POPULATION, RESOURCES, AND TECHNOLOGY: POLITICAL IMPLICATIONS OF THE ENVIRONMENTAL CRISIS

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Virtually everyone recognizes the existence on an environmental crisis in the world today, but many uncertainties remain concerning the precise nature of this crisis and its domestic and international implications. This much is clear: The world's population is continuing to grow at an alarming pace; finite resources are being utilized at exponential rates; and technological advances are contributing to negative ecological outcomes. These trends have been documented extensively. Their political significance, however, has received little attention if only because the visibility of the problem is such a recent phenomenon. This article is addressed to some of the political consequences and international implications of the environmental crisis.

I. INTRODUCTION: PROBLEMS AND PERSPECTIVES

The magnitude of man's impact on his environment necessitates a readjustment of current perspectives on ecological issues and a redefinition of our conventional views concerning social and political order, both domestic and international.[1] We are now confronted with the need to examine the effects of variables that have been generally viewed as nonpolitical in nature. The problem is to specify those ways in which international politics and the environmental crisis are interrelated and to chart the linkages between ecological and political perspectives. Networks of interdependence are intricate and complex;

[1] See *Man's Impact on the Global Environment: Assessment and Recommendations for Action,* Report of the Study of Critical Environmental Problems (Cambridge, Mass: Massachusetts Institute of Technology, 1970); *Environmental Quality: The Second Annual Report of the Council on Environmental Quality, together with the President's Message to the Congress* (Washington: Government Printing Office, August 1971); and Walt Anderson, ed., *Politics and Environment: A Reader in Ecological Crisis* (Pacific Palisades, Calif: Goodyear Publishing Co., 1970).

an issue that might appear to be only of national concern may have global implications. But it is naive, premature, and empirically invalid to suggest that the environmental crisis will necessarily result in greater international cooperation. The opposite is equally plausible. A realistic assessment of the present situation must weigh the evidence between these two hypotheses. This article takes one step in this direction by summarizing the relevant evidence pertaining to various aspects of the environmental crisis and by highlighting the actual as well as the potential political implications. We do not anticipate arriving at any clear answers, but we must begin to put the pieces together by identifying those parameters that are critical for both research and policy planning.

The interrelationships between man's impact on his environment and his attempts to manipulate and control that environment provide the key for defining the problem. Of the numerous relevant dimensions the most basic and the most critical are those related to population dynamics, resource constraints, and technological developments. These may be thought of as distinct vectors of the environmental crisis, but their interdependence makes the resulting dynamics highly interactive. Sources of environmental problems attributable to population growth can rarely be distinguished from the effects of technological advancement or the underlying resource base. It is also difficult, if not impossible, to isolate the political consequences of population growth from those pertaining to technology or to resources. The population equation is generally defined in terms of the accompanying resource and technology calculus. For purposes of analysis, therefore, it is difficult to examine independent, intervening, and dependent effects without becoming entangled in dynamics of feedback and reciprocal causation.

We break down the problem to discuss: 1) the international implications of population dynamics, resource constraints and distribution, and technological developments; 2) the interdependencies and reverberating effects associated with efforts to cope with any one dimension singly; and 3) the ways by which the conduct of research in the academic community may address itself more clearly to environmental problems. A social science perspective is adopted here, but a certain amount of technical and scientific detail is also necessary for any analysis of this kind. Our concern is with the political—and potentially conflictual—implications of the present global predicament. A prime objective will be to highlight the implications for more technologically developed as well as less developed societies. In this regard our empirical analysis will center specifically around Japan, the People's Republic of China (Communist China), the Union of Soviet Socialist Republics, and the United States.

II. POPULATION DYNAMICS: MEASUREMENT PROBLEMS AND POLITICAL ISSUES

There are many uncertainties regarding the precise nature of the population problem and extensive disagreement as to the optimal mode of analysis to employ. The issue is inevitably defined in terms of referent variables (i.e., space, food, and resources) and as a problem of variable dimensions (i.e., levels, rates of growth, distributions, compositions, densities, or movements), all of which depend largely upon the choice of referent variables. To complicate matters further there are considerable statistical uncertainties pertaining to population projections and estimates of the earth's carrying capacity, and there are economic, political, and cultural uncertainties concerning potential sources of constraints on population growth.

Turning first to statistical uncertainties, we observe that existing data on levels and rates of growth, and on projections and expectations, are fraught with ambiguity and error occasioned as much by the difficulties of compiling accurate statistics (or gauging the range of measurement error) as by the choices of intervening sociological or economic indicators. United Nations projections, for example, are generally based upon the assumption of continuing progress in economic and social development and upon the continued availability of needed resources.[2] Variability in these assumptions inevitably colors the nature of the projections and, by extension, our assessments of the problem.

The United Nations Statistical Office publishes three variants of world, regional, and national population projections. These are designed to represent different assessments of error around the most plausible estimates. They are useful for research and policy planning, but considerable caution must be exercised concerning their potential sources of error. UN statistics are generally based upon the official data of member countries. Possible errors or deliberate modifications of official statistics make it difficult to assess their accuracy. In addition, since population projections are intimately tied to economic and social projections, errors in estimates of growth and development are invariably felt in demographic assessments. In view of these ambiguities some experts have concluded that we are "playing with predictions that are wrong and have always been wrong."[3] More im-

[2] United Nations, Department of Economic and Social Affairs, *World Population Prospects as Assessed in 1963* (Population Studies, No. 41) (United Nations Publication Sales No: 66. XIII. 2 [UN Document ST/SOA/Ser. A/41]) (New York, 1966), p. 6.

[3] M. C. Shelesnyak, ed., *Growth of Population: Consequences and Controls: Proceedings of the First Conference of Population Held at Princeton, New Jersey, September 27-30, 1968* (New York: Gordon & Breach, Science Publishers, 1969), p. 57.

portant, however, is the direction of error: To date, population projections have consistently *underestimated* potential rates of growth.

Alterations made in the UN projections between 1963 and 1968 are illustrative of possible errors (although there is no assurance that the projections corrected in 1968 will prove more accurate than their predecessors). "By 1985 . . . the revised projections add 187 million (4.0 per cent) to the world total as assessed in 1963, of whom only 19 million are in the more developed regions (1.5 per cent of their total) and 168 million in the less developed regions (4.8 per cent of their total)."[4] Such adjustments result mainly from modification of mortality and fertility assumptions in less developed countries.

There are related statistical uncertainties involving the earth's capacity to sustain the burgeoning population. According to some calculations the food supply might be increased ninefold with the cultivation of all possible land and the utilization of considerable technological advances; given adequate distributions, such levels of output could sustain a global population of 30 billion.[5] At present rates of growth this level would be reached within 100 years. Estimates of the earth's carrying capacity, however, have also been conservative. Partially biased or more optimistic assessments of carrying capacity center around 40 billion. The difficulty with all of these estimates is that they often disregard synergistic effects and chain reactions involving technological innovations and utilization of untapped resources. Such effects might enable the earth to support an even larger population than has been estimated to date. Conversely, synergistic effects could also exacerbate an already critical situation.

In view of these statistical uncertainties, coupled with basic definitional and empirical disagreements concerning optimum population levels, it is difficult to assess the validity of either optimistic or pessimistic views. Also, the concept of "optimum" is fraught with built-in conceptual problems many of which are related to the referent variable. The basic question is: "Optimum with respect to what?" The economic optimum is not necessarily congruent with the political optimum. At the level beyond mere subsistence the optimum may be culturally and sociologically defined; it is thus impossible to employ this concept as a useful measuring instrument for a precise definition of the population problem.

If we assume that growth cannot continue forever, we must examine the mechanisms by which added population places undue

[4] United Nations, Population Division, *World Population Prospects, 1965-1985 as Assessed in 1968* (Working Paper, No. 30) (New York, 1969), p. 7.

[5] In this regard see United States House of Representatives, Subcommittee of the Committee on Government Operations, *The Effects of Population Growth on Natural Resources and the Environment, Hearings,* 91st Cong., 1st sess., September 15-16, 1969, p. 5.

pressures on material and psychological needs and constraints upon further growth. But where are the sources of constraints to be found? Basic to the constraint question are the dual vectors of absolute global *shortages* of life-sustaining materials versus imbalances in regional *distributions*. In each case experts tend to identify the sources of potential dislocation with 1) food, 2) availability of resources, and 3) general environmental quality. But there is strong disagreement concerning the relative importance of each factor in constraining population growth.

Let us turn first to the political implications of the food situation. Studies undertaken by the Food and Agriculture Organization (FAO) have found the relationship between population growth and food needs to be one of almost perfect positive correlation. Future trends in food demand are almost totally dependent upon future populations. At the 1965 United Nations World Population Conference it was estimated that in order to meet food needs with a modest improvement in the quality of diet "the total food supplies will have to be increased by 43 per cent by 1970, 103 per cent by 1980 and 261 per cent by 2000."[6] Because of cultural problems and the long time lags involved birth control or fertility reduction cannot be considered an immediate solution to expected food shortages. Viewed in these terms, two perspectives on the food issue converge: the technological feasibility of increasing supplies versus the sociological feasibility of constraining demand and adjusting tastes to novel diets and substitute crops. It is not uncommon for technological solutions to be neutralized by cultural opposition.

Much of the prevailing optimism concerning the food situation emanates from technological considerations. Marxist spokesmen are perhaps the most positive when appraising the future capabilities of food production. From their perspective the critical issues pertain to distribution and management and not to the earth's productive capacity.[7] Yet, the proposition that the world is becoming increasingly unable to feed itself is also rejected by authorities in the West. The key issues are less those of distribution than of damage to the earth occasioned by the extensive use of fertilizers and accompanying strains on yield and productive capability. In these terms technological advances allow for increased yield; but yield increase often produces added burdens on the earth's capabilities.

