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LITERATURE-BASED INDICATOR TECHNIQUES FOR PROFILING SCIENCE AND TECHNOLOGY INFRASTRUCTURE IN DEVELOPING COUNTRIES

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I. Introduction

The R&D infrastructure of less developed countries is usually relatively small, poorly financed, and concentrated on the biological sciences. Lacking modern laboratory facilities and instrumentation, hampered by poor communications and unreliable utilities, and isolated by limited funds for travel and journal subscriptions, scientists in developing countries are often viewed as doing peripheral, insular research rather than participating in mainstream international science.[1] As a consequence, the application of techniques developed to monitor research activity and assess scientific capabilities in the developed world, particularly those using data on the international scientific literature, is often seen as inappropriate. The prevalence of unpublished reports and other grey literature, as well as the inability to pay page charges required to publish in mainstream journals, means that a large part of the "output" of research activity in developing countries remains invisible to such quantitatively oriented techniques. Of particular concern to many observers is the limited coverage of third world and non-English language journals in the Institute for Scientific Information's

[1] S. Arunachalam, "Peripherality in Science: What Should be Done to Help Peripheral Science Get Assimilated into Mainstream Science," Paper delivered at the International Conference on Science Indicators for Developing Countries, Paris, October 1990.

(ISI's) database, one of the more important sources of quantitative data for these "bibliometric" indicators.[2]

At the same time, it has been shown that scientific communities in developing countries are not necessarily stratified into a separate elite mainstream group and a locally-oriented tier of more peripheral scientists producing mediocre science.[3] In fact, as developing countries have made conscious efforts to extend their research capabilities by expanding their systems of higher education, they become increasingly visible in international bibliographic databases, including that of ISI. This working paper examines some of the issues concerning the application of bibliometric indicators to developing countries and highlights some of the information that has developed with their increasing visibility.

II. Scope of Database Coverage

Table 1 shows changes in the number of papers covered in two bibliometric models of international scientific activity based on the ISI database, which includes the Science Citation Index (SCI)

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[2]M. Moravcsik, Strengthening the Coverage of Third World Science (Eugene, Oregon: International Task Force for Assessing the Scientific Output of the Third World, 1985).

[3]T.O. Eisemon and C. Davis, "Publication Strategies of Scientists in Four Peripheral Asian Scientific Communities: Some issues in the Measurement and Interpretation of Non-Mainstream Science," in P.G. Altbach et al. Scientific Development and Higher Education: The Case of Newly Industrializing Nations (New York: Praeger, 1988).

and the Social Sciences Citation Index (SSCI). Most of the more advanced countries show a relatively stable pattern of small increases or decreases between the two years, although there are larger increases for Japan, Italy, France, and some of the poorer European countries. Eastern Europe and the Soviet Union mostly show declines. By contrast, every developing country in the table (Latin America and the Pacific Rim) shows a percentage increase in the number of papers that is greater than the overall increase of 1.78 percent for the entire 1988 database, with some of the more successful newly industrializing countries (NICs), such as Taiwan and South Korea, showing increases of more than 50 percent. Moreover, the increasing ties to international mainstream science of the NICs is highly specialized in fields contributing to industrial development and competitiveness, as will be discussed below.

The data are often sparse, particularly for small developing countries, and the scope (proportion of international research activity overall) of activity quite limited. There is, however, useful information to be derived from indicators based on ISI's database, although the data should be viewed as but a partial perspective on R&D activity in the third world. Figure 1A shows the overall scope of research activity of a range of developing countries in terms of the percent of research areas appearing in a 1985 model of international scientific activity derived from ISI's database. Figure 1B shows the much smaller scope of mainstream activity characteristic of some of the least developed

countries, even ones as large as Indonesia (population, c. 167 million). Table 2 provides a detailed breakdown by field for the same four Pacific Rim developing countries appearing in Figure 1B in a 1988 database. It shows the effects of the typical developing countries' pattern of being concentrated on the biological sciences, or in general biology and earth and atmospheric (geosciences), where geographical access to specific species or formations is fundamental to certain problem areas. The above average scope of Thailand's coverage of Solid State Physics/Materials Science is unusual, and, while the number of areas is small, the data are not so sparse as to be discounted as an artifact. The above average coverage of Economics/Management Science by Thailand and the Philippines appears to be a consequence of substantial international collaboration in those fields.[4]

III. National Research Portfolio Patterns

National patterns in the distribution of effort across scientific fields and research areas are highly uneven, and may be indicative of funding patterns, areas of strength or weakness, and science or industrial policy objectives. An initial survey of such patterns among Pacific Rim nations showed an interesting contrast between the profiles of industrialized, newly industrializing, and

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[4]H.R. Coward and R.R. Fresne, Research Activity in the Pacific Rim Nations: Survey of a 1988 Bibliometric Database, Final Report (Washington, DC: SRI International, March 1990).

developing countries.[5] While the industrialized countries tended to closely parallel their overall share of the 1985 co-citation database in each of sixteen scientific fields (i.e., not to show strong patterns of over- or under-emphasis of particular fields), developing countries showed an expected tendency to emphasize the biological sciences because of long-standing concerns with medicine, general biology, and agricultural science (see Figures 2A and 2C). Japan deviated from most developed countries in showing a strong emphasis on applications-oriented physical sciences, including chemistry, physics, and solid state physics/materials science. In contrast, the newly industrializing countries (NICs) all showed a profile similar to that of Japan with an additional two fields of emphasis consistently being mathematics/computer science and engineering (see Figure 2B). The Peoples' Republic of China (PRC), by most economic criteria a developing country, showed a strong NIC profile. The consistency of this pattern among the NICs suggests that this research portfolio profile is a useful indicator of development potential, and the strength of China's profile implied that nation may more properly belong in the NIC comparison group than the developing country category that economic data suggest.

An updated survey using 1988 data showed that the pattern continued in a database in which, as noted above, the NIC countries

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[5]H.R. Coward, Research Activity in the Pacific Rim Nations (Arlington, VA: SRI International Science and Technology Policy Program, October 1988).

showed substantial increases in their overall visibility in mainstream international science. A methodological difference in the construction of the 1988 database had the effect of increasing the central tendency of emphasis ratios for all countries (i.e., the ratios, which measure deviation from the world average by dividing the proportion of a country's activity in a particular field by the percentage of world activity in that field, showed less variance from the world average across the entire world data set than was the case of the 1985 database).[6] This shows most strongly in the data for Japan, in which the emphasis ratio is closer to "1" in the case of every field except for basic bioscience (and the very small science & engineering education field), as shown in Figure 3A. Most of the NICs also reflected the more central tendency (Figures 3B-D), but the profile emphasizing the physical sciences, mathematics, and engineering remains strongly characteristic of these countries. The pattern is particularly clear in the case of China (Figure 3B), adding the geosciences and astronomy to the "NIC five" fields. The developing countries showed continuing emphasis on at least three of the four biological fields (Figures 3E-G). Malaysia retreated from showing signs of shifting to a NIC profile, while Thailand showed sharply increased emphasis on the fields of solid state physics/materials science and economics/management science, possible precursors of a more NIC-like profile.

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[6]Coward and Fresne, op.cit. (1990).

The strength of China's NIC performance is emphasized in Table 3. This shows Chinese demographics (number and percentage of papers) for individual focused research areas in the 1988 database (the C1 numbers and Cluster names) in descending order of percent of papers from the PRC. National participation in the research areas is heterogeneous, with the PRC never accounting for as much as one-third of the 1988 papers. This indicates that the areas do not represent a nationally parochial approach, which is sometimes the case with data showing very high percentages of participation from a developing country. Moreover, except for one area dealing with geology (C1 number 3824), all of the high PRC participation areas fall in the NIC-profile fields (SRI Fields), with the greatest emphasis on solid state/materials science (7), which is far ahead of physics (6), chemistry (5), mathematics/computer science (10), and a single area in engineering (11).

Is China's increasing visibility the consequence of collaboration with scientists in industrialized countries? Papers with more than one country address represent instances of international collaboration. In the 1988 data, only about 25 percent (729 PRC papers of a total of 2746) represented international collaboration, with about half of these (366 papers) involving U.S. institutions. The PRC is clearly capable of standing on its own in the international literature.

The fact that the ISI data represent but a partial view of R&D in developing countries should be stressed in the context of the NIC profile suggested by these data. The fact that China or South

Korea are shown as emphasizing applications-oriented physical sciences and engineering in these data do not mean that there is not substantial activity in the biological sciences in these countries. It does mean that the biological work is less visible in the international mainstream literature and may well be more peripheral or insular than that in the physical sciences. Whether these patterns are attributable to the general expansion of the higher education systems of these countries or to specific policies intended to promote particular areas of strength remains an open question.[7]

The NIC profile as an indicator of developmental potential emerged from analysis of data on the Pacific Rim nations. Data from earlier analyses of field participation in Eastern Europe and Latin America, based on the 1985 database, show interesting parallels. Figures 4A-D on Eastern European countries all show strong emphasis on four of the five NIC profile fields. Table 4, comparing the five largest Latin American countries with the world distribution in terms of field percentages, shows a weaker pattern. Brazil has the strongest NIC profile, being above the world average in all five fields (but only barely in engineering), while Chile has the weakest with only chemistry above the world average. Argentina, Mexico, and Venezuela are each above average in three.

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[7]Eisemon and Davis, op.cit. (1988)

IV. Rapidly Developing Research Areas

Research areas in a co-citation database can be characterized by a number of quantitative attributes. The areas are defined by clustering together older, highly cited and co-cited documents (the measure of co-citation is the frequency with which publications are paired in the reference lists of later papers), representing concepts, methods, and discoveries important to ongoing work. When these defining papers are recently published documents: i.e., in which the average age of these defining papers is low, or where these defining papers include several that were very recently published). This suggests that the research area is developing rapidly as researchers become increasingly dependent upon recent findings to advance the field. It is difficult for even mainstream-publishing researchers in developing countries to be on the cutting edge, with the result that developing countries are generally below the world average in their participation in such research areas. Table 5 shows data by scientific field for Pacific Rim nation activity in areas that appear to be moving rapidly in the form of a ratio to the proportion of all areas in each field in that category (16 percent, overall). Many of the cells for the NICs and Developing Countries are based upon very small numbers (one or two research areas in a small field), but Thailand's high ratio of 1.2 overall is primarily based upon a respectable showing in basic bioscience (9 areas) and a surprisingly high 3.56 in solid state/materials science (28 areas), both areas with a significant

level of activity. Although generally less than 1, the ratios of the NICs in basic bioscience and/or solid state/materials science, fields of importance to biotechnology and microelectronics are often respectable showings.[8]

V. Institutional Development of Infrastructure

One way of considering the evolution of national R&D infrastructures is to measure the emergence and productivity of institutional centers of research activity in terms of their publications appearing in mainstream international science. A comparison of institutional data for eight smaller countries in 1985 and 1988 revealed patterns of both continuity and change. Although differences between the 1985 CRP database and the 1988 ISI Research Front Database used in this study mean that the data used to produce the rankings are not precisely comparable (the 1985 data ranked institutions on the basis of the number of research areas in which they appeared--with papers often appearing in more than one area, while the 1988 data represent exact paper counts), the 1985 rankings would probably be the same ir individual paper counts were available from the CRP system. It should be noted, however, that the sparse data matrices for such small countries require cautious interpretation. (The 1985 rankings were designated as P

[8]Coward and Fresne (1990), op.cit.

= Primary or S = Secondary on the basis of breaks in the frequency counts.)

The evolution of infrastructure in Taiwan (Table 6) and South Korea (Table 7) represents an interesting contrast. While both showed a sharply increased presence in the 1988 data, Taiwan's much greater increase in number of publications represented less in the way of institutional change than was the case for South Korea.

Taiwan had the more diversified infrastructure in the institutional data from 1985. The 1988 data show a 75 percent increase in the number of papers in the database, increasing Taiwan's share from 0.18 to 0.31 percent. Institutionally, there are some changes, but mostly in the lower tier institutions. The institutions ranked as the first five retained their positions, but significant changes appear to be taking place among the lower ranked institutions, including a rise of biomedical centers. The National Sun Yat Sen University now ranks below the National Central University and the Chang Gung Memorial Hospital (with the Veterans General Hospital above both). The Tatung Institute of Technology has become a significant secondary institution, and the National Taiwan Institute of Technology, ranked 12th in 1985, now stands ahead of the National Chung Hsing University, the Chung Yuan Christian University, and the Tamkang University (which has become a minor player). In addition, the Chung Shan Institute of Science and Technology has become a noticeable secondary institution.

Taiwan's "great leap forward" in visibility in the overall data, accompanied by some interesting shuffling of secondary

institutions contrasts with the situation in South Korea. Here, the jump in visibility is not so great, but is still more than 50 percent (from 0.12 percent to 0.19 percent. Institutionally, there is increasing depth of the infrastructure as evidenced by the emergence of numerous "new" (i.e., newly visible in the database) institutions that are, in some cases, making major inroads in the standings of the ranking institutions in 1985. The Korean Advanced Institute of Science and Technology has clearly displaced Seoul National University as the premier research center in South Korea.

