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International Perspectives on Technology Assessment

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ABSTRACT

Technology assessment (TA) has attracted worldwide attention, but at present TA means different things to different countries. In industrialized market economy countries, TA consists of policy studies that deal with the side effects of technology. In centrally planned economy countries, TA is considered another tool for social management of technology. For developing countries, TA is expected to help in selecting appropriate technologies for development. These different perspectives have significant implications not only in how TA is done differently in different countries, but also in how international and global TA can be done effectively.

Introduction

Technology assessment (TA) has attracted worldwide interest. Discourses in TA have appeared in the literature of many countries and have taken place within several parts of the United Nations system. The professional society in this field, International Society for Technology Assessment (ISTA), has held conferences in a number of countries. Its Second International Congress on Technology Assessment was held at The University of Michigan, Ann Arbor (U.S.A.) in October, 1976, and was attended by participants from over fifteen countries [1]. Subsequently, an international conference on "Technology Assessing: The Quest for Coherence" was sponsored by the East-West Center in Honolulu, Hawaii in May/June, 1977, attended by a number of experts from Asian developing countries as well as from industrialized market economy countries. Another international workshop on "Systems Assessment of New Technologies: International Perspectives" was later sponsored by the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria in July 1977. The workshop was attended by a number of experts from Eastern Europe and from other industrialized countries. Having been involved in the discussions at all three international conferences, the author found that TA has different meanings, emphases, premises, and processes in different countries. This is not surprising, as Rosenberg, among others, has stressed [2] that the same technology will have very different consequences in societies whose institutions, values, resource endowments, and previous histories vary. This paper is written on the basis of the three international TA conferences mentioned above and is an attempt to make a systematic comparison of the different thrusts, concerns, institutions, and practices of TA in different societies. It is hoped that this comparison will help international understanding and cooperation in the field of technology assessment.

To facilitate comparison, the bulk of this paper consists of three sections devoted respectively to the industrialized market economies, centrally planned economies, and developing countries. Although generalization of TA patterns in each group of countries is

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attempted, the existence of significant heterogeneity within each group will be acknowledged. The fourth and last section of this paper presents the author's view on global TA, which potentially should involve transnational cooperation across the three groups of countries mentioned above.

Industrialized Market Economies

Industrialized countries with market economies, including all the OECD countries,[1] have traditionally taken a comparatively laissez faire attitude toward both their economic and their technological activities. With these activities managed mainly in the private sector, their recent histories are adorned with the success of technologies that have been harnessed to serve a diversity of intended purposes mostly reflected in the marketplace. However, this very ''success'' of technological change has often brought about unintended consequences that are often undesirable from the standpoint of certain segments of the society, or the society as a whole. The pursuit of narrowly defined objectives resulting in undesirable side effects for the society at large has been aptly called ''tyranny of small decisions'' [3]. Much emphasis of technology assessment in market economies has been put on the avoidance of this tyranny through the systematic anticipation of the side effects of technology and the timely policy action to ward off the negative consequences. The emphasis on the unintended consequences of technology has led to several major thrusts of TA in industrialized market economies. First, TA is purported to be and is becoming an assessing activity that is broader than the traditional evaluative and planning activities (cost-benefit analysis, evaluation research, planning-programming-budgeting system, etc.) that are concerned only with the intended consequences. For example, the TA community has been repeatedly urged to study who would gain and who would lose, how, what, and how much (*distributive* cost-benefit analysis), if certain technologies were allowed to be deployed without modification. A correlated thrust of TA in industrialized market economies is toward public participation. Admittedly more a goal than an accomplishment at present, public participation in TA has found increasing receptivity [5] in those industrialized economies where the traditional political process is openly adversarial. The publics whose interests and participation are considered include the parties that may be affected by the technology (or technology-related problems) and the adversary social groups.

Since unintended consequences of technology often take a long time to manifest themselves—emission of air pollutants became a serious side effect of the automobile only after 50 years of its mass production—assessment of major technologies in industrialized market economies has been conducted with longer and longer time horizons. To cite a few American examples familiar to us, the Federal Aviation Administration (FAA) completed a mini-TA on the microcomputer [6] toward the year 2000; the Energy Research and Development Administration (ERDA) sponsored a TA on solar energy [7] with a time horizon of the year 2020, and the Environmental Protection Agency (EPA) is supporting an integrated technology assessment of coal energy [8] until the year 2030. The long-term assessment of technological consequences is dufficult but considered necessary. Social

[1] These countries are members of the Organization for Economic Cooperation and Development. They are the North American countries of Canada and the United States, the Western European countries of Austria, Belgium, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom, and the Pacific countries of Australia, New Zealand, and Japan.

values and structures may undergo drastic changes over decades, rendering extrapolation of quantitative trends on the basis of empirical data unreliable. Two fundamental improvements over the past practice have been suggested for dealing with long-term TA. One is to include in substantive TA projects the historical perspectives that are pertinent to the social and technological developments to be projected. There is no assurance that the historian's inputs are useful and incorporable to substantive TA that is addressed to the long-term future. However, pertinent historical perspectives can impart to serious technology assessors the necessary humility, sensitivity, and wisdom in thinking about the future [9]. There appears to be a serious lack of historical perspectives in most substantive TAs conducted, and the correction of this deficiency is a plausible future trend in TA practice [10]. The second suggested improvement for dealing with long-term TA is to think about the future in a *creative* mode. Instead of extrapolating current social trends into the future or choosing a particular deterministic future as the social norm, a range of alternative futures will be created dialectically on the basis of plausible social values. The effects of technology and the corresponding policy responses in the long-term TA will be embedded in the set of alternative futures thus created. A specific example of TA in the creative futures mode can be found in the EPA project [8]. It should be noted that all the three long-term TA projects cited previously [6–8] have used the creative futures mode to various degrees.