[6] United Nations, Department of Economic and Social Affairs, *Proceedings of the World Population Conference, Belgrade, August 30-September 10, 1965* (United Nations Publication Sales Nos: 66.XIII.2-5 [UN Documents E/CONF. 41/2-5]) (New York, 1966), Vol. III: *Selected Papers and Summaries of the Papers for Meetings*, p. 421.

[7] K. M. Malin, "Food Resources of the Earth," in ibid., p. 390.

When viewed in a regional context, however, the food problem assumes new dimensions revealing a serious gap between developed and developing countries in their ability to meet their food requirements. The interactive effects of the food and technology gaps make each even more salient than would otherwise be the case. The inevitable interjection of political discourse when confronting these differentials adds further uncertainty to an already complex system of relations.

Of the many factors in the food problem the transfer of food is especially fraught with critical international implications. The salience of the food issue in developing societies is such that in today's world the development of international guidelines for food distribution ranks in importance with the need for guidelines in international transfers of knowledge and skills. In this context the domestic situation of donor countries is an important factor influencing the possibilities for the development of international food transfer guidelines. For example, the ability of the United States to supply a substantial part of the future world deficit is undoubtedly curtailed by the expansion of urban areas at the expense of cropland. Despite technological advances it is expected that future demands for recreation will further restrict agricultural output. In this respect it is estimated that, by the year 2000, "satisfaction of all projected demands would mean the use of every acre in the 48 contiguous states, including deserts, mountain peaks, and marshes. Even at that, there would result a net shortage of 50 million acres. . . . Excluding recreational needs there would still be a shortage."[8] We need not generalize from the United States case to Canada or to other donor countries for this much is clear: Levels and rates of population growth, in combination with levels and rates of technological development, give rise to demands that increasingly call upon the utilization of land for purposes other than agriculture.

Another key factor in the food transfer equation pertains to the usages of fertilizers. Aside from the problems of fertilizer shortages, of shortages in component minerals, or of the unanticipated negative consequences of fertilizer usages the increased fertilizer usage in recipient countries occasions corresponding increases in fertilizer imports. The case of Communist China may be the rule rather than the exception as the implications of growth trends reveal. Although it was in a position of agricultural self-sufficiency in the 1950s, Communist China is now dependent upon imports of grain and fertilizers. In view of present population projections it is expected that Com-

[8] Hans H. Landsberg, *Natural Resources for U.S. Growth: A Look Ahead to the Year 2000* (Baltimore, Md: Johns Hopkins Press [for Resources for the Future, Inc.], 1964), pp. 173-174.

munist China will need to increase its grain output by 50 to 60 million tons in the 1970s, requiring in the process 20 to 30 million tons of chemical fertilizers per year.[9]

The world's oceans have been proposed as a substitute for land in food production, but their contribution has been overestimated. At least within the next ten to twenty years they cannot be considered as economically realistic sources of food for mankind. Furthermore, basic international differentials in the distribution of knowledge and skills contribute to further inequalities in the eventual uses of oceans. Land-based production is still the only viable alternative.[10] Also, while migration of population within national boundaries might alleviate some regional shortages, migrations alone cannot be viewed as a globally applicable solution to national problems. Invariably international linkages will become more rather than less salient.

In view of these considerations we are forced to note the obvious: In many countries the meeting of food needs increasingly involves imports. International implications of national needs must be carefully examined. In the absence of international guidelines for the transfer of food and fertilizers such needs inevitably involve dependency relationships. We know that dependency relations are not new, but it is important to realize their potential implications. Recent investigations have indicated that the dynamics of conflict are invariably embedded within situations of dependency and that these are reinforced when dependencies extend across several issue areas thus possibly institutionalizing hostilities rather than diluting them.[11]

III. POLITICAL IMPLICATIONS OF POPULATION DYNAMICS: NATIONAL AND INTERNATIONAL PERSPECTIVES

Statistical uncertainties are matched by equally great uncertainties regarding the socioeconomic and political implications of continued population growth. The basic malthusian thesis that indefinite population growth will bring widespread poverty is applicable only under conditions of isolation from international trade, minimal standards

[9] Victor-Bostrom Fund and Population Crisis Committee, *Population and Family Planning in the People's Republic of China* (Washington, Spring 1971), pp. 12-13. This is an estimate of total annual fertilizer needs.

[10] The effects of the Green Revolution are not to be denied. But implications in the context of related factors, such as population growth and technological growth (or lag), are more ambiguous. See Graham Jones, *The Role of Science and Technology in Developing Countries* (New York: Oxford University Press, 1971).

[11] For a summary of recent findings see Robert C. North and Nazli Choucri, "Population and the International System: Some Implications for United States Policy and Planning" (Paper prepared for the National Commission on Population Growth and the American Future, August 1971).

of living, marginal flexibility in technology, and low energy output. In such cases fluctuations in food availability have direct effects on the number of people depending upon a given set of resources. Today such conditions are most closely approximated by the close to subsistence levels of many Asian and African countries. However, if one of these factors is absent, the malthusian rationale is undercut by the possibility of modifying the underlying resource base.[12]

In negating the malthusian premise the marxist perspective defines the problem in terms of distribution: If resources and technology were properly utilized and distributed, the entire population of the world could subsist on existing resources. The concept of absolute overpopulation is, in principle, denied. Missing from both the malthusian and the marxist perspectives is a sufficient appreciation of the implications of differential levels of technology and their repercussions on the viable resource base and on the external environment.

The nonmalthusian view, propounded by Jean Mayer, considers the relationship of changes in levels of wealth to changes in levels of population. The case is made for population control on exactly the inverse of the basic malthusian premise: Controlling the number of the rich is deemed far more crucial than controlling the number of the poor. This view highlights a basic reality of our times for the rich consume more, pollute more, and discharge greater amounts of waste in the atmosphere. In terms of the environmental crisis population control is a more critical problem in developed societies than in less developed societies in which technological deficiencies and low energy outputs do not cause large-scale, negative environmental outcomes. However, with increasing industrialization pollution and waste may not be readily avoided.

Yet, population control alone is not an adequate solution. Without resorting to the extremes of Paul Ehrlich's position it might be emphasized that population growth occasions a nonlinear, negative impact on the environment.[13] Thus, it is imperative that population, resources, technology, and environmental effects be considered jointly. No less important is a reassessment of the social, economic, and political rules and regulations that were developed at a time when the environmental crisis was less pronounced. We are presently witnessing the cumulative effects of dynamics that were set in motion much earlier than has been recognized. Indeed, the effects of population growth are characterized by long time lags. Inadequate assessments

[12] Edward A. Ackerman, "Population and Natural Resources," in *The Study of Population: An Inventory and Appraisal,* ed. Philip M. Hauser and Otis Dudley Duncan (Chicago, Ill: University of Chicago Press, 1959), pp. 637-638.

[13] Paul R. Ehrlich and John P. Holdsen, "Impact of Population Growth," *Science,* March 26, 1971 (Vol. 171, No. 3977), p. 1212.

of the problem might activate causal chains of reactions whose implications might not be fully understood and of whose consequences we are not fully cognizant.[14] Equally important is an emerging appreciation of 1) what it is that we need to be asking, 2) what it is that we need to know, and 3) what it is that we do know about the *political* implications of the present environmental crisis.

At a general level of abstraction recent trends seem to indicate that increased population means more government and that more government means greater regulation of individual behavior. The trend toward centralization emerges as much from the increasing complexity of social organization as from the recognition that resource constraints imposed by growing population need to be subject to discipline regarding their uses.[15] But there is no indication that this trend toward increased centralization continues on the supranational level. Scarcities might well obstruct the development of international organizations.

Among the most critical implications of increasing populations for political systems and social institutions are the following: Population growth places unavoidable and increasing demands for goods and services upon national government.[16] In underdeveloped countries it is generally the lowest economic or politically powerless groups which remain unattended in the allocation of resources and wealth. Severe problems of governmental management that result from population pressures are especially evident in countries that are both large and less developed. Aside from pressures on the allocation of resources numbers alone are not crucial to the political process in developing societies. But they are increasingly important in developed societies in which political participation is high and in which demands can be expressed proportionately to numbers. Related to this is the consideration that governments find themselves in a position to manipulate the population issue in desired ways. In countries where there are insufficient job opportunities there is a tendency to channel excess manpower into the educational system, thus overburdening educational facilities and artificially underemploying labor.

However straightforward these implications might be, their ramifications in terms of political instability or violent behavior are highly ambiguous. Indeed, there is no evidence that population densities

[14] Statement of E. F. Watt, *The Effects of Population Growth, Hearings,* September 15, 1969, p. 33.

[15] Emilio Q. Daddario, "Technology and the Democratic Process," *Technology Review,* July-August 1971 (Vol. 73, No. 9), p. 20.

[16] Myron Weiner, "Political Demography: An Inquiry into the Political Consequences of Population Change," in *Rapid Population Growth: Consequences and Policy Implications* (Baltimore, Md: Johns Hopkins Press, 1971), pp. 567-617.

per se lead to instabilities. Those correlations that do exist are spurious and do not hold cross-culturally. Many densely populated areas of the world have been highly stable, and many of the most unstable areas in Latin America and Africa have low population densities.[17] More rigorous, multivariate, statistical analysis of the relationship between density and internal violence or instability has reinforced this singular absence of relationship, causal or otherwise.[18]

The related proposition that density occasions external violence is also dubious. Many high-density countries lack the capabilities for effective expansion or external aggression. Whatever relationship exists is neither direct nor empirically evident. If at all causally connected, linkages between population and war are likely to be mediated by intervening effects of technological development and resource constraints.