VI. National Activity in an Emerging Field

More focussed analyses of national participation in particular fields or subfields can be developed from the data. In this case, the structured character of a co-citation database provided the means of identifying a set of 61 focused research areas constituting "high temperature superconductivity" research in a 1988 database. Table 8 shows the national demographics of this field in terms of both the number of papers and percent of the total number of 1988 papers identified. Listed in descending order of the "Expectation Ratio" (percentage of papers in the field divided by percentage papers in the model), the field is one in which a number of developing countries at NIC or near-NIC status show higher than expected participation (based on one paper, Liechtenstein's number one ranking is not significant). Table 8 shows Thailand having more than 4 times as many papers in the field

as would be expected on the basis of its 0.07 percent of the database (refer to Table 1). The PRC, India, Argentina, Taiwan, and South Korea are other developing countries with above expected participation in the field, while the United States is below at 83 percent of its expected number of papers. The country on which this example focused, Japan, has nearly two and one-half times the expected number of papers.

A more detailed examination of three Japanese institutions is shown in Table 9, including information on both 1988 researchers (Citing Papers/Authors) and the contributions of researchers from these institutions to the older, highly cited and co-cited papers that define the intellectual base (Base Papers/Authors) that underlies current work in the field. For this study, Japanese institutions were ranked on the basis of the number of base papers and current papers that they had contributed to the field and both base and current authors identified. While SRI International's TechMonitoring service had identified a number of Japanese institutions as being significant players in the field, these did not include all of those that appeared in the larger analysis from which this is drawn. Thus, the Okazaki National Research Institute of Molecular Science had not been identified by TechMonitoring as a major player in the field.

In the case of Matsushita's Central Research Laboratory, the continuity represented by the presence of four authors in both the base and current papers, combined with a number of additional researchers among the current citing authors suggests circumstances

in which a laboratory is being extended around a team of scientists that have done important work in the past. By contrast, the disappearance of three base paper contributors from the set of current citing researchers from Tohoku University and their appearance at the Okazaki Institute suggests mobility--movement of scientists to a new laboratory. In fact, close examination of the data suggests that there is a collaborative relationship between the Institute and the Tohoku University.

VII. Demographic Data in Science Indicators

Literature-based data are viewed as output indicators because of the tradition of publishing openly the results of scientific research efforts that is the norm of science. The relationship between such output indicators and inputs to the R&D enterprise represents an important area of endeavor in developing improved indicators. It was noted above that the reasons for increased visibility of the NICs in mainstream international science remain unclear. The degree to which particular science policies or research funding priorities have produced the focused profiles of the NICs, as opposed to this being a more indirect consequence of decisions to expand the higher education sector is not known. Data on funding and manpower inputs, as well as policy initiatives, are needed to elucidate the relationship.

In general, the use of literature-based indicators represents only a small part of efforts to develop quantitatively based views

of the R&D enterprise and its relationship to other social and economic variables. Table 10 shows an early SRI effort to collect Pacific Rim demographic and economic data in a manner that could be related to bibliometric indicators. With countries ranked in terms of the GNP per capita indicator of relative national wealth, the comparison groups generally show a high degree of consistency in the orders of magnitude of the bibliometric indicators within each group. China's position tying with the Philippines for the second lowest number of papers per capita is consistent with the PRC's position at the bottom of the GNP per capita scale, but its overall position in the bibliometric data is so much greater in scale that it far outweighs the other developing countries. Malaysia's position in the bibliometric-based data is consistent with the other developing countries, while its GNP per capita makes it marginal as to whether it belongs to the NIC group. In fact, as noted above, China's bibliometric profile was that of a NIC, suggesting an adjustment in the comparison groups, while Malaysia was marginally more a developing country in 1985, and slipped further toward a developing country's research profile in the 1988 data.

A much more elaborate effort at developing a matrix that relates input data to literature-based output indicators appears in Table 11. As a heuristic exercise, it is interesting as much for the puzzling anomalies that result as for anything that it reveals concerning the relationship of the R&D enterprise to development. Data on Gross Expenditure on R&D (GERD) or total

number of Research Scientists and Engineers (RSE) comparable to those compiled by the OECD on industrialized countries is usually not available for the developing world, and what data is available is often of doubtful accuracy. The table uses both OECD and UNESCO sources. Anomalies among the industrialized countries, such as the apparent efficiency of the oft maligned British R&D system in the number of papers per scientist and engineer or per million dollars of GERD, and a visibility that is five or six times that of the United States or Japan in terms of the scope of its research per capita or dollar invested may be caused by data definitions, but raise serious concerns about the interpretation of the indicators. When data on developing countries show Chile as being ten times as efficient as the British by the same measures, and Singapore, Sri Lanka, or Yugoslavia completely out of line with their comparison groups, the problem more clearly lies with the quality of the data.

The sparsity of data in the developing country part of the matrix, as well as the dubious quality of what is there, emphasizes the distance that must be covered before an adequate foundation can be laid for understanding the relationship between the scientific and technological infrastructure of a nation and its economic development. Although the NICs appear to provide a clear and fairly consistent model that suggests a close tie between the expansion of R&D capabilities and a successful path to development, the picture provided with available indicators is a partial one much in need of improvement.

TABLES

TABLE 1

INTERNATIONAL COMPARISON OF SCIENTIFIC ACTIVITY
BASED ON NUMBER OF PUBLICATIONS IN A 1985 AND 1988 BIBLIOMETRIC DATABASE

Country	1985 Papers	1988 Papers	Percent Change	% of 1985 Papers	% of 1988 Papers
World (database)	339,544	345,585	1.78%	100.00%	100.00%
MAJOR SCIENTIFIC POWERS					
United States	143,422	147,335	2.73%	42.24%	42.63%
United Kingdom	32,301	31,969	-1.03%	9.51%	9.25%
Japan	22,436	25,417	13.29%	6.61%	7.35%
Fed.Rep.Germany	21,813	22,170	1.64%	6.42%	6.42%
France	17,488	19,076	9.08%	5.15%	5.52%
U.S.S.R.	15,274	13,686	-10.40%	4.50%	3.96%
Italy	9,275	10,440	12.56%	2.73%	3.02%
WESTERN EUROPE					
Netherlands	7,192	7,809	8.58%	2.12%	2.26%
Sweden	6,982	7,004	0.32%	2.06%	2.03%
Switzerland	5,241	5,444	3.87%	1.54%	1.58%
Belgium	3,504	3,520	0.46%	1.03%	1.02%
Spain	3,368	4,534	34.62%	0.99%	1.31%
Denmark	3,242	3,156	-2.65%	0.95%	0.91%
Finland	2,454	2,447	-0.29%	0.72%	0.71%
Norway	2,073	1,949	-5.98%	0.61%	0.56%
Austria	2,004	2,052	2.40%	0.59%	0.59%
Greece	835	1,052	25.99%	0.25%	0.30%
Eire	607	755	24.38%	0.18%	0.22%
Portugal	250	378	51.20%	0.07%	0.11%
EASTERN EUROPE					
Poland	2,902	3,032	4.48%	0.85%	0.88%
Dem.Rep.Germany	2,474	2,246	-9.22%	0.73%	0.65%
Czechoslovakia	1,976	1,718	-13.06%	0.58%	0.50%
Hungary	1,533	1,427	-6.91%	0.45%	0.41%
Yugoslavia	751	996	32.62%	0.22%	0.29%
Bulgaria	594	606	2.02%	0.17%	0.18%
Rumania	403	250	-37.97%	0.12%	0.07%

TABLE 1 (CONT'D.)

INTERNATIONAL COMPARISON OF SCIENTIFIC ACTIVITY
BASED ON NUMBER OF PUBLICATIONS IN A 1985 AND 1988 BIBLIOMETRIC DATABASE

Country	1985 Papers	1988 Papers	Percent Change	% of 1985 Papers	% of 1988 Papers
PACIFIC RIM					
Advanced					
Australia	8,091	8,295	2.52%	2.38%	2.40%
New Zealand	1,625	1,685	3.69%	0.48%	0.49%
Newly Industrializing					
China	1,571	2,746	74.79%	0.46%	0.79%
Taiwan	615	1,085	76.42%	0.18%	0.31%
South Korea	416	650	56.25%	0.12%	0.19%
Hong Kong	409	462	12.96%	0.12%	0.13%
Singapore	244	282	15.57%	0.07%	0.08%
Developing					
Thailand	185	237	28.11%	0.05%	0.07%
Malaysia	115	120	4.35%	0.03%	0.03%
Philippines	81	93	14.81%	0.02%	0.03%
Indonesia	55	62	12.73%	0.02%	0.02%
LATIN AMERICA					
Brazil	1,351	1,499	10.95%	0.40%	0.43%
Argentina	983	1,146	16.58%	0.29%	0.33%
Mexico	694	721	3.89%	0.20%	0.21%
Chile	513	581	13.26%	0.15%	0.17%
Venezuela	246	255	3.66%	0.07%	0.07%
Colombia	51	65	27.45%	0.02%	0.02%
Peru	34	69	102.94%	0.01%	0.02%

Notes:
1985 figures based on Center for Research Planning DSS Database.
1988 figures based on ISI Research Front Database.

Source:
SRI International, Science and Technology Policy Program

TABLE 2

Scope of 1988 Research Activity in Pacific Rim (Developing Countries by Field)

FIELD	THAILAND	MALAYSIA	PHILIPPINES	INDONESIA
Clinical Biology	5.5%	2.6%	0.9%	1.1%
Basic Bioscience	3.8%	1.5%	2.0%	0.9%
General Biology	4.7%	3.9%	5.1%	2.2%
Agricultural/Animal Science	8.2%	4.7%	6.5%	2.2%
Chemistry	2.0%	1.7%	0.6%	0.4%
Physics	0.0%	0.8%	0.3%	1.3%
Materials Science/Solid State	4.3%	0.2%	0.0%	0.4%
Geosciences	3.7%	0.8%	1.6%	3.7%
Astronomy/Astrophysics	0.0%	0.0%	0.0%	2.0%
Math/Computer Science	1.2%	0.5%	0.2%	0.5%
Engineering	2.2%	2.9%	0.4%	0.7%
Psychology/Psychiatry	1.0%	0.5%	2.0%	0.0%
Economics/Management Sci.	7.1%	0.0%	4.5%	0.6%
Social Sciences	2.4%	0.3%	1.4%	0.7%
Science/Engineering Education	0.0%	0.0%	0.0%	0.0%
Multidisciplinary	1.7%	0.0%	0.0%	1.7%
Total Scope	3.7%	1.7%	1.4%	1.0%

Source: SRI International, Science and Technology Policy Program (Based on ISI "Research Front" Data Base).

1988 Research Areas with High Chinese Participation

SRI Fields	C4	C3	C2	C1	PRC Papers	PRC Percent	Cluster Names
6	0	0	0	3972	5	31.25	RANDOM LATTICE; MONTE-CARLO SIMULATION; MASSLESS FERMIONS
7	0	0	474	6811	5	27.78	INTERNAL-FRICTION PEAK; STRUCTURAL RELAXATION; SINTERED ULTRA-FINE ALUMINUM PRODUCTS
5	2	49	137	6557	5	25.00	OXOVANADIUM(IV) COMPLEXES; ACETONE BENZOYLHYDRAZONE; STRUCTURAL ASSESSMENT
11	0	0	0	2518	3	25.00	NON-LINEAR OBSERVER DESIGN; MODEL-REFERENCE ADAPTIVE-CONTROL SCHEME FOR PURE-FEEDBACK NONLINEAR-SYSTEMS
5	0	124	701	5332	4	23.53	WILKINSON CATALYST-INDUCED ADDITION
10	2	26	545	4668	3	23.08	EXPERIMENTALLY DERIVED FUZZY MEMBERSHIP FUNCTION FOR GRAY LEVEL IMAGES; HVS THRESHOLDING; UNCERTAINTY MANAGEMENT
7	2	33	632	5770	5	22.73	TWO-DIMENSIONAL ELECTRON LAYER IN A BOUNDED SYSTEM; EDGE MAGNETOPLASMONS; CYLINDRICAL QUANTUM WELL; SURFACE OF SUPERFLUID HE-4
7	0	0	14	4603	5	20.83	MAGNETIC-PROPERTIES OF FE-RICH RARE-EARTH INTERMETALLIC COMPOUNDS; THMNT2 STRUCTURE; SPIN REORIENTATION TRANSITIONS IN DY(FE11TI)
7	2	33	147	2134	15	18.99	POLARON CYCLOTRON-RESONANCE MASS OF A TWO-DIMENSIONAL ELECTRON-GAS; SEMICONDUCTOR HETEROSTRUCTURES; OPTICAL PHONON ENERGY REGION
7	2	33	147	4229	7	17.50	HOT-ELECTRON TRANSPORT; MANY-VALLEY SEMICONDUCTORS; GAAS QUANTUM WELLS; THERMAL NOISE; ALGAAS/GAAS HETEROJUNCTIONS
7	0	0	474	3540	5	16.67	HIGH-PURITY ALUMINUM; BAMBOO BOUNDARY INTERNAL-FRICTION PEAK; DISLOCATION MICROSTRUCTURE OF PURE COPPER; STEADY-STATE CREEP RATE; CYCLIC STRESS
5	0	17	401	3000	3	16.67	IONOPHORES FOR ALKALI CATIONS; CROWN ETHERS; BENZOCROWN DERIVATIVES; LITHIUM PICRATE
6	2	7	132	687	3	16.67	CHOU-YANG MODEL; CHARGED-PARTICLE PSEUDORAPIDITY DISTRIBUTIONS AT COLLIDER ENERGIES; PARTITION TEMPERATURE; E+E- ANNIHILATION; PBARP COLLISIONS
10	0	0	0	6502	3	15.79	TERNARY LOGIC FUNCTIONS; MULTIPLE-VALUED MOS CURRENT-MODE CIRCUITS; VERTICAL INTEGRATION OF INALAS INGAAS RESONANT TUNNELING STRUCTURES
7	0	0	14	6575	3	15.79	CO-CR PERPENDICULAR MAGNETIC RECORDING MEDIA; LARGE-SCALE HEAD MODEL; COHCR THIN-FILM FLEXIBLE DISK
7	2	23	44	4714	3	15.79	PHOTOCONDUCTIVITY IN HYDROGENATED AMORPHOUS-SILICON; RECOMBINATION DYNAMICS FOR A-SI-H; GAP STATES; ANNEALING BEHAVIOR
7	2	12	127	211	3	15.79	OPTICAL WAVE-GUIDE; STIMULATED FAR-INFRARED RADIATION EMISSION; TE-TM MODE CONVERSION
7	2	62	189	7753	8	15.38	GLASSY PD-U-SI ALLOYS; ICOSAHEDRAL QUASICRYSTALLINE PHASE; AL-MN QUASI-CRYSTALS
7	2	34	73	6346	9	15.00	DEEP IMPURITY LEVELS IN SEMICONDUCTOR SUPERLATTICES; VACANCY CHARGE STATES; ELECTRONIC-STRUCTURE OF SURFACES; SILICON VALENCE BANDS
7	0	0	0	7386	3	14.29	ABSORPTION-BAND OF RUBY; LASER SPECTROSCOPY; THERMOCHEMICALLY REDUCED MGO CRYSTALS
7	0	0	0	765	7	13.73	THIN YBA2CU3O7-DELTA FILMS; JOSEPHSON JUNCTION ARRAYS; GRANULAR SUPERCONDUCTORS; MAGNETIC-FIELD PENETRATION DEPTH; FUNCTION OF TEMPERATURE
8	2	46	121	3824	7	13.73	HIMALAYAN TIBETAN TECTONIC EVOLUTION; NORTHERN PAKISTAN; EARTHS CRUST; CONTINENTAL SUBDUCTION ZONE; PALEOMAGNETIC CONSTRAINTS; CENTRAL THAILAND
7	2	33	147	6782	3	13.64	TWO-DIMENSIONAL ELECTRON-GAS; GAAS HETEROSTRUCTURES; ENERGY RELAXATION; INSB BICRYSTALS

