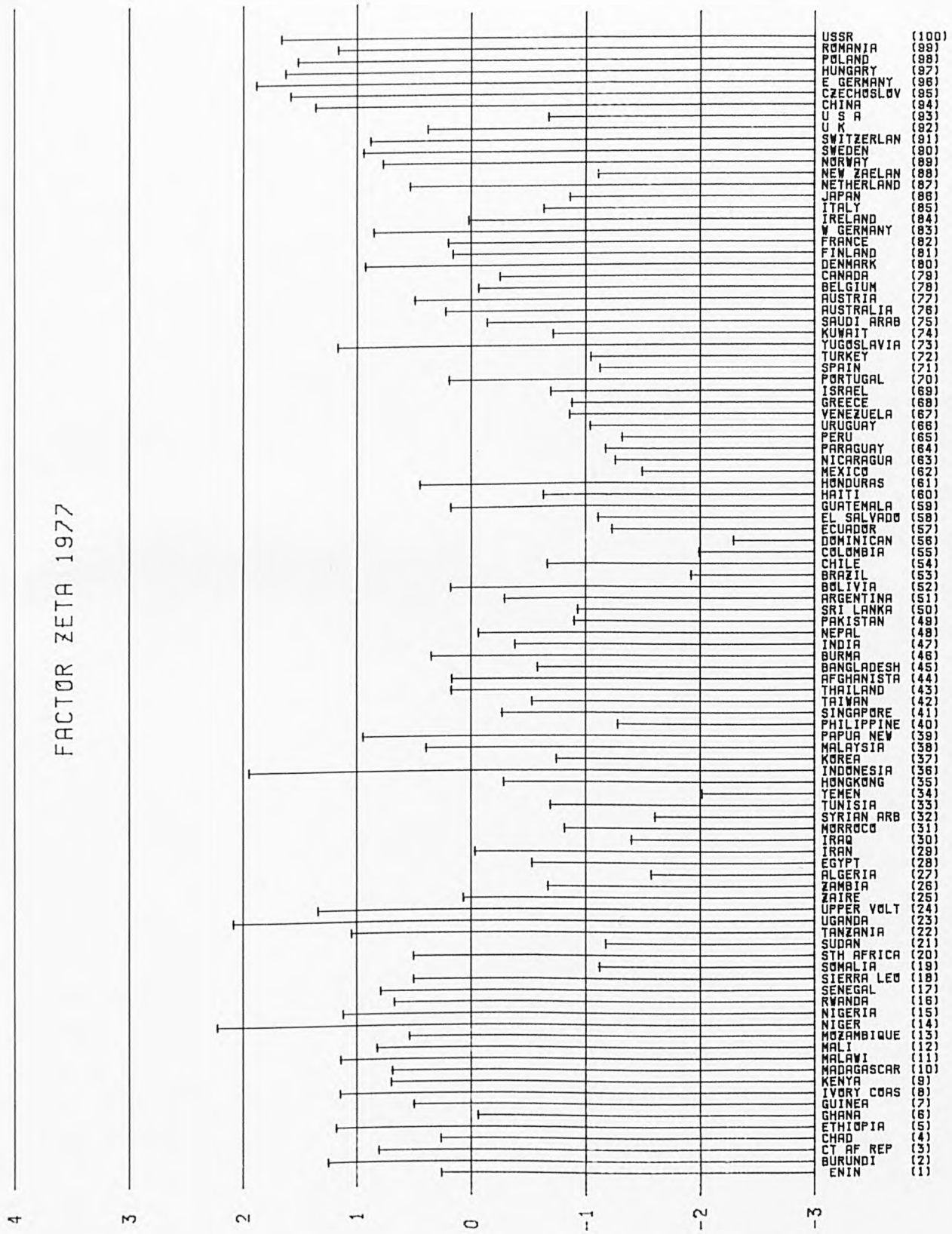
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