This relationship is emphasized even more forcefully by Alfred Sauvy, past president of the United Nations Population Commission. The theory that "overpopulation causes wars is attractive at first sight: when men lack room they are held to feel the need to spread out and take the land and wealth of others." However, there are many highly populated countries that have not been expansionist and other less populated ones that have been highly belligerent. Sauvy is led to the conclusion that "wars are not due to unrest of compressed populations, but to differences in pressure."[19] Acutely overpopulated societies do not generally command the capabilities or resources for sustained military activity. Despite some prima facie evidence in this direction no one has yet demonstrated the direct link between population and war. This link, in fact, has been refuted in two large-scale, empirical studies of conflict and warfare.[20]

Conversely, the *interactive* effects of population growth, technological development, and resource constraints have, in several cases, contributed to the extension of national activities outside of territorial boundaries. For example, nineteenth-century colonial expansion was accompanied by considerable population growth in Europe in combination with increases in economic productivity and technological capabilities. Investigations by Robert North and myself have traced these dynamics to the outbreak of war in 1914 and to the subsequent re-

[17] Ibid.

[18] See, for example, Douglas Albert Hibbs, "Domestic Mass Violence: A Cross-National Causal Analysis" (Ph.D. diss., University of Wisconsin, 1971).

[19] Alfred Sauvy, *General Theory of Population* (New York: Basic Books, Publishers, 1969), p. 516.

[20] The Correlates of War Project, under the direction of J. David Singer, University of Michigan, and the Studies in International Conflict and Integration, under the direction of Robert C. North, Stanford University, both report this same absence of *direct* link between population (density) and war.

constitution of international politics during the interwar years.[21] Not unrelated are the official arguments presented by both the German and the Japanese leaderships in support of their positions and policies. *What is critical, therefore, is the nature of the population-resource-technology calculus.* Unless capabilities are available, unless a certain level of skills can be called upon, and unless certain resource needs or constraints are present, it is difficult to see how the population variable *alone* would provide important motivation for violence and warfare.

It is also frequently suggested that the widening gaps between affluent and poverty-stricken states will lead directly into war, the implication being that the starving millions will be goaded into violence by their misery. This is unlikely. The threat of international violence emerges less from such possibilities than from second- or higher-order effects linking competition and interactions between larger states to political considerations affecting poorer societies. When technological and resource variables are interjected into the equation, the calculus becomes one of mapping out linkages and transactions between technologically advanced and technologically deficient states, between resource-rich and resource-poor, and between high-energy and low-energy societies.

Not unrelated is the consideration that many of the resources vital to continuing growth and advanced industrial societies are located in poverty-stricken, low-energy, and low-technology societies. Their territories and accompanying resources supply the arena for potential conflicts and competition between more advanced states, and they themselves are likely to be under pressure to line up on one side or the other. Control and penetration by advanced industrial societies assures continuing flows of needed resources. The erosion of cold-war dynamics in no way militates against these processes. The use of trade, foreign aid, and other modes of transfer are rarely devoid of political pressures.

In these terms national propensities for expansion, conflict, and violence differ considerably depending upon the nature of the population-resource-technology calculus. States rating high on population, technology, and resources are likely to be associated with modes of international behavior markedly different from those associated with low population, low technology, and low resources—or variants thereof. Comparing states along these dimensions might highlight the political dimension. For example, the differences in modes of external

[21] Nazli Choucri and Robert C. North, "Dynamics of International Conflict: Some Policy Implications of Population, Resources and Technology," *World Politics,* supplementary issue on *Theory and Policy in International Relations,* forthcoming.

behavior throughout the past century between the Scandinavian countries and the major powers are illustrative of these interrelationships.[22] The Scandinavians were inclined to rely upon trade rather than upon colonial expansion for the satisfaction of needs and demands. There were many reasons why this was the case. Not incidental is the fact that the Scandinavians registered low on population, high on technology, and low on resources. Conversely, Germany and Japan, during the interwar period, were both high on population and technology and low on resources.[23] China in 1912 could be viewed as high on population, low on technology, and low on resources whereas today the balance is much more on the high population, high technology, and possibly even the high resources end of the continuum. To note the differences in China's external orientation over the past century may be to point to the obvious, but the differences are not unrelated to changes in attributes and capabilities of which population, resources, and technology are the most crucial.

Of course these comparisons are all relative, and what might be viewed as high in one context may be considered low in another. The intensely interdependent nature of these dynamics makes any generalizations extremely hazardous. Nonetheless, several inferences may be drawn from these sketchy comparisons: 1) Population alone has no political implications, domestically or internationally; 2) a state's population must be viewed in conjunction with its resources and technological capabilities; 3) different combinations of population and capability allow for different internal and external policies and behaviors; and 4) only through second-order effects do population variables assume any political importance.

In terms of *political* considerations the most critical international implications of the population-resource-technology calculus are those associated with conflict and violence. Elsewhere we have argued that major wars often emerge by way of a two-step process: first in terms of internally generated pressures toward expansion of interests that are occasioned by growing needs and demands and then in terms of reciprocal comparisons, rivalries, and conflicts for control over resources, valued goods, territory, or spheres of influence.[24] Each step is closely related to the other, and each is intimately tied to the nature of the underlying population-resource-technology differential.

[22] Nazli Choucri, with the collaboration of Robert C. North, "In Search of Peace Systems: Scandinavia and the Netherlands, 1870-1970," in *War, Peace and Numbers,* ed. Bruce M. Russett, forthcoming.

[23] Richard P. Lagerstrom and Robert C. North, "Germany and Japan: A Comparative Application of a Model of Expansion" (Paper prepared for the Western Political Science Association Meeting, April 8-10, 1971).

[24] Choucri and North, in *World Politics,* forthcoming. Also see Robert C. North and Nazli Choucri, *Nations in Conflict: Prelude to World War I,* in preparation.

A major part of contemporary international complexities can be traced to the fact that the highly industrialized countries, which contain only a small portion of the world's population, consume a disproportionate share (on a per capita basis) of the world's supply of energy-producing fuels and mineral resources. About 6 percent of the world's population consumes close to 40 percent of the world's processed resources year by year.[25] The imbalances are equally pronounced in the raw materials sphere: Thirty percent of the global population lives in industrialized areas and consumes about 90 percent of the total world production of energy and mineral resources.[26] Additionally, increasing trends toward the establishment of processing plants in technologically deficient areas are associated with differentials in labor costs.

While it is indisputable that benefits accrue to developing societies in their transactions with industrialized states, it is not our purpose to clarify the cost-benefit calculus for the parties involved. We seek only to highlight various implications of these differentials—in resources and in technology—for contemporary international politics. The empirical data we bring to bear on this issue and the inferences which they allow pertain specifically to four major powers—Communist China, Japan, the Soviet Union, and the United States—and their relationships with other states and potential global repercussions. Our concerns are mainly with the international implications of national behavior, with specific emphasis upon potential conflict-producing dynamics.

IV. ENERGY DEMANDS: INTERACTIVE EFFECTS OF POPULATION AND TECHNOLOGY

The combined populations of Communist China, Japan, the Soviet Union, and the United States amount to 1.3 billion, growing at an average rate of 1.3 percent per year. This growth will undoubtedly continue to generate rapidly increasing demands for both the mineral and energy-producing resources that are so critical to industrial processes. There is considerable disagreement between scholars and policymakers concerning the precise loads to be expected on economically available energy sources. While it is apparent that the more technologically advanced countries enjoy a crucial advantage in obtaining resources that are difficult to reach or that require high levels of knowledge and skills and sophisticated machinery to process, less apparent

[25] Daddario, *Technology Review,* Vol. 73, No. 9, p. 20.
[26] M. King Hubbert, "Mineral Resources and Rates of Consumption," in *Proceedings of the World Population Conference, 1965,* Vol. III, p. 318.

are the potential repercussions of existing technological differentials among the various states of the world. These differentials are compounded further by the impressive postwar increases in the number of sovereign states in the international system. This proliferation has vastly complicated the process of international interaction, and this is further exacerbated by sharp differentials in populations, in access to resources, and in levels of technological development.

One key to defining the energy vector of the environmental crisis lies in the consideration that every advance in technology—every application, every invention, and every discovery—requires resources from the environment. Historically, technological developments have given rise to new energy and resource requirements without marked advances in energy-saving and energy-producing technologies, and there is every reason to believe that future developments in technology will occasion more extensive resource requirements. Today there is greater agreement between experts on variable estimates of the extent or nature of future requirements than on optimal modes of meeting those requirements. By necessity the development of guidelines for present resource allocations to meet expected future needs is central to any energy calculus and accompanying political and economic implications.

Because the industrialized countries consume most of the world's production of energy, forecasts of energy supply and demand are generally calculated in terms of one or more advanced countries and largely as a function of projected changes in standards of living and associated needs. When continued access to external sources of energy is assumed, the short-term outlook for more developed countries appears to be adequate, if not optimistic. In a 1966 study the Organisation for Economic Co-operation and Development (OECD) concluded that "ample supplies will be available for OECD countries at reasonable costs to support continued economic growth up to 1980 and beyond."[27] There is every reason to believe that this estimate can easily be extended to the year 2000. However, when the assumption of continued access to external sources is relaxed, or when individual domestic sources of energy are examined, assessments such as these emerge in a new light: It becomes apparent that new sources of commercially available energy are required and implications of increasing reliance upon energy imports must be critically evaluated and reassessed.