Source: SRI International, Science and Technology Policy Program (Based on ISI "Research Front" Database).

TABLE 4

Research Activity Field of Emphasis: Latin America and the United States

Field	World	USA	Latin America	Argentina	Brazil	Chile	Mexico	Venezuela
Clinical Medicine	22.8%	23.0%	18.2%	14.8%	13.1%	26.2%	17.3%	16.8%
Basic Biology	33.9%	34.8%	36.4%	41.6%	32.6%	33.9%	36.6%	38.5%
General Biology	3.0%	2.9%	3.6%	2.4%	2.9%	3.5%	3.3%	6.5%
Agroscience	2.3%	2.3%	2.1%	1.7%	1.6%	1.6%	1.5%	1.7%
Chemistry	8.7%	8.7%	10.4%	14.7%	10.1%	9.8%	10.6%	12.6%
Physics	4.0%	4.1%	6.0%	7.2%	8.8%	4.6%	6.6%	2.1%
Solid State/Mat Sci	9.2%	8.8%	10.3%	10.8%	15.4%	4.3%	10.7%	11.8%
Geosciences	3.7%	3.7%	3.9%	2.0%	4.4%	3.4%	4.1%	2.3%
Astronomy	1.2%	1.2%	3.4%	3.0%	3.5%	9.9%	4.3%	0.8%
Math/Computer Sci	4.0%	3.9%	3.2%	1.5%	5.2%	2.2%	2.3%	5.3%
Engineering	3.7%	3.4%	2.6%	2.5%	3.8%	1.6%	1.7%	2.9%
Psychology	4.5%	4.6%	2.4%	1.3%	1.4%	1.8%	4.9%	1.1%
Economics/Mgt. Sci	2.3%	2.3%	1.2%	0.5%	1.5%	0.7%	0.9%	1.5%
Social Sciences	3.1%	3.1%	1.1%	0.6%	0.9%	0.0%	1.1%	1.7%
S&E Education	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%
Gen Sci./Multi.	1.4%	1.1%	0.5%	0.9%	0.3%	0.2%	0.5%	0.2%
All Fields	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Percent = Number of Areas in Field / Total Number of Areas)

Table 5: Rapidly Developing Research Areas (Ratio to World Baseline)

		Industrial Countries				Newly Industrializing Countries					Developing Countries			
Field	World	U.S.	Japan	Australia	New Zealand	China	Taiwan	South Korea	Hong Kong	Singapore	Thailand	Malaysia	Philippines	Indonisia
Clinical Biology	1.00	0.99	0.82	1.01	1.05	0.86	0.65	1.02	0.93	0.67	0.73	0.65	0.75	1.05
Basic Bioscience	1.00	1.00	1.00	1.03	1.16	0.90	0.82	0.98	0.70	0.67	0.98	0.56	1.85	0.49
General Biology	1.00	0.98	0.85	0.60	0.46	0.43	0.78	0.93	0.98	0.89	0.43	0.51	0.00	0.00
Agricultural/Animal Science	1.00	1.01	0.81	0.54	0.51	0.93	0.00	1.03	0.00	1.16	0.40	0.00	0.00	0.00
Chemistry	1.00	0.98	0.94	0.85	0.71	0.59	0.38	0.44	0.78	0.85	0.44	0.00	1.37	0.00
Physics	1.00	0.99	0.98	0.52	0.66	0.67	0.56	0.85	0.77	1.29	–	3.87	0.00	0.00
Materials Science/Solid State	1.00	1.01	1.00	0.94	1.35	0.97	0.89	0.94	0.45	0.61	3.56	0.00	–	1.48
Geosciences	1.00	1.00	0.50	0.71	0.32	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astronomy/Astrophysics	1.00	1.00	0.79	1.08	0.75	0.80	–	1.07	2.13	–	–	–	–	2.13
Math/Computer Science	1.00	1.02	0.41	0.44	0.31	0.56	0.24	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Engineering	1.00	0.94	0.37	0.80	0.99	0.20	0.25	0.33	0.00	0.69	0.00	0.00	0.00	8.63
Psychology/Psychiatry	1.00	1.01	0.66	0.72	0.76	0.00	0.76	0.00	0.31	0.89	0.00	0.00	0.00	–
Economics/Management Sci.	1.00	1.00	0.24	0.52	0.55	0.00	0.00	0.89	0.00	0.00	0.00	–	0.00	0.00
Social Sciences	1.00	0.99	0.50	0.54	1.05	0.00	0.56	0.00	0.00	0.00	0.81	0.00	0.00	0.00
Science/Engineering Education	1.00	1.00	--	0.00	0.00	–	–	–	0.00	–	–	–	–	–
Multidisciplinary	1.00	0.83	0.97	1.33	2.32	1.45	0.00	0.00	0.00	0.00	0.00	–	–	0.00
Cluster Total	1.00	0.99	0.92	0.89	0.90	0.80	0.69	0.74	0.75	0.63	1.20	0.53	0.71	0.70

Table 6

TAIWAN INSTITUTIONAL RANKINGS

1985 Rank		1988 Papers	Institution
1	P	218	NATL TSING HUA UNIV
2	P	207	NATL TAIWAN UNIV
3	P	165	ACAD SINICA
4	P	91	NATL CHENG KUNG UNIV
5	P	72	NATL CHIAO TUNG UNIV
		70	VET GEN HOSP
8	S	42	NATL CENT UNIV
		41	NATL DEF MED CTR
7	S	39	CHANG GUNG MEM HOSP
		39	NATL YANG MING MED COLL
		37	TATUNG INST TECHNOL
6	P	26	NATL SUN YAT SEN UNIV
		25	NATL TAIWAN UNIV HOSP
9	S	22	NATL CHUNG HSING UNIV
		22	IND TECHNOL RES INST
		20	NATL TAIWAN NORMAL UNIV
12	S	13	NATL TAIWAN INST TECHNOL
		12	TRI SERV GEN HOSP
10	S	11	CHUNG YUAN CHRISTIAN UNIV
		10	CHANG GUNG MED COLL
		9	FU JEN CATHOLIC UNIV
		9	CHUNG SHAN INST SCI & TECHNOL
		8	KAOHSIUNG MED COLL
		7	CHENG KUNG UNIV
		6	NATL TAIWAN COLL MARINE SCI & TECHNOL
		5	MACKAY MEM HOSP
		4	CHIA NAN JR COLL PHARM
		4	CHUNG CHENG INST TECHNOL
		4	FENG CHIA UNIV
		4	TAIPEI CITY PSYCHIAT CTR
11	S	4	TAMKANG UNIV

Table 7

SOUTH KOREA INSTITUTIONAL RANKINGS

1985 Rank		1988 Papers	Institution
2	P	222	KOREA ADV INST SCI & TECHNOL
1	P	96	SEOUL NATL UNIV
		40	YONSEI UNIV
		38	KOREA UNIV
		21	PUSAN NATL UNIV
		17	KYUNGPOOK NATL UNIV
		14	CHUNGNAM NATL UNIV
		13	HANYANG UNIV
		13	INHA UNIV
		12	POHANG INST SCI & TECHNOL
		10	CHONNAM NATL UNIV
		10	KYUNG HEE UNIV
3	S	10	SOGANG UNIV
		9	KOREA RES INST CHEM TECHNOL
		8	CHONBUK NATL UNIV
		8	KOREA INST TECHNOL
5	S	8	SUNG KYUN KWAN UNIV
		6	CHUNGBUK NATL UNIV
		6	JEONBUG NATL UNIV
		6	KOREA CANC CTR HOSP
4	S	6	YEUNGNAM UNIV

TABLE 8

1988 National Participation in
High Temperature Superconductivity Research

Country	Field Papers	Field Percent	Expectation Ratio
LIECHTENSTEIN	1	0.01%	26.06
ROMANIA	38	0.29%	4.57
THAILAND	27	0.21%	4.22
PEOPLES R CHINA	329	2.51%	3.53
INDIA	552	4.23%	2.82
JAPAN	2252	17.27%	2.43
SWITZERLAND	354	2.71%	2.19
ARGENTINA	67	0.51%	1.59
TAIWAN	59	0.46%	1.61
POLAND	145	1.11%	1.49
SOUTH KOREA	31	0.23%	1.47
PORTUGAL	16	0.13%	1.45
BULGARIA	29	0.22%	1.45
USSR	692	5.31%	1.36
CZECHOSLOVAKIA	77	0.59%	1.34
YUGOSLAVIA	38	0.29%	1.29
SRI LANKA	2	0.02%	1.22
MEXICO	27	0.21%	1.18
FED REP GER	860	6.60%	1.16
FRANCE	687	5.26%	1.08
VIETNAM	1	0.01%	1.02
BRAZIL	46	0.36%	0.98
NETHERLANDS	247	1.89%	0.95
HUNGARY	38	0.29%	0.87
ISRAEL	117	0.90%	0.85
LEBANON	1	0.01%	0.85
UNITED STATES	4424	33.91%	0.83
SPAIN	109	0.83%	0.71
CHILE	13	0.10%	0.69
ITALY	241	1.85%	0.69
COLOMBIA	1	0.01%	0.63
GREECE	21	0.16%	0.63
MOROCCO	2	0.01%	0.62
NORWAY	38	0.29%	0.61
BELGIUM	61	0.47%	0.56
GER DEM REP	39	0.30%	0.51
AUSTRIA	32	0.25%	0.50
ALGERIA	1	0.01%	0.43
CANADA	267	2.05%	0.43
ENGLAND	383	2.94%	0.41
DENMARK	40	0.31%	0.40
AUSTRALIA	107	0.82%	0.37
IRELAND	9	0.07%	0.37
U.K.	394	3.02%	0.36
SWEDEN	68	0.52%	0.30
NEW ZEALAND	16	0.12%	0.28
EGYPT	5	0.04%	0.25
FINLAND	19	0.15%	0.23
VENEZUELA	2	0.01%	0.21
SOUTH AFRICA	11	0.08%	0.17
NIGERIA	1	0.01%	0.08
SCOTLAND	9	0.07%	0.07
WALES	2	0.01%	0.05
HONG KONG	1	0.00%	0.03
Total	13,044	100.00%	1.00

Table 9

SAMPLE OF JAPANESE RESEARCHERS AND INSTITUTIONS IN SUPERCONDUCTIVITY RESEARCH

INSTITUTION	BASE PAPERS	BASE RANK	CITING RANK	SRI	BASE AUTHORS	BASE PAPERS	CITING AUTHORS	CITING PAPERS
MATSUSHITA ELECT IND CO LTD CENT RES LAB	3	8	13	Y	ADACHI H	2	ADACHI H	15
					HIROCHI K	2	HIROCHI K	11
					SETSUNE K	2	SETSUNE K	15
					WASA K	2	WASA K	17
							ICHIKAWA Y	8
							HATTA S	6
							KAMADA T	5
							MITSUYU T	3
							KAWASHIM.S	2
							KOHIKI S	2
							KUGIMIYA K	2
							ADACHI S	2
							HIGASHIN.H	2
							INOUE O	2

NOTE: "Base Papers" refer to older highly cited and co-cited papers defining various research areas, while "Citing Papers" refer to the current 1988 papers appearing in those areas in the 1988 ISI Research Front Database. A "Y" under "SRI" indicates that SRI's TechMonitoring Service had identified the institution as being significantly involved in high temperature superconductivity research.