Present and future reliance upon imported energy varies extensively. Some countries import chiefly for economic advantage—when

[27] Organization for Economic Co-operation and Development, *Energy Policy: Problems and Objectives* (Paris, 1966), p. 143.

the costs of imported fuels are lower than the costs of domestic exploitation—and others import from economic necessity. In many cases the situation is such that domestic sources are simply not available or present levels of technology do not permit internal exploitation at other than prohibitive prices. Among developed states the situation looks as follows: Measured in terms of metric coal equivalents, most industrialized societies—including France, the Federal Republic of Germany (West Germany), Japan, the Netherlands, the Scandinavian countries, the United Kingdom, and the United States—are net energy importers. According to recent United Nations figures the United States produced an annual average of about 37.5 percent of the world's total production of energy between 1955 and 1968 while consuming a little over 39.8 percent.[28] The balance is on the inflow side. Japan produced 2.1 percent of the world's total and consumed over 3.3 percent. Again the balance is on inflow. The West European countries all consumed a larger share of world energy than their contribution in terms of domestic production. By contrast, of all the industrialized states only the Soviet Union is a net exporter, producing considerably more than is utilized domestically. Although the Soviet Union produces and consumes less than one-half of the total energy processed by the United States, the absolute levels involved are still extremely high. During the same period Communist China seems to have struck a balance, consuming approximately as much as was produced internally.

There is a strong, positive relationship between industrialization, energy consumption, and standard of living.[29] In the United States, for example, each person on the average consumes more than 3100 calories every day, a standard shared by less than 10 percent of the world's population.[30] It has been estimated that if present growth rates were to continue, 130 years would be required for some of the poorer countries to reach the level of per capita income which is now characteristic of the richer countries. Some may take less, others much longer. But by that time, at present growth rates, the population of the poorer countries would reach 130 billion persons.[31]

Implicit in differentials of income and capability are certain

[28] See United Nations Statistical Office, *World Energy Supplies* (UN Documents ST/STAT/Series J, Nos. 4-12) (New York, 1961-1969).

[29] Gerald Manners, *The Geography of Energy* (London: Hutchinson and Co., 1964). Because the correlation between energy consumption and economic activity is so close, one is often used to estimate the other.

[30] Harrison Brown, James Bonner, and John Weir, *The Next Hundred Years: Man's Natural and Technological Resources: A Discussion Prepared for Leaders of American Industry* (New York: Viking Press, 1963), p. 10.

[31] Harrison Brown, "Science, Technology and the Developing Countries," *Bulletin of the Atomic Scientists,* June 1971 (Vol. 27, No. 6), p. 11.

critical considerations. For example, rapid increases in world population impose severe burdens on efforts to raise standards of living: An annual population growth of one percent requires an annual growth of 4 percent in national income in order to maintain existing standards of living.[32] A world population of seven billion, living at the economic standard of the United States, would require from 200 to 400 times the present annual rates of mineral resources consumption (and commensurate magnitudes of energy fuels).[33] Implications of this nature raise serious questions concerning the dominant form of transaction between developed and developing societies: raw material exchanges for finished products or industrial goods. Undoubtedly, the encouragement of trade with developing societies enhances chances of industrialization and provides needed capital and other goods. But, at the same time, the prospect of rising prices for both fuel and mineral resources associated with impending constraints or local shortages (defined in economic terms) undoubtedly works to the disadvantage of those societies less capable of meeting prices.

The sometimes symbiotic relationship between a major industrialized state and a predominantly agrarian or commercial society leads to dependency relationships which are generally termed patron-client, colonial-colonized, or penetrating state—host country. The labels differ according to the degree of institutionalization in the relationships and the extent to which patterns of interaction, exchange of goods, and transference of services are legitimated by formal alliance relationships or by other authoritative means of control. This is not to suggest that all relationships between unequal parties are exploitative in nature but rather that assistance and exploitation are sometimes closely related.

The political implications of transaction patterns are more clearly seen in the area of mineral resources than in the energy field. Critical to energy considerations is the fact that if all countries were to follow a path of industrialization charted by advanced societies, with accompanying patterns of consumption and demand, the problem of future supply would be vastly more critical than it is at present. Over the past twenty years demand for energy in the United States has increased at an average annual rate of 3.1 percent.[34] It is esti-

[32] Zdenek Vavra, "Projections of World Population (Distinguishing More Developed and Less Developed Areas at Present)," in *Proceedings of the World Population Conference, 1965,* Vol. 2: *Selected Papers and Summaries: Fertility, Family Planning, Mortality,* pp. 49-53.

[33] Statement by Preston E. Cloud, Jr., *The Effects of Population Growth, Hearings,* September 15, 1969, p. 6.

[34] United States Bureau of Mines, *Mineral Facts and Problems, 1970* (Washington: Government Printing Office, 1970), p. 13. The 1970 edition of this volume places great emphasis on prediction and forecasting. In view of the

mated that the absolute consumption of electric power in the United States alone is doubling every ten years and, on a per capita basis, every twelve years.

The demand for energy for the rest of the world has been growing at rates nearly double those of the United States, with the largest growth in the industrialized countries of Asia and Africa. Energy consumption for commercial purposes is also growing faster in the less developed countries. Despite variabilities in philosophical perspectives—whether malthusian, nonmalthusian, or marxist—it is difficult to see how resultant levels of energy demand can be met with known sources of fuel. For this reason the critical imperatives in the energy field include: 1) increasing the efficiency of present energy systems; 2) improving production methods to minimize environmental resistance; and 3) developing new energy systems.[35]

But will present reserves of fossil fuel be sufficient to meet rising demands until the commercial development of alternative sources of energy? Throughout human history more than three-quarters of the world's total energy consumption has depended upon fossil fuels. By current calculations, however, fuel shortages are expected in the foreseeable future (at least in economic terms), but much in dispute is the question of whether the lifetime of fossil fuel reserves is in fact 30 or 300 years. A general consensus seems to emerge that in the short run—from now until the turn of the century—known fuel reserves are adequate to meet expected rises in demands. Beyond this the situation remains uncertain.[36] *The primary danger, however, is not one of fuel depletion but of rising costs of energy processing: dollar costs, real costs, and costs to the environment occasioned by*

interdependence between economic, technological, and other factors it has been deemed necessary to develop alternative predictions based on contingency forecasting techniques. See pages 9-11 of the 1970 edition for a description of method, assumptions, and caveats. For each mineral resource the Bureau of Mines presents a "high," "median," and "low" prediction of demand and supply in 2000. Contingencies and caveats are clearly spelled out. The 1965 edition relies on more inflexible trend extrapolation techniques.

[35] Ibid., p. 19.

[36] Between now and whenever the new technologies achieve effective output there will be a difficult period during which the countries of the world will be relying heavily upon oil, coal, and other traditional resources. Thus, in a technical sense the energy crisis is not imminent. Yet many social and political implications are already manifest, and many more can be foreseen in decades to come. The eventual technological capability to build fast breeder reactors is not in question despite uncertainties concerning their timing for commercial purposes. Once breeders do become operational on a large scale, they would supply a large part of the world's energy demands for several centuries to come. At efficient rates of uranium usages it is estimated that the date of depletion of the energy stock would be prolonged to at least a millenium. See Hans Thirring, *Energy for Man: Windmills to Nuclear Power* (Bloomington: Indiana University Press, 1958).

extraction. The development of alternative forms of energy is seen as a means of offsetting inevitable increases in the costs of processing fossil fuels. But uncertainties involving the timetable for the commercial development of nuclear energy, of thermonuclear fusion, or, even more remotely, of solar energy make it difficult to assess prospects beyond the year 2000.[37]

In terms of political implications only giant industrial states will be able to afford or even possess the capabilities for developing the new technologies. States that succeed in reducing the costs of energy before others will thus be able to gain important advantages in the world market and strengthen their industrial capability and leverage for influence in the less developed world. This will almost certainly create or perpetuate dependency relationships and competition between industrialized states for influence in less developed regions. Although the problem of energy distribution internationally is more likely to be alleviated by the development of cheap nuclear power, from this perspective, at least, differentials in costs will undoubtedly render inequalities of wealth even more salient than they are today.

The farther one projects into the future, the more dependent forecasts are upon continued technological and social development to sustain and support emerging technologies. On balance it appears that in the field of energy supply and demand, in which the long-range outlook is almost wholly dependent upon new technologies, speculating beyond the year 2000 is less fraught with difficulties on the demand side than on the supply side. In terms of the larger environmental crisis, however, it is difficult to appreciate the full implications of the resource vector without a parallel perspective on minerals.

V. RESOURCE CONSTRAINTS: MINERAL DISTRIBUTIONS AND INTERNATIONAL IMPLICATIONS

The critical issues for mineral resources involve demand and

[37] These comparisons are, strictly speaking, not exactly comparable. But as one expert puts it:

> Unless we find a lot more uranium, or pay a lot more money for it, or get a functioning complete breeder reactor or contained nuclear fusion within ten or fifteen years, the energy picture will be far from bright. There is good reason to hope that the breeder will come, and after it contained fusion, *if* the U^{235} and helium hold out—but there is no room for complacency.

(Preston E. Cloud, Jr., "Realities of Mineral Distribution," in *The Effects of Population Growth, Hearings,* p. 225, reprinted from *Texas Quarterly,* Summer 1968 [Vol. 2, No. 2], pp. 103-126.) Estimates and calculations are wildly approximate and are complicated even further by the factor of delay between discovery and exploitation of deposits. There is also the possibility that if poorer ores are usable, as they presumably would be with breeders, the supply of uranium should not be an immediate constraint.

depletion, costs and distribution. The magnitude of consumption in the United States alone during the past 30 years has exceeded all known previous consumption aggregated over the history of mankind. The costs of many minerals are rising faster than the growth of the economy and, for many minerals, the rates of discovery and development of new reserves have been declining over the past twenty years. From a global perspective, therefore, the main cause for alarm seems to be the exponential rise in rates of extraction and usage. The major international repercussion of such trends is that most industrialized states are becoming increasingly dependent upon external sources for satisfaction of domestic needs.[38]

As with other vectors of the environmental crisis, the evidence is sufficiently ambiguous to occasion radically different assessments of problems and prospects. Added complications are occasioned by methods of projections: Frequently used contingency techniques are primarily based upon projection of rates of population growth and economic performance, thereby compounding uncertainties. In many cases assessments of future supply and demand of mineral resources portray a bleak situation in view of the rising extraction and consumption rates in conjunction with the projected rates of population growth. Rarely included in the same analyses are projections of future supplies or possible substitutes. Pessimistic views regarding the future adequacy of raw materials tend to overlook the fact that both reserves and demands are functions of time: The amount of resources available tends to increase with new discoveries, new substitution possibilities, and new technological developments. The pattern of copper, whose reserves in the United States have remained relatively constant over the past 30 years, or iron ore, whose worldwide reserves are considered to have doubled over the past decade largely due to technological improvements in extraction and processing, illustrate two cases in point. Nonetheless, the interactive effects of technological development and increasing substitution possibilities raise serious questions concerning the validity of the more pessimistic assessments.

Conversely, once the cost factor is included in this calculus, the situation looks much different. A major contention between optimists, who foresee mineral plenty, and pessimists, who project unavoidable shortages, is whether cost increases of a dislocating nature can, in fact, be averted. Magnitudes of costs and not absolute depletions are at issue, costs which could impose severe strains on industrial economies if not large-scale disruptions of the underlying substructure.

In those terms optimism regarding mineral resources is predi-

[38] *Minerals, Facts and Problems, 1970,* pp. 2-5.

cated on the development of low-cost, energy-intensive modes of extracting progressively lower grades of ores at only gradually increasing prices. The basis for this position is the observed relationship between the concentration of a mineral and its abundance. But the arithmetic-geometric ratio, whereby the amount of mineral increases exponentially as its concentration decreases arithmetically, is applicable only to certain minerals. For some minerals the arithmetic-geometric ratio is simply not applicable; for others the difference between the concentration of ore in presently mined ore bodies and the concentration in much lower but more abundant grades is prohibitively large. Such is the case with tin, nickel, molybdenum, manganese, cobalt, industrial diamonds, lead, and zinc.[39] The concentration of these minerals is very high in known mining locations and very low in all other rock. This situation, in effect, buttresses more pessimistic assessments of future resource supplies. It also undercuts the basic rationale underlying more optimistic assessments which are based on inferences drawn from the arithmetic-geometric ratio in cases in which it is simply not applicable.

Still unclear, however, is the ability of industrial society to develop economically viable substitutes for all critical minerals that are scarce as well as to increase significantly the possibilities of recycling, often called secondary production. Comparatively little recycling is presently undertaken in the United States or elsewhere, largely because of the geographic dispersion of recyclable substances. The problem here is one of organization and not of technological feasibility (although they are highly interdependent).[40]

In sum, while there is little consensus about the severity of mineral depletion, there is general agreement concerning the definition of the relevant factors. Both optimists and pessimists view technology as the most crucial variable. Cheap energy, energy-intensive extraction of low-grade ores, and substitutions of more plentiful raw materials for minerals facing shortages are held as keys to the problem, but the actual feasibility of these solutions is much disputed. More complex and still unclear, however, are the political—especially international—implications of the resource situation in the present and immediate future. Although resources may be located in less developed countries, in terms of applying known technology the developed countries are clearly at an advantage. This, coupled with their increasing dependence upon external resources, raises important questions concerning future trends in international policies although

[39] Preston E. Cloud, Jr., "Realities of Mineral Distribution," *Texas Quarterly*, Summer 1968 (Vol. 2, No. 2), pp. 103-126.

[40] In this regard see *Minerals, Facts and Problems, 1970.*

relations between developed societies are no less crucial in a world of potential mineral scarcity.

In the introduction to a volume on the international minerals situation, *Mineral Facts and Problems: 1970*, the United States Bureau of Mines notes that an increasing reliance by industrial countries upon external resources in recent years has been coupled with decreasing reliance on any one source. As a step toward mapping out some of the political implications of these developments for Communist China, Japan, the Soviet Union, and the United States the author has sought to determine the extent of their reliance upon foreign sources for 37 mineral resources critical to industrial processes by computing a dependency index based upon the latest available data. The index, defined as imports-exports-consumption, allows for a comparative assessment of reliance upon external sources mineral by mineral across countries.[41] This index, of course, is influenced by the specific definition of imports, exports, and consumption as presented by the Bureau of Mines. It is also influenced by variability in data accuracies and estimates. Allowing for a margin of measurement error for cross-national comparisons, the appendix to this article summarizes the dependency trends in these four countries, discussed more extensively below.

According to computations based upon governmental data the United States is highly reliant upon external sources for manganese, nickel, platinum, tin, zinc, bauxite, beryllium, chromium, cobalt, and fluorspar, and it is moderately reliant upon imports of mercury, titanium, iron ore, copper, and aluminum.[42] Manganese is essential to steel production, and, in view of the source countries—Brazil (26 percent) and Gabon (31 percent)—it may be the most likely mineral constraint for the United States in this century. Major exporters for other essential minerals are Belgium-Luxembourg, Canada, Mexico,

[41] See the appendix for discussion of the dependency index measure and for problems and caveats. See Nazli Choucri and Dennis L. Meadows, with the research assistance of Michael Laird and James P. Bennett, "International Implications of Technological Development and Population Growth: A Simulation Model of International Conflict" (Cambridge, Mass: Department of Political Science and Alfred P. Sloan School of Management, Massachusetts Institute of Technology, September 1971), for an earlier, briefer version of this comparative discussion of mineral resources in four states. The dependency index measure ranges from +1 to −1 in cases in which stockpiles are excluded; otherwise the measure may exceed +1. A quotient closer to +1 signifies greater reliance on external sources; conversely, one closer to −1 signifies greater dependence on internal sources. See the appendix for sources of data cited below and the period over which computations are based.

[42] Conversely, the United States is a net exporter of molybdenum, tungsten, vanadium, coal, gold, helium, sulfur, and magnesium. For other key minerals, such as iron ore, copper, petroleum, and natural gas, there has been no trend toward increasing United States reliance on foreign sources since 1958.

the Philippines, the Republic of South Africa, Spain, Thailand, and the United Kingdom. With few exceptions *exporting countries are either allied directly to the United States or lie within the American sphere of influence.*

In the case of the Soviet Union the situation is almost the reverse. It is demonstrably less reliant upon external sources. There are only two industrial minerals for which net imports exceed 20 percent of current consumption. One is bauxite, imported from Greece (40 percent) and the Socialist Federal Republic of Yugoslavia (60 percent). To date the Soviet Union has preferred to import bauxite from closer (and presumably more secure) sources despite lower quality rather than to acquire higher quality bauxite from more extensive deposits in Jamaica and Surinam (both of which are leading exporters to the United States). The second mineral is tin, imported from Malaysia (30 percent) and the United Kingdom (68 percent). However, since cheap substitutes do exist for tin, this metal cannot be considered militarily or industrially crucial.

Differences between the United States and the Soviet Union in terms of reliance upon external sources is even more forcefully portrayed in a recent study noting that of 36 minerals crucial to industrial processes the Soviet Union is self-sufficient in 26 and the United States is self-sufficient in only seven.[43] To some extent these divergent trends have resulted from consciously pursued policies. The United States has generally permitted individual firms to pursue short-term profit maximization and limited its support for domestic extraction industries to exploration and depletion subsidies. In addition, the United States has stockpiled minerals thought, at some point, to have been strategically important (and, in many cases, continues to do so despite changing situations). Soviet policies, in contrast, have generally been directed toward achieving industrial as well as short-term military independence of foreign sources for most crucial minerals. Foreign trade has always been subservient to the requirements of central planning: Economic and political considerations have customarily molded Soviet trade patterns.[44] In those terms at least the United States is considerably more vulnerable to dislocations occasioned by discontinuities in mineral flow.[45]

By these computations Communist China is almost totally self-

[43] Dr. Raymond Ewell, "U.S. will Lag U.S.S.R. in Raw Materials," *Chemical and Engineering News,* August 24, 1970 (Vol. 48), pp. 42-46.

[44] Charles K. Wilbur, *The Soviet Model and Underdeveloped Countries* (Chapel Hill: University of North Carolina Press, 1969).

[45] Several earlier studies have uncovered the same basic trend noted here. See Ewell, *Chemical and Engineering News,* Vol. 48, pp. 42-46; G. A. Rousch, *Strategic Mineral Supplies* (New York: McGraw-Hill Book Co., 1939); and

sufficient in mineral resources. With the exception of titanium (used mainly in high-speed aircraft and other military applications) it produces practically all of the minerals and fossil resources it needs for consumption. We have calculated the dependency index for 1966 and again for 1968, and the same general patterns emerge. Of course, uncertainties concerning the accuracy of Communist Chinese data make these inferences tentative, but the emerging trends are unmistakable.

By contrast Japan is almost totally dependent upon external sources for key minerals. There are thirteen important minerals for which imports equal or exceed 80 percent of consumption. These include both fuel and industrial resources. Of all of the technologically advanced powers Japan is confronted with no alternative other than reliance upon uninterrupted international trade to sustain its economy. In this case the issue is not whether resources might be acquired more cheaply elsewhere but that they are simply not available in Japan. Unlike the United States or the Soviet Union cost considerations are not as directly relevant.

Reliance on external sources raises the dual questions of security and continuity of relations with exporting states, be they developed or developing. In the case of the United States the leading mineral exporters are Canada and Mexico. Although, in those two cases at least, serious disruptions of resource flow are unlikely, the situation is more uncertain with respect to Brazil and Gabon (magnesium), or to Malaysia and Thailand (tin), or to Jamaica (bauxite), or to the Republic of South Africa and the Philippines (chromium), among others.[46] Because the political scene is highly fluid, it is increasingly difficult to forecast future outcomes on the basis of linear extrapolations from the past. Thus, in assessing future resource needs for any state political and economic factors become inevitably intertwined. It is therefore important to examine the availability issue in a wider environmental context.