Table 9 (Continued)

BASE PAPER ADDRESS	BASE PAPERS	BASE RANK	CITING RANK	SRI	BASE AUTHORS	BASE PAPERS	CITING AUTHORS	CITING PAPERS
TOHOKU UNIV	7	4	2	Y	ONODA M	3		
DEPT ENGN SCI					HOSOYA S	2	HOSOYA S	1
INST MAT RES					SATO M	2		
IRON STEEL &					SHAMOTO S	2		
OTHER MET RES INST								
							SYONO Y	18
							MUTO Y	17
							KIKUCHI M	17
							KOBAYASH.N	16
							NOTO K	8
							HIRABAYA.M	7
							HIRACA K	7
							SASAKI T	7
							TOKIWA A	7
							KAJITANI T	6
							FUJIMORI H	5
							KUSABA K	5
							IWASAKI H	5
OKAZAKI NATL INST MOLEC SCI	3	8	9	N			SATO M	10
							SERA M	8
							FUKUDA K	6
							KONDOH S	6
							SHAMOTO S	4
							ANDO Y	3
							NASU K	3
							INOKUCHI H	2
							ONODA M	2
							MORI T	2

TABLE 10

PACIFIC RIM NATIONS IN A 1985 MODEL OF SCIENCE:
DEMOGRAPHICS AND SCIENTIFIC ACTIVITY

Country	1984 Population (in millions)	GNP per Capita	No. Papers	% Papers	No.Papers per M Pop.	No.Res. Areas	% Res. Areas
World (Model)	--	--	339,544	100.00	--	37,003	100.0
United States	236.3	13160	143,422	42.24	607.7	35,505	96.0
Industrialized:							
Australia	15.5	11140	8,091	2.38	522.0	11,534	31.2
Japan	119.9	10080	22,436	6.61	187.1	17,624	47.6
New Zealand	3.2	7920	1,625	.48	507.8	2,993	8.1
Newly Industrializing:							
Singapore	2.5	5910	244	.07	97.6	422	1.1
Hong Kong	5.5	5340	409	.12	75.7	746	2.0
Taiwan	19.2	2540	615	.18	32.0	1,058	2.8
South Korea	40.6	1910	416	.12	10.2	756	2.0
Developing:							
Malaysia	15.3	1860	115	.03	7.5	184	.5
Philippines	54.5	820	81	.02	1.5	126	.3
Thailand	51.7	790	185	.05	3.6	298	.8
Indonesia	161.6	580	55	.02	.3	97	.3
China	1034.5	310	1,571	.46	1.5	2,286	6.2

TABLE 11

Matrix of R&D Related Indicators

Country	GNP per Capita	GERD (M)	Pop. (M)	RSE	Papers	% of Papers	Papers/ Mil. Pop.	Papers/ Hrd. RSE	Papers/ M$ GERD	Research Areas	% Res. Areas	RAs/ Hrd. RSE	RAs/ M$ GERD
World (1988 Database)					345,585	100.00%				8,177	100.0%		
MAJOR SCIENTIFIC POWERS													
United States	$17,324	$111,755	241.5	772,700	147,335	42.63%	610	19.07	1.32	7,994	97.8%	1.03	0.07
United Kingdom	$11,491	$14,371	56.7	98,000	31,969	9.25%	564	32.62	2.22	6,722	82.2%	6.86	0.47
Japan	$12,332	$40,083	121.4	381,300	25,417	7.35%	209	6.67	0.63	5,546	67.8%	1.45	0.14
PACIFIC RIM													
Newly Industrializing													
China	$290	NA	1068.5	NA	2,746	0.79%	3	NA	NA	1,723	21.1%	NA	NA
Taiwan	NA	NA	NA	NA	1,085	0.31%	NA	NA	NA	999	12.2%	NA	NA
South Korea	$2,690	NA	42.1	32,117	650	0.19%	NA	2.02	NA	727	8.9%	2.26	NA
Hong Kong	$8,070	NA	5.6	NA	462	0.13%	11	NA	NA	461	5.6%	NA	NA
Singapore	$7,654	$101	2.5	2,401	282	0.08%	113	11.75	2.81	340	4.2%	14.16	3.38
Developing													
Thailand	$824	$128	51.7	NA	237	0.07%	5	NA	1.85	304	3.7%	NA	2.38
Malaysia	$1,810	NA	16.5	NA	120	0.03%	7	NA	NA	142	1.7%	NA	NA
Philippines	$590	$61	58.4	5,919	93	0.03%	2	1.57	1.52	116	1.4%	1.96	1.90
Indonesia	$429	$188	166.9	24,895	62	0.02%	0	0.25	0.33	81	1.0%	0.33	0.43
ASIA													
India	$300	$1,597	797.5	100,136	5110	1.48%	6	5.10	3.20	2,746	33.5%	2.74	1.72
Pakistan	$350	$108	102.5	9,325	125	0.04%	1	1.34	1.16	169	2.1%	1.81	1.57
Sri Lanka	$400	$10	16.4	1,939	43	0.01%	3	2.22	4.26	71	0.9%	3.66	7.03
AFRICA													
Egypt	$680	NA	50.1	NA	498	0.14%	10	NA	NA	530	6.5%	NA	NA
Kenya	$330	NA	22.1	361	150	0.04%	7	41.55	NA	200	2.4%	55.40	NA

TABLE 11 (CONT'D.)

Matrix of R&D Related Indicators

Country	GNP per Capita	GERD (M)	Pop. (M)	RSE	Papers	% of Papers	Papers/ Mil. Pop.	Papers/ Hrd. RSE	Papers/ M$ GERD	Research Areas	% Res. Areas	RAs/ Hrd. RSE	RAs/ M$ GERD
World (1985 Database)					339,544	100.00%				37,003	100.0%		
LATIN AMERICA													
Brazil	$2,020	$1,724	141.4	32,508	1,351	0.40%	10	4.16	0.78	2,258	6.1%	6.95	1.31
Argentina	$2,390	$896	31.1	10,486	983	0.29%	32	9.37	1.10	1,704	4.6%	16.25	1.90
Mexico	$1,830	$950	81.9	16,679	694	0.20%	8	4.16	0.73	1,397	3.8%	8.38	1.47
Chile	$1,199	$74	12.3	1,587	513	0.15%	42	32.33	6.94	1,031	2.8%	64.97	13.95
Venezuela	$2,717	$188	17.3	4,568	246	0.07%	14	5.39	1.31	475	1.3%	10.40	2.52
Colombia	$1,240	NA	29.5	NA	51	0.02%	2	NA	NA	92	0.2%	NA	NA
Peru	$1,470	NA	20.2	4,058	34	0.01%	2	0.84	NA	87	0.2%	2.14	NA
Jamica	$940	NA	2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EASTERN EUROPE													
Poland	$1,930	NA	37.7	NA	2,902	0.85%	77	NA	NA	3,861	10.4%	NA	NA
Dem.Rep.Germany	NA	NA	NA	NA	2,474	0.73%	NA	NA	NA	NA	NA	NA	NA
Czechoslovakia	NA	NA	NA	NA	1,976	0.58%	NA	NA	NA	2,775	7.5%	NA	NA
Hungary	$2,240	NA	10.6	NA	1,533	0.45%	145	NA	NA	2,505	6.8%	NA	NA
Yugoslavia	$2,480	$23	23.4	NA	751	0.22%	32	NA	32.65	1,271	3.4%	NA	55.26
Bulgaria	NA	NA	NA	NA	594	0.17%	NA	NA	NA	NA	NA	NA	NA
Rumania	NA	NA	22.9	NA	403	0.12%	18	NA	NA	NA	NA	NA	NA

FIGURES

FIGURE 1A

SCOPE OF RESEARCH ACTIVITY IN 1985 MODEL:
PACIFIC RIM AND SELECTED COMPARISON NICs

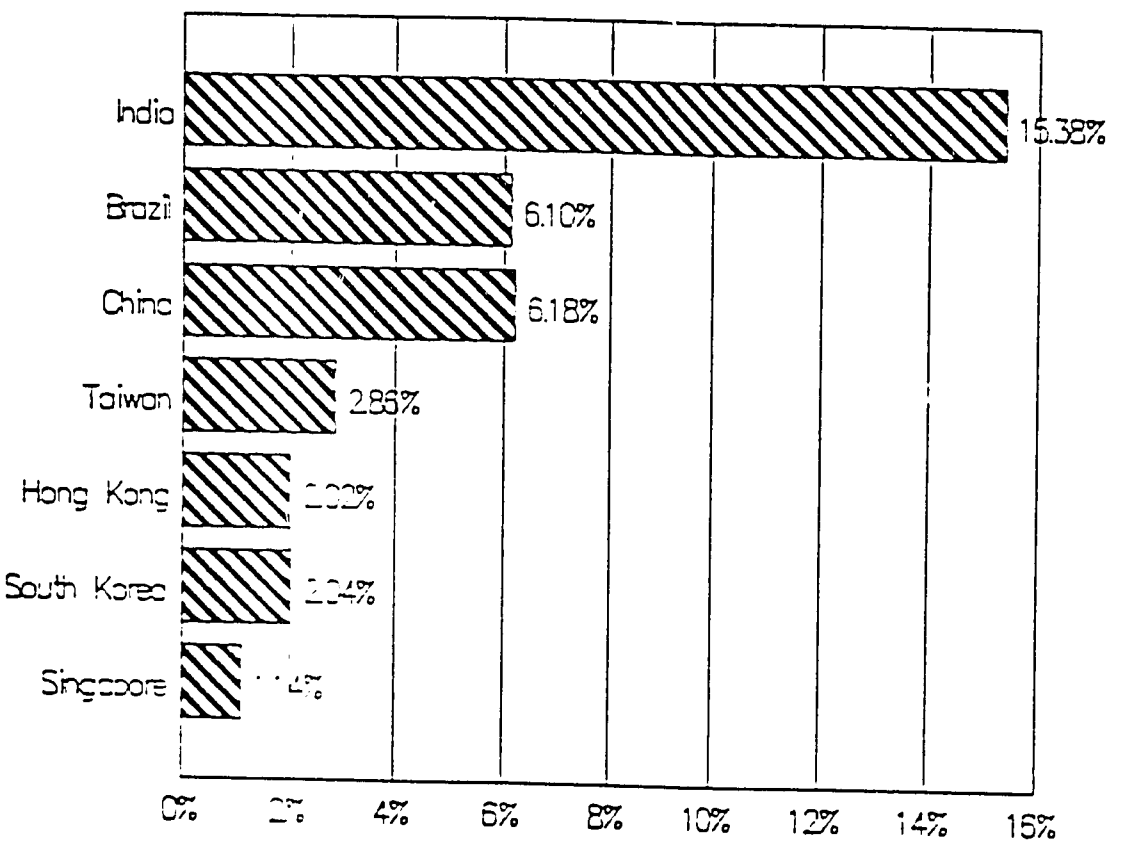


FIGURE 1B

SCOPE OF RESEARCH ACTIVITY IN 1985 MODEL:
PACIFIC RIM DEVELOPING COUNTRIES

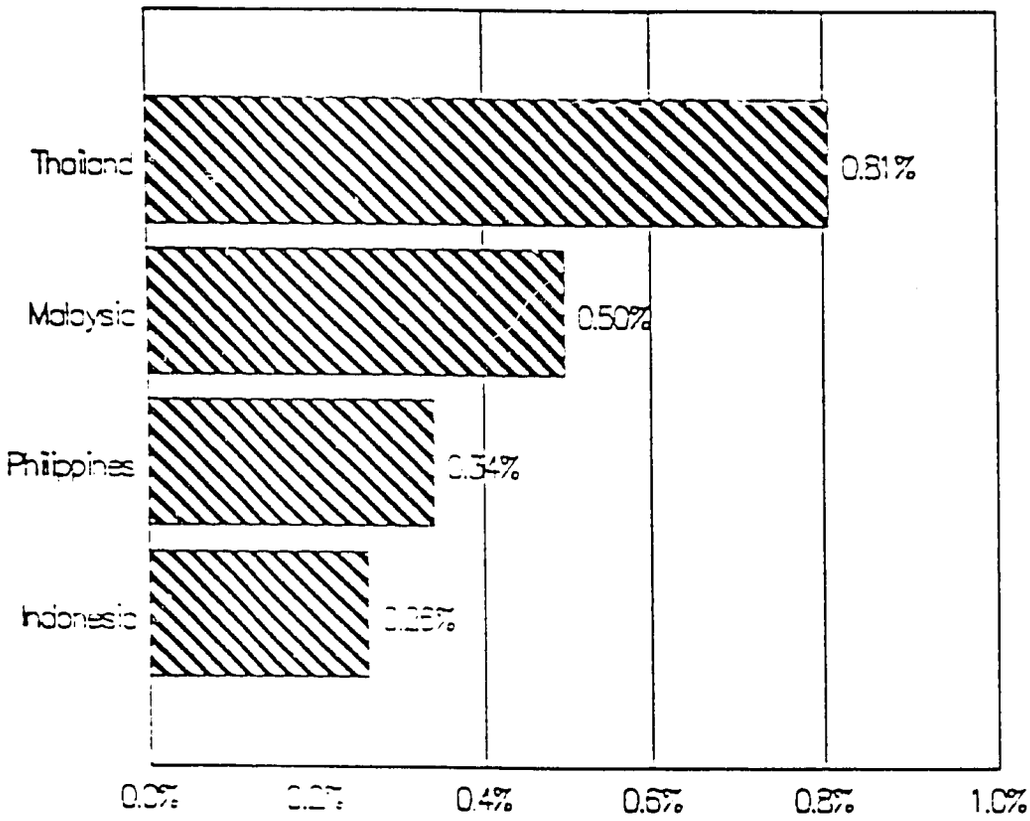
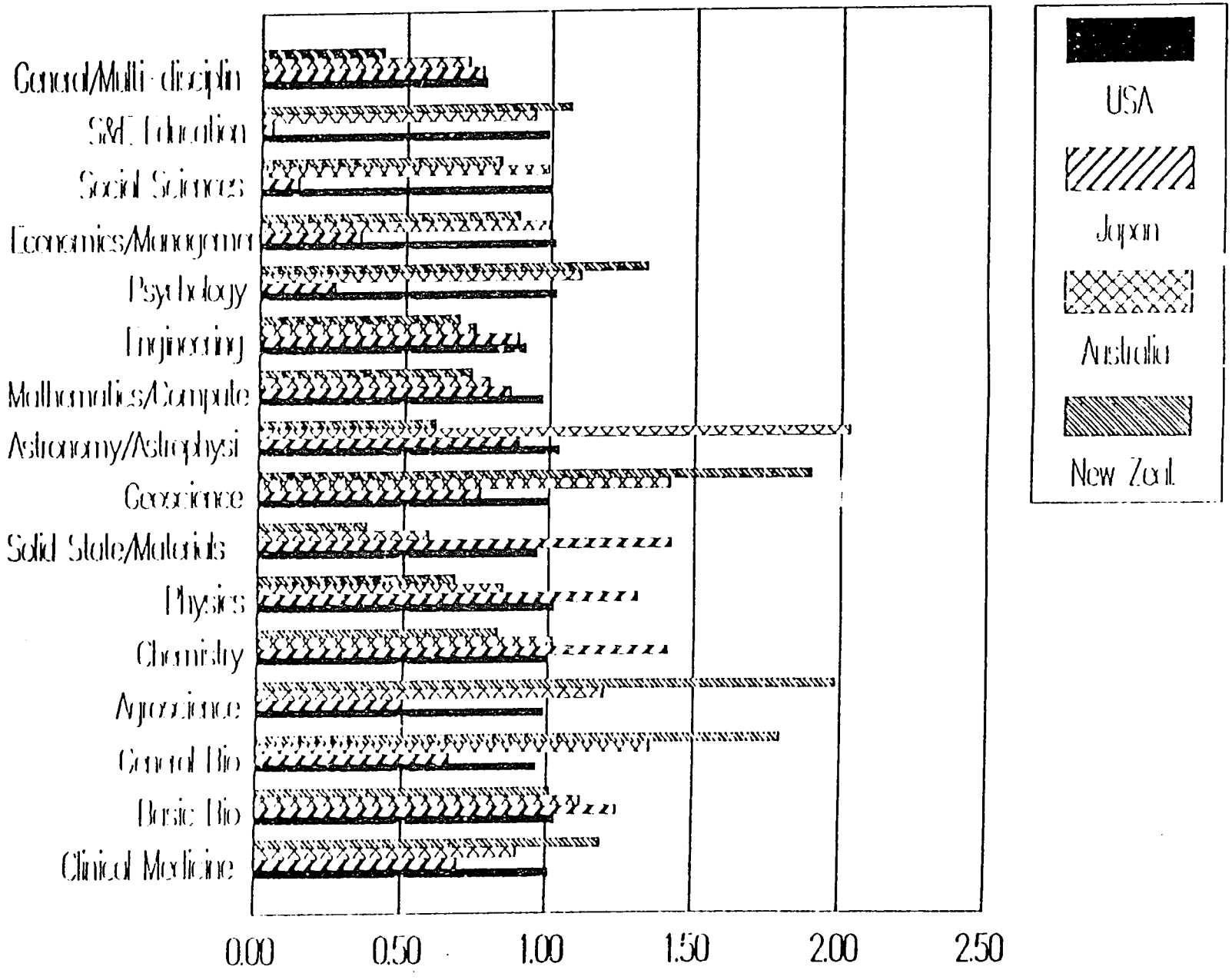
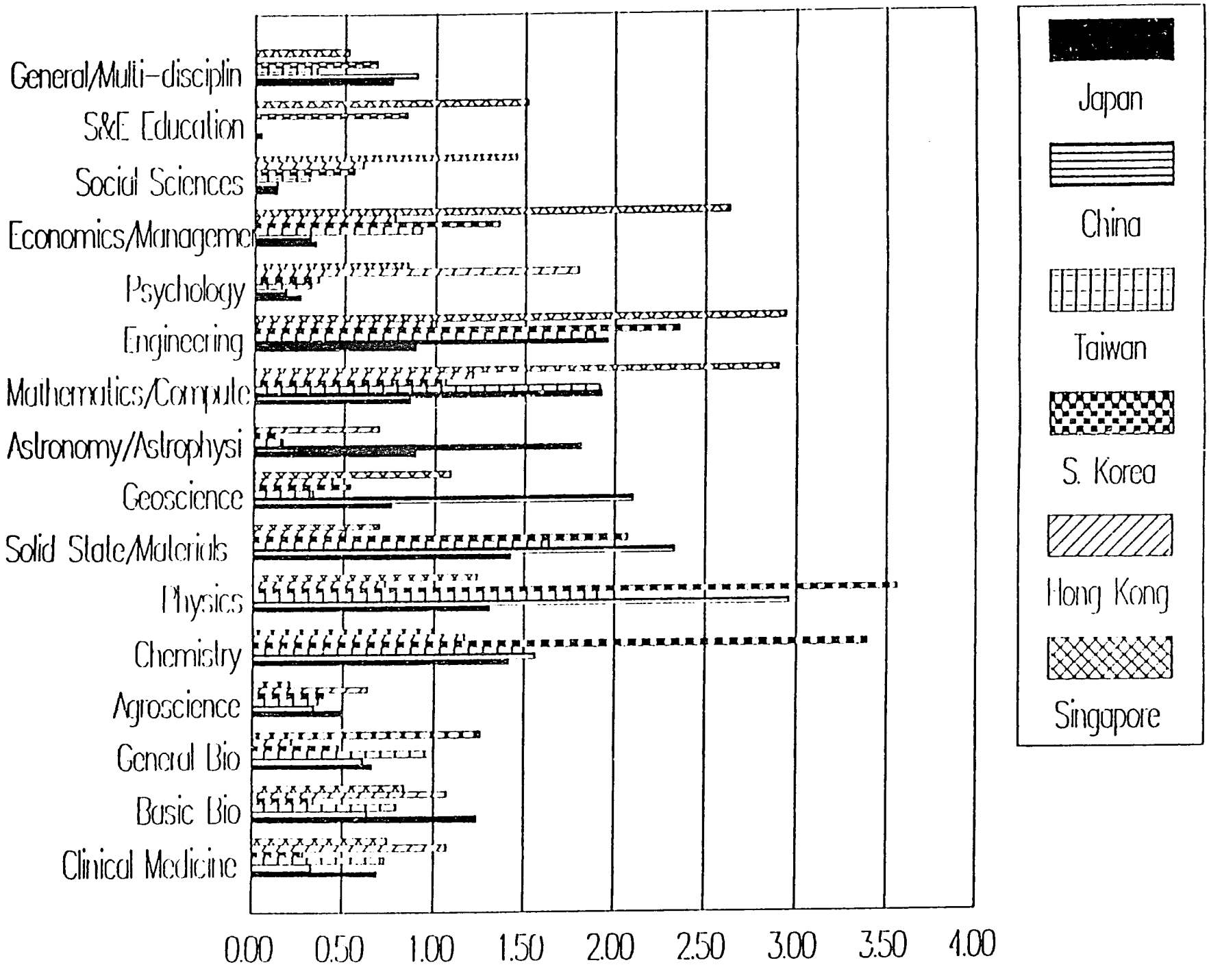


Figure 2A: EMPHASIS RATIO: INDUSTRIALIZED COUNTRIES

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S&E Education
Social Sciences
Economics/Managemen
Psychology
Engineering
Mathematics/Compute
Astronomy/Astrophysi
Geoscience
Solid State/Materials
Physics
Chemistry
Agroscience
General Bio
Basic Bio
Clinical Medicine
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Japan
China
Taiwan
S. Korea
Hong Kong
Singapore

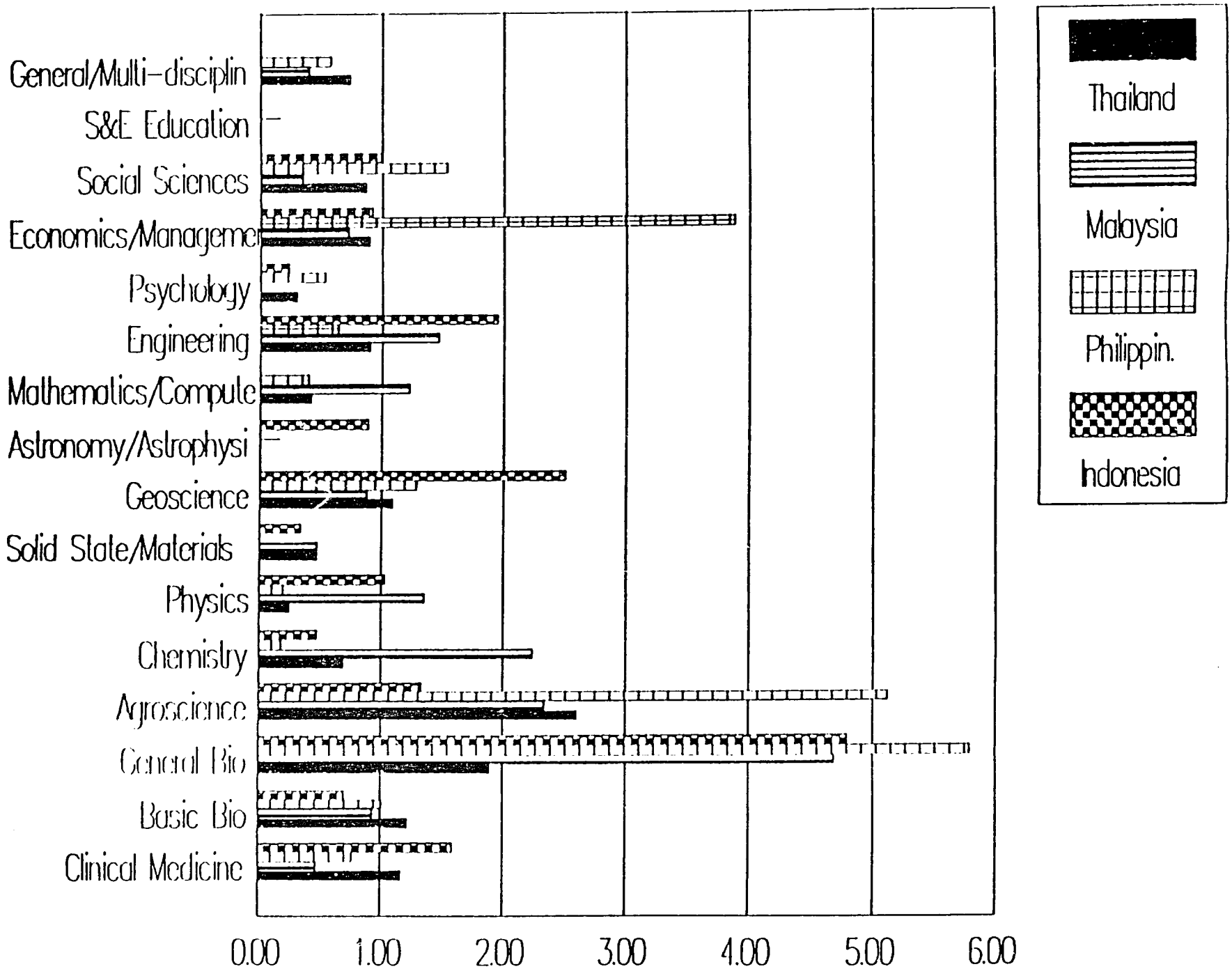

General/Multi-disciplin
S&E Education
Social Sciences
Economics/Managemer
Psychology
Engineering
Mathematics/Compute
Astronomy/Astrophysi
Geoscience
Solid State/Materials
Physics
Chemistry
Agroscience
General Bio
Basic Bio
Clinical Medicine
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Thailand
Malaysia
Philippin.
Indonesia