In view of the interdependencies between determinant variables the comparative importance of individual minerals for each state can be evaluated on a two-dimensional field.[47] One axis measures the centrality of the mineral to a state's economy; the other measures

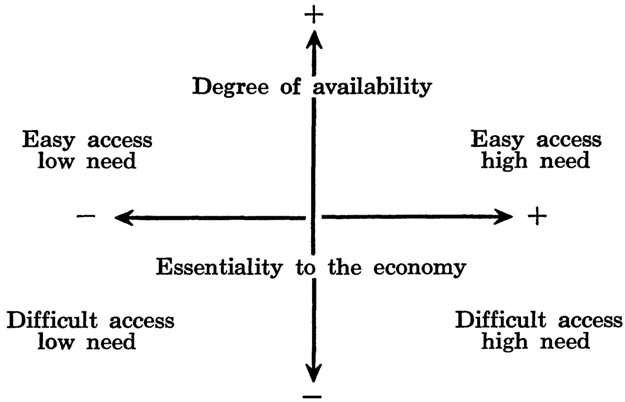
Charles F. Park, Jr., *Affluence in Jeopardy* (San Francisco, Calif: Freeman, Cooper and Co., 1968). A fourth study rated eleven states according to self-sufficiency regarding 26 industrial minerals; see C. K. Leith, I. W. Furness, and Cleona Lewis, *World Minerals and World Peace* (Washington: Brookings Institution, 1943). A table comparing the eleven countries according to degrees of self-sufficiency is presented on page 45.

[46] By contrast the Soviet Union is a major exporter of chromium to the United States.

[47] I am grateful to James P. Bennett for assisting in formalizing these distinctions.

the overall availability, including political and economic factors, roughly as in figure 1.

FIGURE 1. COMPARATIVE IMPORTANCE OF MINERALS



This crude perspective might highlight the relative cruciality of key minerals while allowing for cross-national comparisons. The most serious difficulty with such assessments—across minerals and across states—is their static nature. Technological innovations, changes in tastes, interaction between prices and availability, and changes in consumption patterns all interject highly variable effects, the implications of which are difficult to gauge. In addition changes in the position of one mineral in the field are inextricably bound with changes in the position of all other minerals. In this context substitutions, recycling, and new discoveries assume critical importance.

The centrality of a mineral depends, among other factors, on the type of economy in question. However, with respect to availability political considerations are paramount. For all states, especially the United States and the Soviet Union, the major questions in this regard pertain to the political orientation of the exporters, their geographic proximity and political volatility, and the degree of international competition for key world resources. Those considerations have become critical to any calculus of future mineral availability and accessibility. Clearly the greatest uncertainties pertain to lower income countries. Rapid industrialization will undoubtedly create additional demands on known reserves and exert pressures for readjustments of present modes of exchange.

The issue is not whether the major powers are exploiting or assisting developing countries—although this is clearly an important question—but that rapid industrialization in low-income countries, coupled with growing populations, will place additional burdens upon national governments and upon the existing resource base. Their national governments in turn—if the past several decades provide ready analogies for the unfolding situation—will undoubtedly express dissatisfaction with the industrialized-power-host-state relationship and demand readjustments. To the extent that major powers are willing to modify patterns of interaction and relationships the imbalances may be resolved by peaceful means. If the costs of readjustments are perceived as being too high, or if crucial national interests are at stake, probabilities are high that the industrialized powers will exert additional pressure, and nonmilitary means of control might give way before direct military coercion.

We realize that the more conflict-related aspects of the environmental crisis have been stressed so far. But we find it difficult to appreciate potential integrative forces in light of political considerations with clear implications for conflict. Conflict-producing dynamics become even more relevant when viewed from a combined population-resource-technology perspective. The synergistic and interactive environmental effects of these three vectors are most apparent in advanced industrial societies although the dynamics in question are emerging increasingly in rapidly developing low-income countries.

VI. CORRELATES OF GROWTH: ENVIRONMENTAL PROBLEMS AND ORGANIZATIONAL IMPERATIVES

The advanced industrial societies have been developing with little serious thought as to how their development—economic, technological, and scientific—may affect their own ecologies and the world environment. Today the global correlates of industrial growth are demonstrable: Much of what is termed production involves, in fact, extraction which depletes resources and occasions increasing environmental pollution. Pollution and depletion are two different manifestations of man's impact on his environment. The former is essentially a by-product of inadequate—but sometimes unavoidable—disposal systems resulting in the corruption of air, water, soil, and other aspects of the environment by human beings as a function of their technology. The latter emerges from the overuse of a given resource or of the more readily available deposits. In these terms pollution and depletion are direct correlates of growth and of man's unwillingness to modify the conditions that aggravate environmental problems. This situation is reinforced by the nature of our social organizations which place little formal value upon minimizing environmental dislocations occasioned by industrial processes and by the increasing numbers of people exposed to, and drawing upon, advancing technology.

By its very nature technological growth generates a vicious cycle: Increasing technology implies greater energy consumption, which implies increasing industrialization, which then generates further demands for material goods and services, which in turn results in greater consumption of more readily available resources, creating greater environmental problems and dislocations. The production, conversion, transfer, and consumption of energy are also responsible for a large part of our environmental problems. But this is only one side of the issue. The other is a materials disposal problem: Increasing technological growth has not given rise to a commensurate concern for the development of optimal modes of material disposal—optimal in both economic and environmental contexts. Thus, water pollution, air pollution, soil dislocation, and the like are different manifestations of our disregard for materials rejected in the course of industrial production. Some methods of disposal place greater loads on the environment than others, and some modes are less costly than others. So far we have opted for minimizing short-range economic costs at the expense of costs generated by longer range effects. Now we are confronted with cumulative environmental effects produced over long periods of time. We need to clean up the mess, and we need to develop preventive guidelines for the future. In each case we have been moving too slowly. That experts disagree as to the actual severity, magnitude, or extent of environmental dislocation should not be construed as a sign of optimism regarding our present predicament: The existence of serious environmental dislocations is not at issue, only their extent.

To place sole responsibility for our environmental crisis on the dynamics of growth would be incomplete and inaccurate. The present situation is further exacerbated by our economic and social systems—whether capitalist, socialist, or a mix thereof—which actively encourage environmental problems, thus rendering the implications of industrialization and population increase even more critical than might otherwise be the case. For example, the exclusion of negative outcomes incurred in the course of production from a price system designed to capture the costs of production encourages disregard for pollution control or for the development of materials disposal systems with minimal negative environmental implications. The transference and use of public goods, such as air and water, at zero cost provides little incentive for active environmental concern. Indeed, the costs of production are minimized by a disregard for effects occasioned by externalities.

By treating the environment as a free public good individuals in a society escape short-range costs, but, in the long run, the costs to the environment are cumulative and cannot be avoided by means other than direct confrontation. We have now begun to realize both the long- and short-range implications of our economic systems. If specific monetary costs were attached to environmental property, the effect would be to introduce cost-benefit criteria into the manipulation of goods that so far have been considered to be essentially free. However, any moves in this direction would involve large-scale organizational changes, a consideration few societies are willing to envisage on a scale which might provide a degree of effectiveness. In these terms advanced socialist societies demonstrate a remarkable similarity of view with their counterparts in the West.

Environmental problems are not confined to industrialized states. Rapidly developing low-income countries are beginning to incur the same kinds of problems. The overuse of soil capacity is not uncommon, and evidence of air and water pollution is becoming increasingly apparent. Unless other countries bear, or at least share, the costs, the political implications of any direct attempts to minimize the environmental side effects of industrialization must, by necessity, involve some explicit control of both pace and extent of growth. In those terms, at least, it is unlikely that developing societies would adopt self-imposed constraints on growth. Concern for the nature of the environment might appear as a luxury that only developed societies can afford. Quality-of-life issues pale in comparison to sustenance of life.

Even more complex is the development of international guidelines for environmental control: The gaps between developed and less developed societies might appear too great to allow for active cooperation in the development of control processes. It must be recognized that aside from political difficulties, the imposition of limits upon industrialization involves severe additional, built-in difficulties which make self-imposed constraints almost impossible. One means of controlling negative environmental outcomes would involve the explicit allocation of national resources for clean-up purposes or for the development of preventive measures in anticipation of environmental problems caused by industrial processes. In light of the scarcity calculus, however, diverting resources to objectives other than those associated directly with the maximizing of productivity is not a practical suggestion.

The important point is that many of our environmental problems are exacerbated—if not directly occasioned—by our social and economic systems. Appropriate organizational changes might make it possible to avert outcomes more serious than those presently apparent. Negative environmental effects are not necessarily correlates of industrial growth. Thy become so only to the extent that explicit provisions for regulation and control of technological externalities are not incorporated into and planned for in the growth calculus. In this context the application of band-aid technology or incremental piecemeal solutions is not likely to make an appreciable dent in the problem at hand. Nor are isolated programs designed to alleviate air or water pollution likely to improve the situation significantly.[48] If national environmental control programs are envisaged, to some extent these might need to be developed along congruent international lines and based upon globally articulated preferences and priorities.[49] The formulation of blueprints is a major undertaking the magnitude of which is dwarfed only by the potential worldwide implications if such efforts are not undertaken in the immediate future. Even more critical is the need to modify our economic systems so as to render them congruent with whatever measures of environmental control are devised. By addressing ourselves only to the clearest manifestations of the environmental crisis, such as air or water pollution, we may be doing future generations a disservice which they might find impossible to rectify. Unfortunately, melodramatic overtones of prevailing doomsday philosophies have resulted in a lessening of our appreciation of present predicaments.