FIGURE 3A

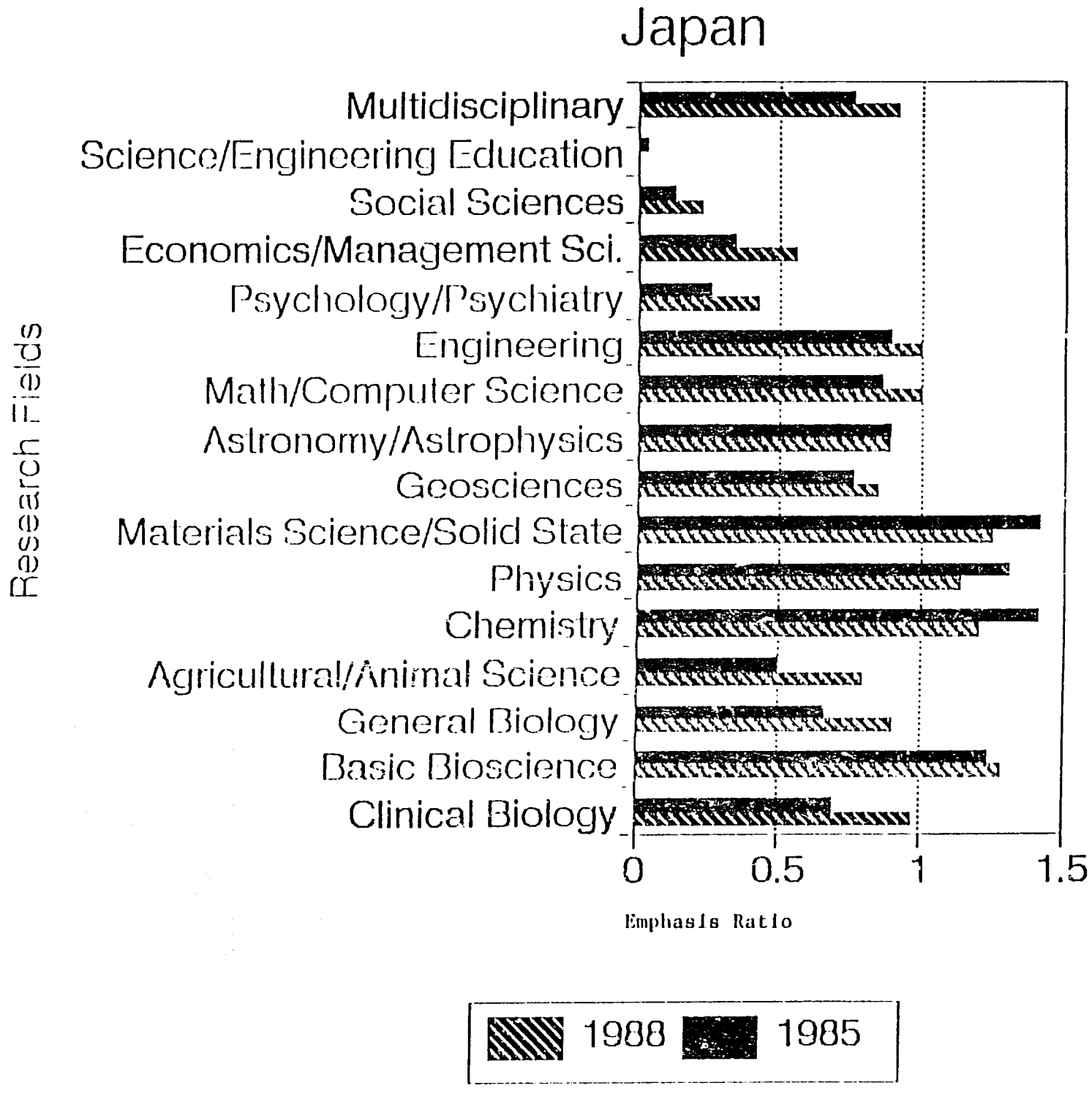

Japan
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0
0.5
1
1.5
Emphasis Ratio
1988
1985

FIGURE 3B

People's Republic of China

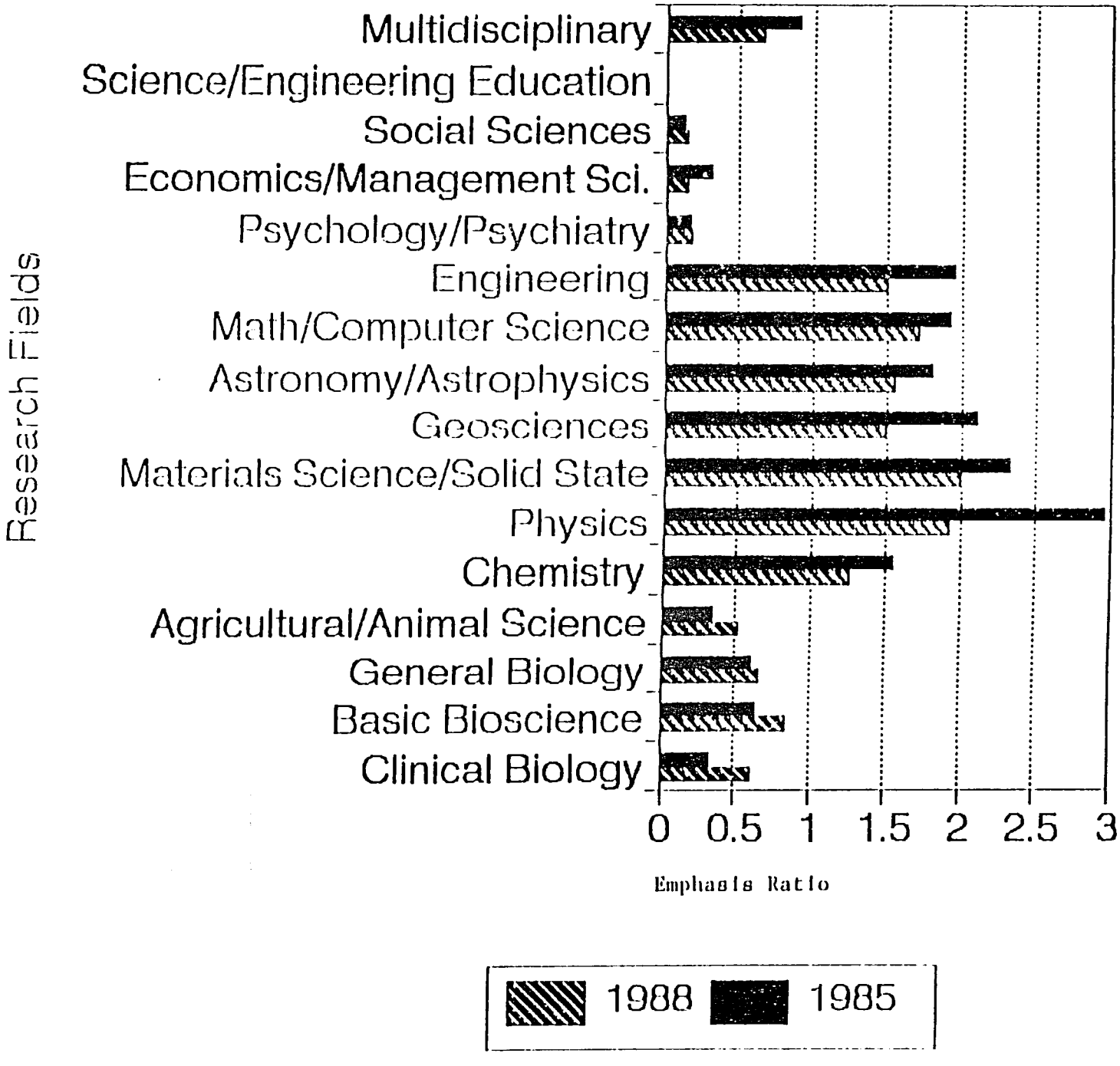


FIGURE 3C

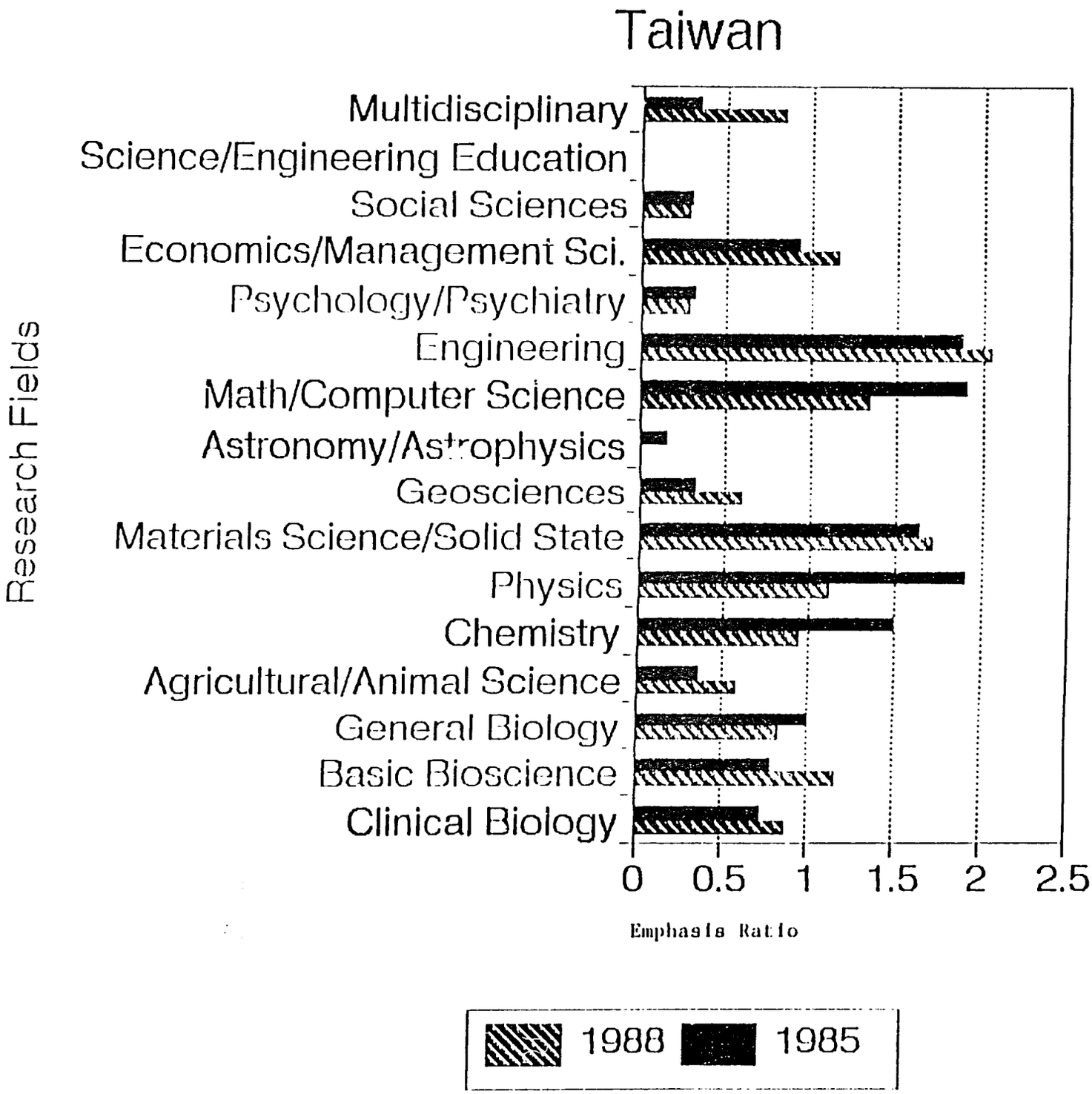

Taiwan
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0
0.5
1
1.5
2
2.5
Emphasis Ratio
1988
1985

FIGURE 3D

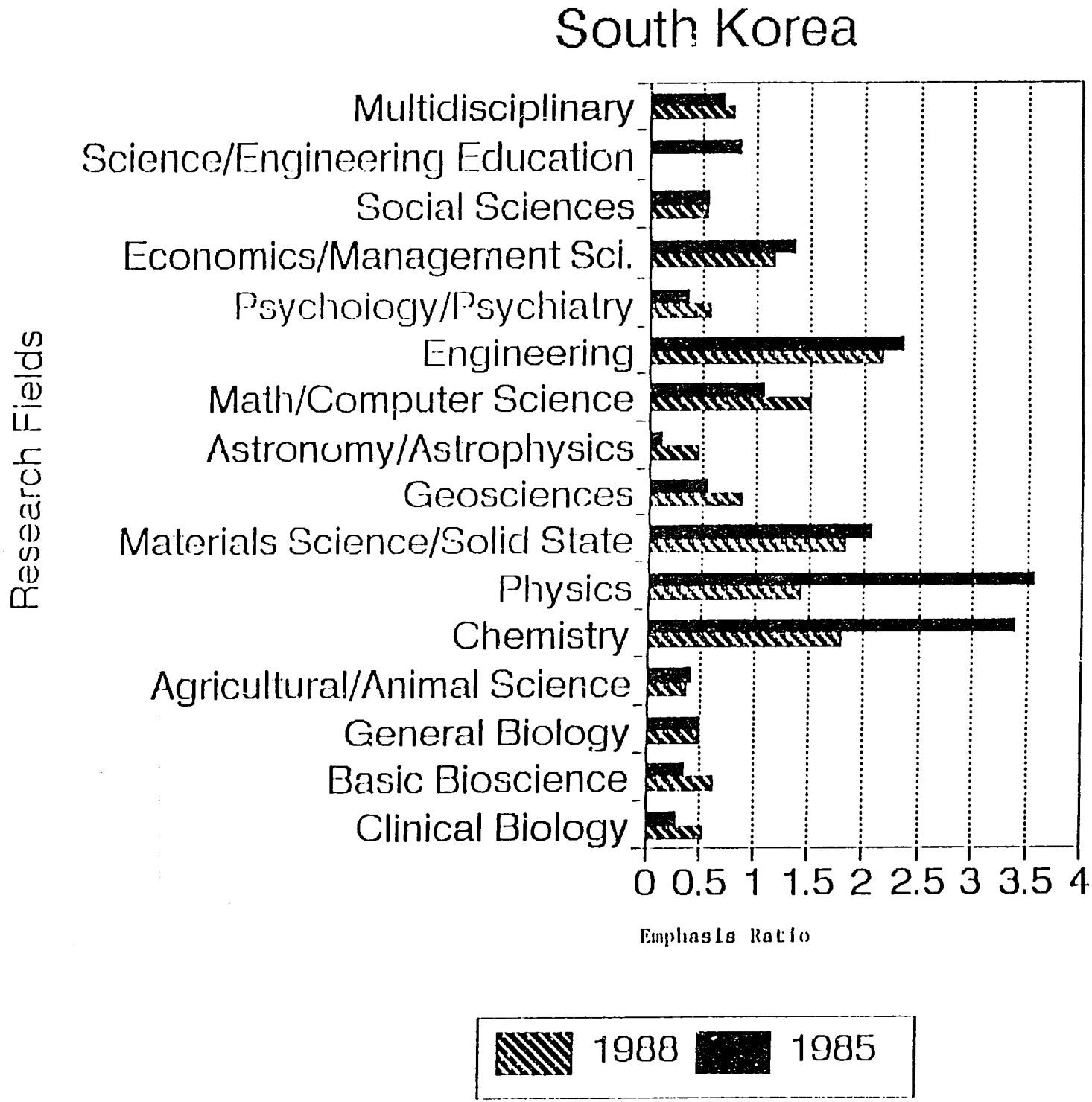

South Korea
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0 0.5 1 1.5 2 2.5 3 3.5 4
Emphasis Ratio
1988
1985

FIGURE 3E

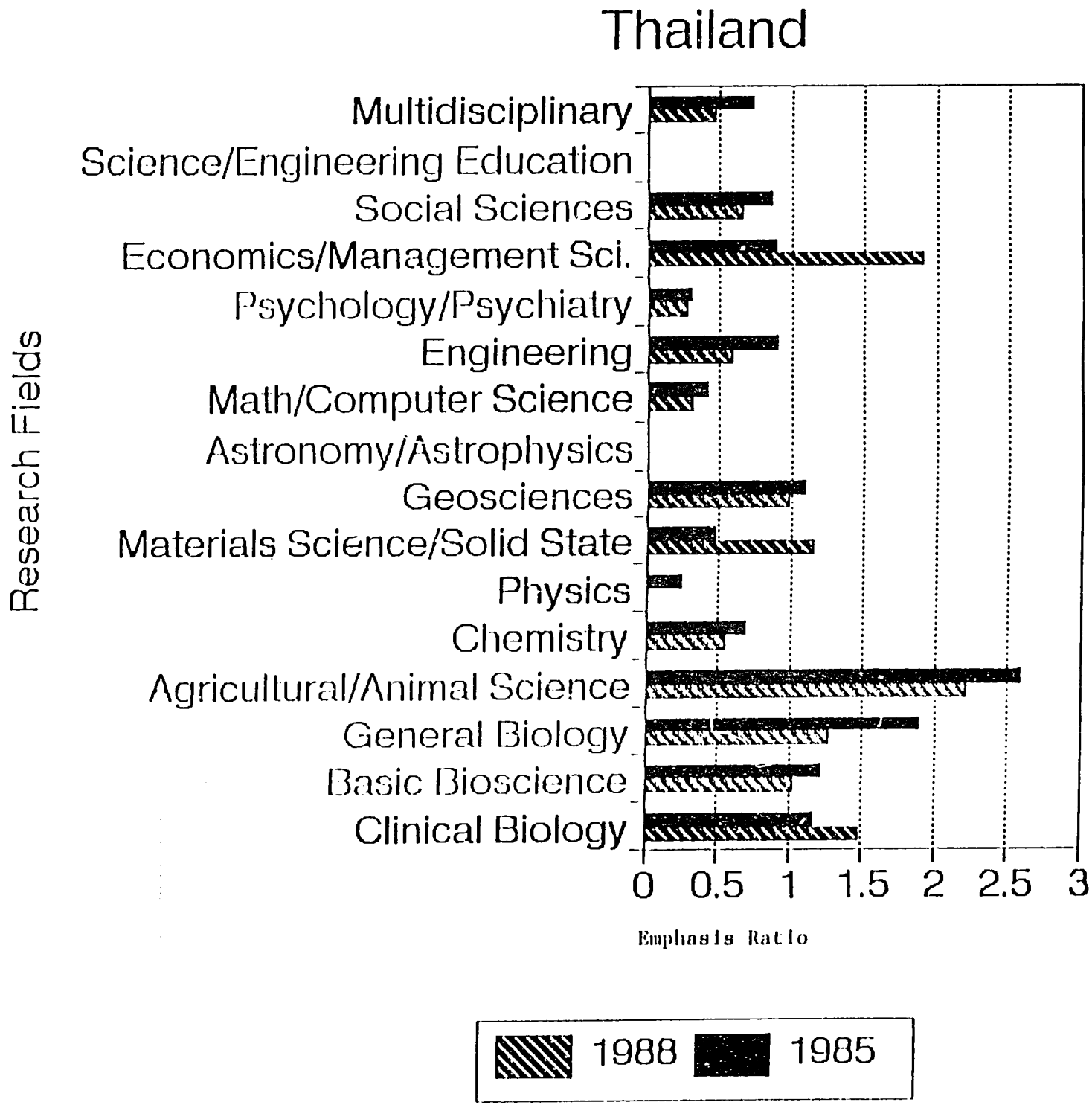
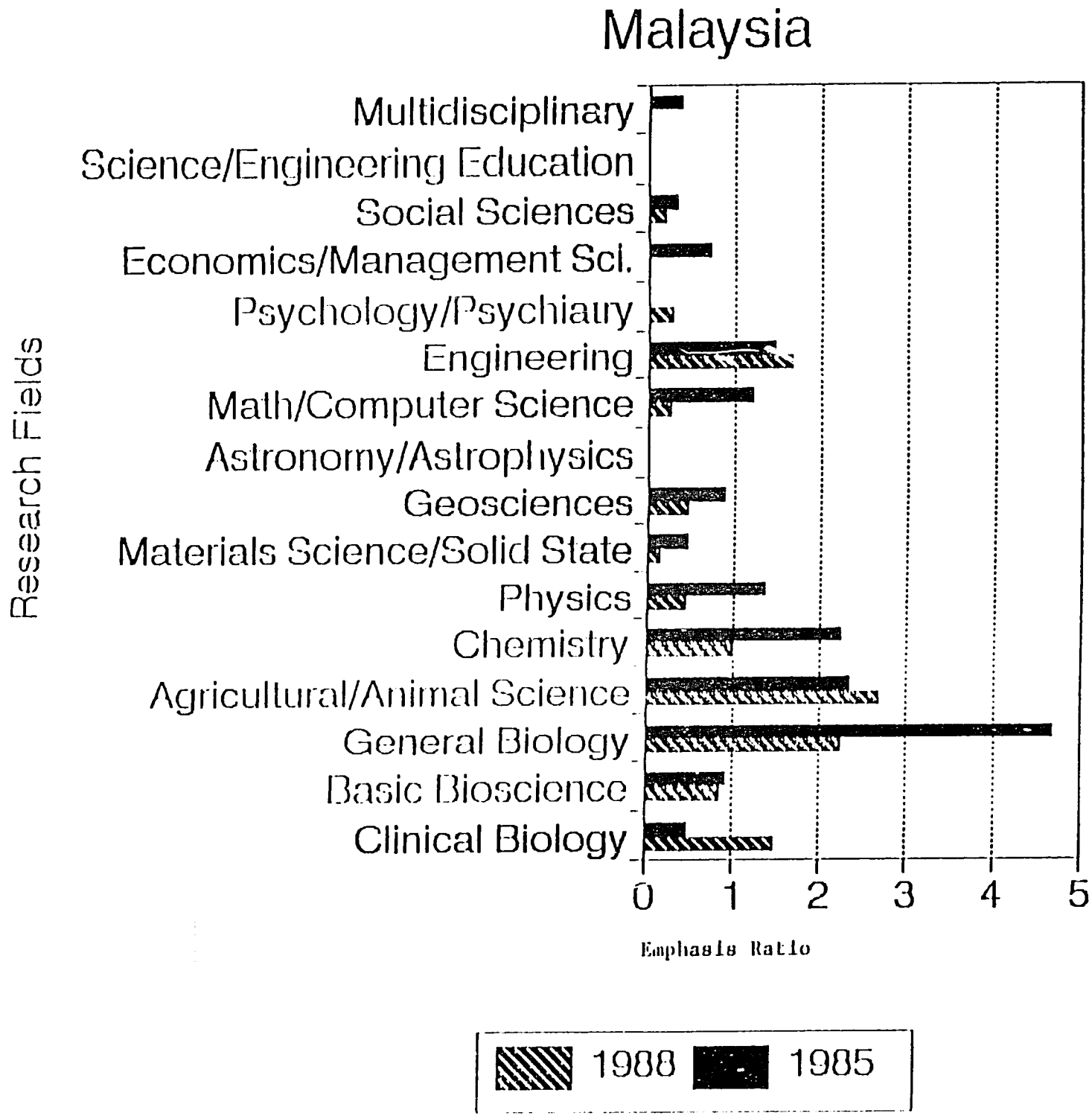

Thailand
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0
0.5
1
1.5
2
2.5
3
Emphasis Ratio
1988
1985

FIGURE 3F


Malaysia
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0
1
2
3
4
5
Emphasis Ratio
1988
1985

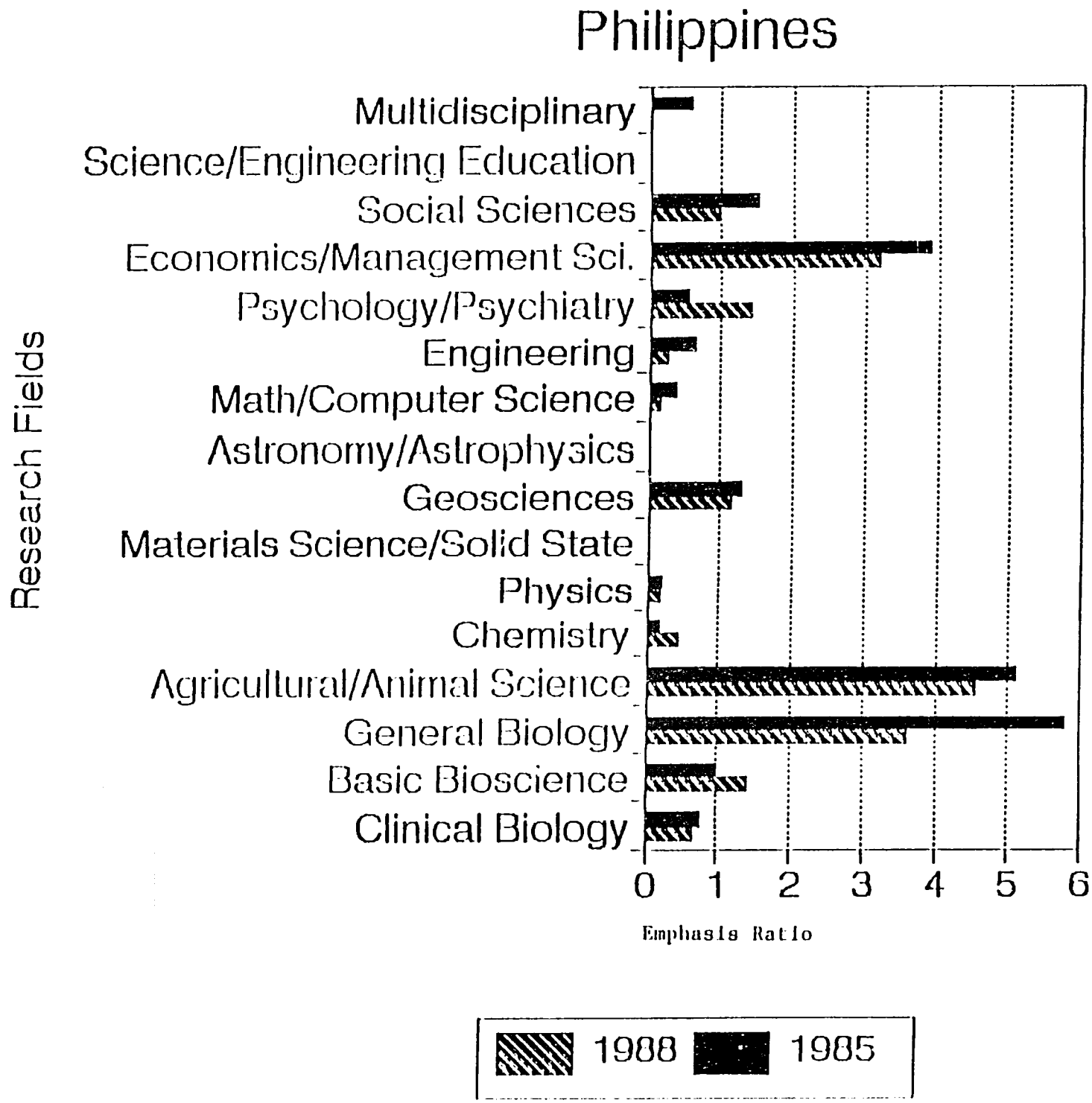

Philippines
Research Fields
Multidisciplinary
Science/Engineering Education
Social Sciences
Economics/Management Sci.
Psychology/Psychiatry
Engineering
Math/Computer Science
Astronomy/Astrophysics
Geosciences
Materials Science/Solid State
Physics
Chemistry
Agricultural/Animal Science
General Biology
Basic Bioscience
Clinical Biology
0
1
2
3
4
5
6
Emphasis Ratio
1988
1985