Aside from cost factors various manifestations of the environmental crisis suggest that in the world of the late twentieth century various forms of ecological factors rank with population, technology, and resources as critical variables requiring measurement and regulation. In view of diverse environmental effects of industrialization, even if the poorer societies were capable of developing at rapid rates in relation to their population growth, a global population living at a standard equivalent to that of the United States would almost certainly create more rather than fewer disturbances in the physical environment, and accompanying patterns of consumption and production would only aggravate the political problems noted above. In those terms population control is not sufficient, nor is control over patterns of consumption in highly industrialized countries, nor the development of international guidelines for projected growth in technology-deficient areas. Such guidelines cannot be adequately developed without our willingness to undertake large-scale reassessments of our values, social and economic systems, and dominant modes of exchange.

The ultimate goal of rapid industrialization pursued by so many lower income countries is loaded with problems and uncertainties the

[48] In this connection see Frank P. Grad, George W. Rathjens, and Albert J. Rosenthal, *Environmental Control: Priorities, Policies and the Law* (New York: Columbia University Press, 1971).

[49] At this point it is difficult to say whether the congruence thesis has much validity; considerable research is still to be done.

magnitudes of which necessitate serious reassessments of the goal itself. Dominant international values emphasize the merit of technological advance. We must no longer accept sustained economic growth as a primary international objective. However, given the imperatives imposed by large and growing populations, it is difficult not to appreciate the necessity for technological advance. We must not accept too readily the assumption that technological innovation per se will alleviate our current problems, just as we must not accept the suggestion that population control per se will alleviate the present environmental crisis. What should be done is difficult, if not impossible, to say with any degree of precision. But we must be willing to reassess even the most hallowed political, social, and economic assumptions and value preferences. Beyond that the merits of alternative solutions or policies can be assessed only in light of the assumptions, data, and modes of analysis upon which they rest.

VII. FUTURE PERSPECTIVES: RESEARCH IMPERATIVES AND POLICY ALTERNATIVES

The global implications of our present predicament can be fully appreciated only in the dual contexts of costs and feasibilities: what needs to be done and what the costs are likely to be. In political terms the major issues of the future concern the control, allocation, and distribution of resources and technology. How this comes about, who develops the guidelines, and what control mechanisms are to be imposed upon the controllers are all crucial questions which pertain directly to whatever type of international institutions might be developed for such purposes. However indispensable many of them may be, present international institutions are scarcely adequate for regulating the critical variables at the core of present environmental problems. Related obstacles involve existing discontinuities in national and international preferences and priorities and accompanying authority structures and processes. In those terms, at least, the evolution of congruent national, regional, and global priorities amounts to a major challenge.

A compelling difficulty emerges from the fact that the dynamics of our present predicament are not fully understood nor are the long-range implications of proposed remedial action. Policies adopted to alleviate one kind of problem all too often produce unexpected consequences. More than ever before it has become necessary to undertake long-range investigations of potential effects occasioned by alternative courses of action. In view of these uncertainties it is important that we develop, refine, and apply methodologies *now* for analyzing relationships and interdependencies involving social organization and habit structure, acquisition of resources, pricing systems, economic and social underpinnings, population dynamics, technological growth, and resulting environmental resistance.

But research and analysis is only one side of the coin. The other, and more critical, imperative is to communicate the results of research to policymakers. The too frequent gap between academic and policy-oriented discourse is a luxury that can no longer be afforded. The academic task is twofold: 1) to specify and compile required data and 2) to analyze the data in a critical fashion. It is necessary to develop priorities for the compilation of data on different aspects of the environmental crisis. In many cases data is indeed available and needs only to be transferred to a format useful for analysis.[50] But this is not always the case. Indeed, we often do not know what it is that we ought to be asking. But in many cases the problem is one of gathering data in primary form.

The situation with respect to analysis is more encouraging. A number of useful and extremely promising methodologies are now available for undertaking concerted analyses of long-range dynamics. But it is necessary to explore ways of communicating their policy-relevant implications to others outside of the academic community. In general the imperatives at hand necessitate less the development of novel modes of analysis than the application of existing modes to problems of concern. The actual choice of method or research technique depends largely upon the specific problem encountered, on intellectual preferences, and on assessments of potential payoffs.

By way of illustrating critical linkages between 1) long-range scientific research, 2) analysis of implications for policymaking, and 3) translation from academic to operational contexts we draw upon three distinct though complementary modes of analysis, each representing different manifestations of policy-oriented methodologies and designed to clarify different aspects of any one issue.

The first of these, system dynamics, is both a philosophical orientation and a specific methodology for analyzing long-range implications of policies and decisions in complex, nonlinear, multiloop systems of which social systems are the most complex. This type of analysis simulates the behavior of systems over a long period, sometimes going as far as 100 years into the future.[51] The kinds of data

[50] The extensive body of statistical data compiled by the United Nations since its inception is only one case in point.

[51] See Jay W. Forrester, "Counterintuitive Behavior of Social Systems," *Technology Review*, January 1971 (Vol. 73, No. 3), pp. 52-68; Jay W. Forrester, *Principles of Systems* (Cambridge, Mass: Wright-Allen Press, 1968); and Dennis L. Meadows et al., "The Limits of Growth: A Global Challenge" (Cambridge, Mass: Alfred P. Sloan School of Management, Massachusetts Institute of Technology, July 9, 1971). (Mimeographed.)

needed to analyze long-range dynamics associated with environmental issues involve observations on population levels, economic performance, resource allocation and utilization, patterns of consumption, technological advances, and so forth. Indeed, considerable analysis of such data is already underway.

A major capability of system dynamics as a research tool lies in the isolation of sensitive points in the system as well as those points which contribute little to future outcomes. The policy relevance of such information is obvious: If we can identify long-range implications of short-range decisions, it might be possible to ground our planning efforts on stronger footing, avoiding actions which appear to occasion benefits in the short term but in fact produce negative outcomes in the long run.

The second research approach, decision analysis, based on bayesian statistics, represents an alternative to classic statistics and is designed to trace the probabilities associated with various outcomes occasioned by alternative decisions at key points. In the context of environmental issues the data requirements involve information on national preferences and priorities, alternative policies and programs, and so forth. This form assesses the probabilities attached to a range of proposed policies thereby allowing for a critical evaluation of feasibilities.[52] However, as is also the case with system dynamics, the cost factor is neither directly nor explicitly introduced into the analysis, a drawback that is not to be minimized for purposes of research.

The third of these research approaches, policy analysis of alternative allocations, deals specifically with cost considerations. It is addressed to different budgets based upon alternative preference structures and priorities. The data needed pertains to budgetary distributions as they relate to environmental issues. What emerges from this approach is the cost calculus attached to alternative modes of resource allocations.[53] The main advantage, therefore, is direct and explicit assessment of the cost-benefit equation which provides crucial information about the cost implications of proposed policies or, alternatively, sets up competing policies and observes their costs and feasibilities.[54]

Obviously, these three modes of research into present environmental predicaments differ considerably in terms of abstraction from

[52] See Howard Raiffa, *Decision Analysis: Introductory Lectures on Choices under Uncertainty* (Reading, Mass: Addison-Wesley Publishing Co., 1968).

[53] See Charles L. Schultze et al., *Setting National Priorities: The 1972 Budget* (Washington: Brookings Institution, 1971).

[54] In this connection it becomes imperative to broaden our concept of cost to incorporate other than direct monetary considerations. For persuasive arguments see Alice M. Rivlin, *Systematic Thinking for Social Action* (Washington: Brookings Institution, 1971).

reality. Of the three, system dynamics is the most comprehensive, yet it is also the most removed from concrete day-to-day decisions that face policymaking communities. Decision analysis and bayesian statistics represent one step in the direction of political realism by providing probabilities attached to alternative paths and outcomes. Analysis of budgeting and resource allocations are the most specific, and they are also closely related to the stuff of politics and most directly concerned with linkages between national resources and national priorities.

To date, each of these methods has been applied in discrete fashion with little consideration for the possibilities of bringing these different scientific procedures to bear upon the development of policy alternatives, domestic or international, and even less consideration for systematic analysis of long-range implications. Through the judicious use of such methods for the analysis of appropriate data it is now possible to construct in a laboratory setting realistic models of social systems which allow for experimentation with hypothetical situations and alternative futures. Drawing upon empirical data on population dynamics, resource constraints, and technological development, these techniques allow us to alter various values for key variables subject to different policy decisions and allow us to observe now the changes that would take place over future time. In addition we can begin to identify the manipulables of a situation, as well as the cost of manipulation.

Systematic research is no substitute for immediate and specific action. But, at the same time an incremental, piecemeal, or band-aid approach to global problems is no substitute for judicious investigation and systematic analysis. The lines of investigation described in the following essay of this volume are illustrative of what must be done before we can estimate variable long-range implications of different policy alternatives.

Currently underway at the Massachusetts Institute of Technology is a series of computer-based simulations of the longer range political and economic implications of population growth, technological developments, and resource constraints.[55] A primary emphasis is on potentials for conflict and warfare. On the assumption that conflict might be avoided if the preventive action is undertaken early enough these investigations have begun to raise a series of "what if" questions pertaining to alternative futures, costs, and feasibilities. For example, what would be the long-range implications for the United States (or other states) if population growth were curtailed sig-

[55] See Choucri and Meadows, "International Implications of Technological Development and Population Growth."

nificantly, or, alternatively, if consumption per capita were reduced, or if the costs of controlling external sources of raw materials and energy-producing fuels become too high, or if competition for resources becomes too intense?