FIGURE 4A

Poland

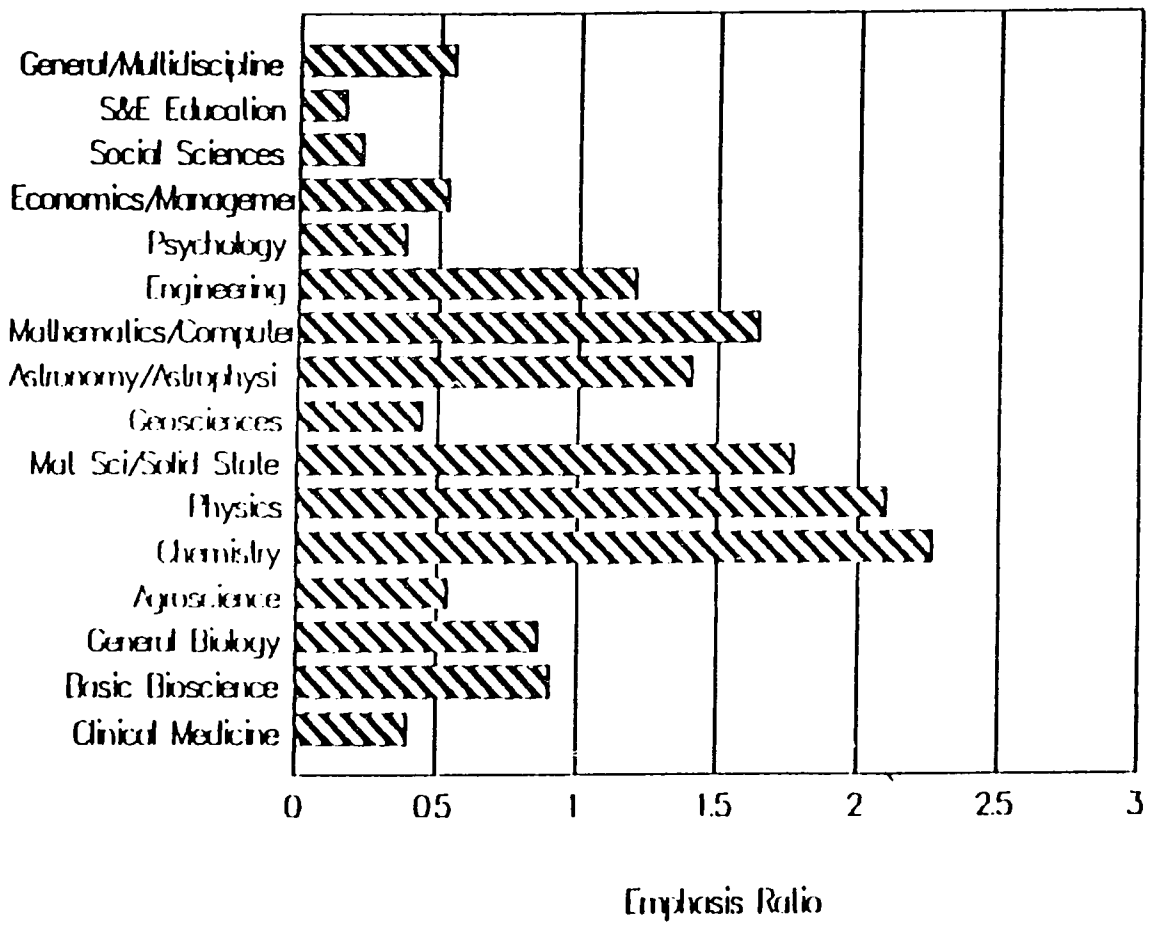


FIGURE 4B

Czechoslovakia

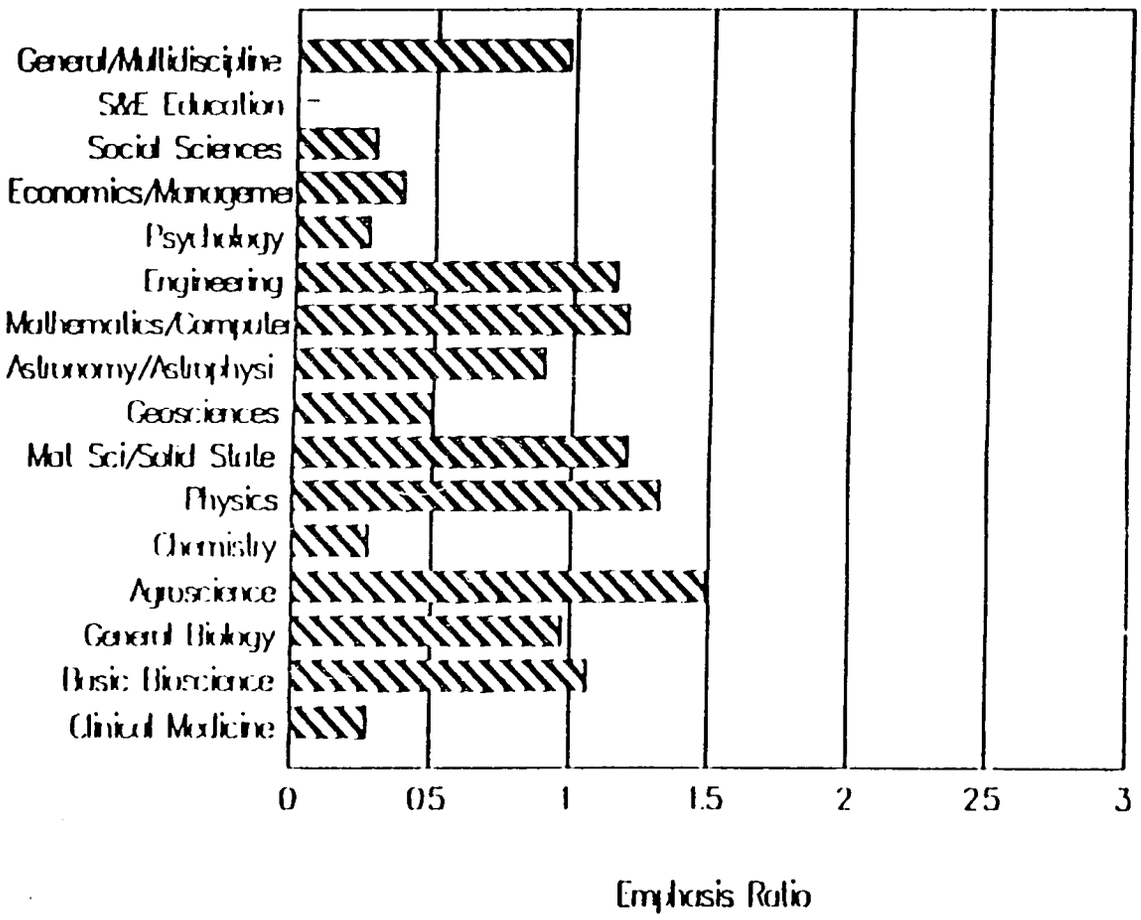


FIGURE 4C

Hungary

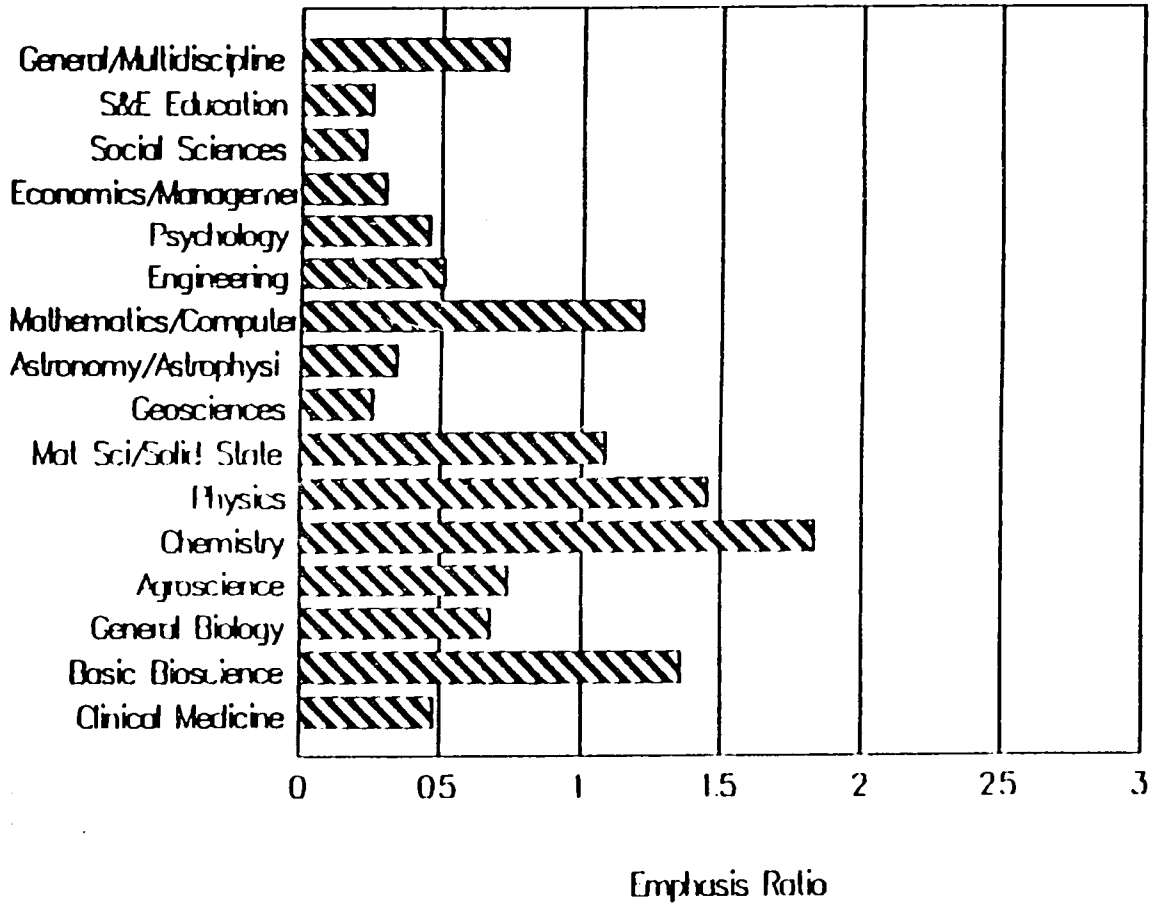
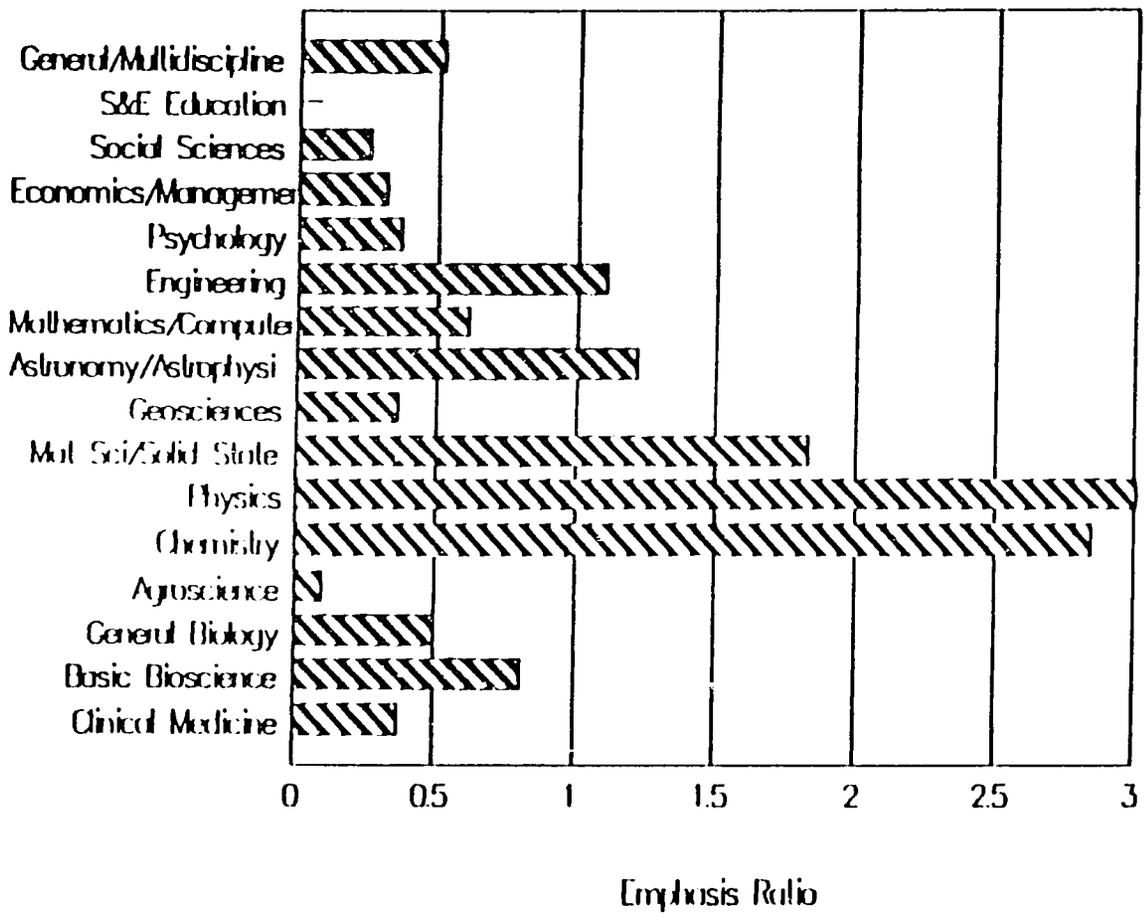


FIGURE 4D

Yugoslavia