Reports of these investigations are presented elsewhere. Let it suffice here to reiterate that appropriate technical skills and accompanying methodologies in addition to a certain amount of empirical data are *presently* available for undertaking extensive investigations of alternative futures and implications and consequences, both domestic and international. The transference of computer-based results from the academic community to the real world may be effectively undertaken through the application of bayesian statistics in conjunction with policy analysis. The bayesian paradigm would allow for the assessment of probabilities associated with different paths or policies that states might pursue in seeking, for example, to assure continued resource availability or to minimize conflict-laden avenues of international behavior. The practical costs involved in adopting one policy over another can then be assessed in the context of overall national preferences and priorities by a judicious application of policy analysis. The most sophisticated and useful of such modes is alternative budgeting analysis in the United States case as undertaken by the Brookings Institution.[56] In this context the political and economic costs and consequences attached to the "what if" or "if . . . , then . . ." questions can be identified and evaluated accordingly. Equally possible are systematic assessments of the political costs and feasibilities of modifying national priorities and habits, expectations and institutions. The situation becomes considerably more complex when one views the world as a whole and assesses the viability of alternative international policies and institutions and their accompanying implications for relations between states.[57]

In sum, research imperatives for the present and immediate future are fourfold: 1) to examine systematically and objectively the longer range implications of short-term actions and decisions; 2) to develop a whole series of alternative policies and alternative futures and examine their implications in laboratory and simulation settings; 3) to translate results into terms that are amenable to analysis of accompanying costs and feasibilities, economic as well as political; and 4) to devise means of disseminating information on methods, procedures, findings, and implications to national leaders and citizens alike in ways that are objective, valid, comprehensible, and believable.

[56] Schultze et al.

[57] For a discussion of these issues from a United States perspective see North and Choucri, "Population and the International System: Some Implications for United States Policy and Planning."

The major concern is to keep the information truthful and accurate.

APPENDIX: DEPENDENCE ON EXTERNAL SOURCES: MINERAL RESOURCES IN COMPARATIVE PERSPECTIVE

This appendix presents in summary form our computations and findings concerning the relative dependence (or reliance) of China, Japan, the Soviet Union, and the United States on external sources for mineral resource requirements. The dependency index has been defined as imports-exports/consumption; or (M-X)/C. As noted in the text above, the index assumes values between +1 and −1. The higher the value or the closer it is to +1, the higher is a state's reliance on external sources for the particular mineral in question. Our computations are presented most extensively for the United States, for which the data are most accurate and available. We note those minerals for which the United States is highly dependent on external sources, those for which it is moderately dependent, and those for which it is only marginally dependent as well as those for which the United States is a net exporter.

DEPENDENCY INDICES: UNITED STATES

Summary

For key minerals, such as iron ore, coal, copper, petroleum, and natural gas, there has since 1958 been no trend toward increasing United States dependence on foreign sources. For minerals for which the United States is and has been for some time highly dependent on foreign sources, over this same time period, no conclusive trend toward greater dependence on foreign supplies appears: The dependency index, (M-X)/C, has increased for some while it has decreased for others.

Two minerals for which the United States is dependent on foreign sources and whose sources of supply are likely to be the most insecure politically are manganese and chromium. Because manganese is essential to steel production, it could be considered the most likely mineral constraint for the United States in this century (see below).

TABLE 1. HIGH DEPENDENCE: DEPENDENCY INDEX IS GREATER THAN .5, OR MORE THAN ONE-HALF OF CONSUMPTION IS (NET) IMPORTED

Mineral	Dependency Index (Average 1966-1970)	Major Sources 1966-1969 (as Percentage of United States Imports)	Trend in Dependency Index 1958-1970
Manganese	.9	Gabon (31 percent) Brazil (26 percent)	Large decrease[a]
Nickel	.7	Canada (90 percent)	Large increase[b]
Platinum group	.7	United Kingdom (43 percent) Soviet Union (26 percent)	Slight decrease
Tin	.6	Malaysia (66 percent) Thailand (27 percent)	Large increase[b]
Zinc	.6	Canada (51 percent) Mexico (18 percent)	Large increase[b]
Asbestos	.8	Canada (92 percent)	(Not computed)
Bauxite	.9	Jamaica (59 percent) Surinam (26 percent)	Unchanged
Beryllium	.7	Brazil (36 percent) India (27 percent)	Erratic, no trend
Chromium	.8	Republic of South Africa (40 percent) Soviet Union (24 percent) Philippines (17 percent)	Slight decrease[a]
Cobalt	.7	Congo (Kinshasa) (43 percent) Belgium-Luxembourg (30 percent)	(Not computed)
Fluorspar	.8	Mexico (75 percent) Spain (14 percent)	Unchanged[c]

[a] Holding United States stocks and stockpiles constant would improve this measure but greatly change the direction of the dependency index trend only in the case of chromium and manganese, where the dependency index, if stocks were held constant, would possibly increase over the period 1958-1970.

[b] 1964-1970 only; for 1958-1964 the trend was downward.

[c] 1959-1970.

TABLE 2. MEDIUM DEPENDENCE: DEPENDENCY INDEX IS LESS THAN .5 BUT GREATER THAN .2, OR 20-50 PERCENT OF CONSUMPTION IS (NET) IMPORTS

Mineral	Dependency Index (Average 1966-1970)	Major Sources 1966-1969 (as Percentage of United States Imports)	Trend in Dependency Index 1958-1970
Mercury	.3	Spain (31 percent) Italy (21 percent) Canada (19 percent)	Slight decrease
Potash	.3	Canada (89 percent)	
Titanium[a]	.3	Australia (92 percent)	Slight increase
Antimony	.4	Republic of South Africa (44 percent) Mexico (26 percent) Bolivia (24 percent)[b]	
Industrial diamonds	.3	Ireland (47 percent) Republic of South Africa (15 percent)	
Iron ore	.3	Canada (53 percent) Venezuela (28 percent)	Unchanged
Lead	.3	Peru (21 percent) Canada (21 percent) Australia (17 percent)	

[a] Rutile only.
[b] Ore and concentrates only.

TABLE 3. LOW DEPENDENCE: DEPENDENCY INDEX IS POSITIVE BUT LESS THAN .2, OR LESS THAN 20 PERCENT OF CONSUMPTION IS (NET) IMPORTS

Mineral	Dependency Index (Average 1966-1970)	Major Sources 1966-1969 (as Percentage of United States Imports)	Trend in Dependency Index 1950-1970
Natural gas	$<.1$	Canada (92 percent) Mexico (8 percent)	
Natural gas liquids	~ 0	Principally Canada	
Petroleum	.1	Canada (35 percent) Venezuela (28 percent)	Unchanged
Rare earths	.1	Australia (64 percent) Malaysia (31 percent)[a]	
Aluminum	$<.1$	Canada (69 percent)	
Copper	.1	Chile (29 percent) Canada (23 percent) Peru (20 percent)	Unchanged

[a] Monazite only.

TABLE 4. MINERALS OF WHICH THE UNITED STATES IS A NET EXPORTER: DEPENDENCY INDEX IS NEGATIVE, OR EXPORTS ARE LARGER THAN IMPORTS

Mineral	Dependency Index (Average 1966-1970)	Major Sources 1966-1969 (as Percentage of United States Imports)
Molybdenum	—.7	Canada (100 percent)
Phosphate rock	—.4	Netherlands Antilles (80 percent)
Silver[a]	—.1	Canada (50 percent), Peru (15 percent)
Sulfur	— 0	Canada (56 percent), Mexico (44 percent)
Tungsten	—.3	Canada (39 percent), Peru (19 percent)
Vanadium	—.1	Canada and Netherlands Antilles
Coal	—.1	Canada and West Germany (1967 only)
Gold	—1.5	Canada (49 percent)
Helium	—1.0	None
Iron and steel scrap	—.1	Canada (95 percent)
Magnesium	—1.8	Canada (50 percent), Norway (28 percent)
(?) Uranium	(?)	Republic of South Africa (79 percent), Canada (17 percent)

[a] Excludes coinage.

DEPENDENCY INDICES: COMMUNIST CHINA, JAPAN, THE SOVIET UNION

Soviet Union 1967	Japan 1968	Communist China 1966	Communist China 1968
Dependency index greater than 0.5			
None	Antimony 1.0	Titanium ?	Titanium ?
	Asbestos 0.9		
	Bauxite 1.0		
	Copper >1.0		
	Petroleum 1.0		
	Platinum 1.0		
	Tin 0.9[a]		
	Tungsten 0.8		
	Zinc >1.0		
	Fluorspar 0.9		
	Titanium 1.0		
	Lead 0.8		
	Mercury 0.8		
Dependency index less than 0.5 but greater than 0.2			
Bauxite	Silver	Copper	Aluminum metal
Tin	Iron ore ?		
Dependency index less than 0.2 but greater than 0			
Cadmium	Coal	Iron ore	Copper
Fluorspar	Coke	Nickel ?	Lead
Mercury	Nickel		Silver
Tungsten			Aluminum metal
Zinc			Zinc
Dependency index apparently equal to zero			
		Antimony ?	Antimony ?
		Asbestos ?	Asbestos ?
		Fluorspar ?	Fluorspar ?
		Petroleum	Petroleum
		Magnesium	Magnesium
		Phosphate rock	Phosphate rock[b]
		Coal	Sulfur
		Iron ore	Coal
Dependency index less than zero			
Antimony	Cadmium	Bauxite	Bauxite
Asbestos	Magnesium	Coke	Coke
Chromium	Sulfur	Tin	Iron ore
Coal		Manganese	Manganese
Coke		Tungsten	Mercury
Copper		Mercury	Tin
Iron ore		Molybdenum	Tungsten
Lead			
Magnesium			
Natural gas			
Nickel			
Petroleum			
Sulfur			

[a] Excludes secondary consumption, the effect of whose inclusion would be to reduce the dependency index (probably not below 0.6 or 0.7).

[b] However, Communist China is a large net importer of fertilizer (see *Mineral Facts and Problems, 1965,* pp. 14, 157).