The emphasis of TA in industrialized market economies to avoid the tyranny of small decisions has presented a dilemma. Underlying vital market forces are basically "small decisions," which by definition do not take large social welfare into account. In such an environment, the image of TA is that of a constraint on the vitality of market forces. We may call TA a "prudent look before we jump," but fundamentally TA is a look on behalf of society before entrepreneurs of technological changes in both private and public sectors are allowed to jump. Boulding estimated that in industrialized market economies, 80% of operational assessments are in the market place, the rest being in the government process [11]. In spite of some pro-TA attitudes expressed by industry [12], there is a general concern that TA as has been practiced in industrialized market economies may stifle technological creativity and deployment. Boulding has sounded the caution that, by stressing the sin of commission, we may neglect the sin of omission [13]. He is afraid that if the sanctions against evil are too severe, they may be applied against honest mistakes to the point where nobody will be willing to do anything or take any risks. The other side of this cautionary coin is that, unless TA becomes espoused by the industrial and technological establishments—the prime movers of technological change—TA may be unable to really affect technology, or even be unable to survive in the long run, in industrialized market economies.

One can argue that the basic issue behind TA in industrialized market economies is whether TA can stimulate creativity as well as judgment with respect to technology. As long as TA is used only to judge technology, its function would be mainly regulatory, and its users would be chiefly regulatory agencies in the government. To that extent, TA could be considered antitechnology by the technology developers. However, if TA is also used innovatively to modify existing technology and to create new technology desired by society at large, its function would also be developmental, and its users would include "protechnology" developers in both public and private sectors [14].

Another way to look at this basic issue is to consider the conceptual model for TA [15] in Fig. 1. The central idea embodied in the diagram is that new technologies are traditionally modified through the primary considerations of technical validity, economic

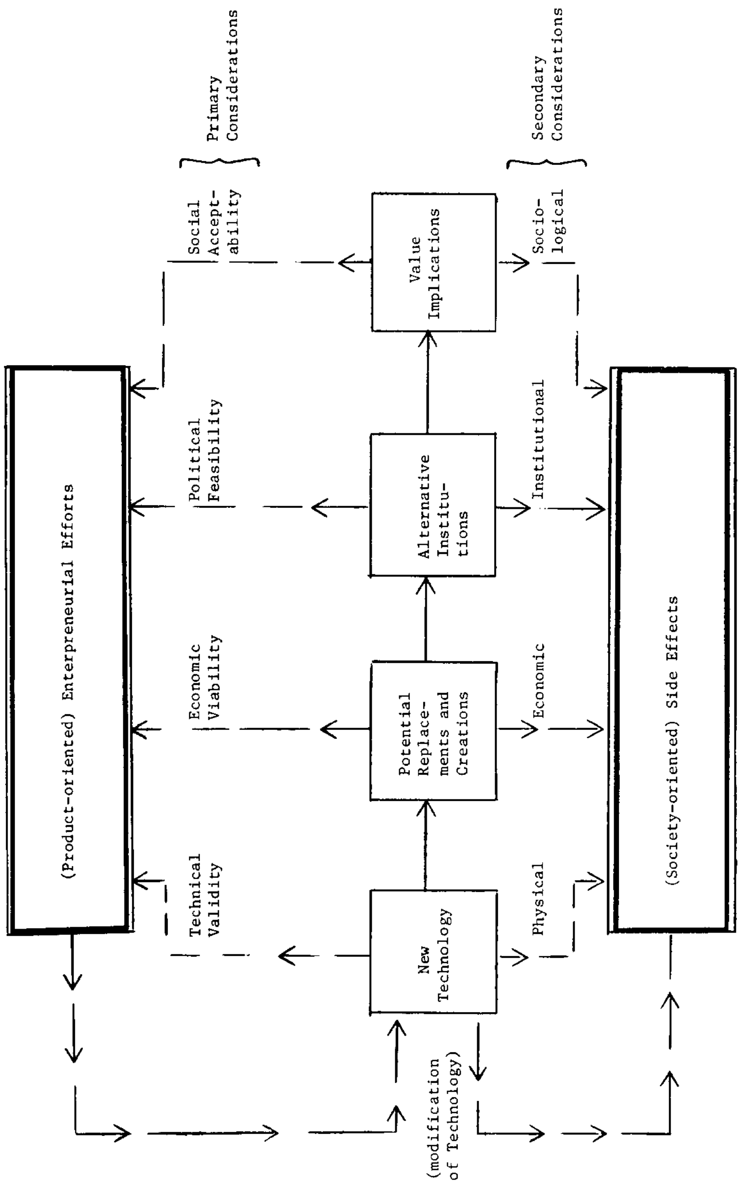

Fig. 1. Technology assessment for industrialized market economies.

viability, political feasibility, and social acceptability, and shown in the upper portion of Fig. 1. Technology developers in both public and private sectors have been playing the role of entrepreneurs to assure that technologies are created or modified to pass all the tests of primary considerations. The lower portion of Fig. 1. represents the various side effects, both beneficial and detrimental, that would be identified by TA as secondary considerations of technological impact from the societal standpoint. The question is whether there is sufficient coupling and incentive to entrepreneurs who will create or modify technologies that will pass all the tests of secondary as well as primary considerations. Some people in industry have indeed espoused evolving social concerns as new opportunities for technological development. An often-cited example is Honda's double-combustion CVCC (compounded vortex controlled combustion) engine, which was developed in response to the social (global as well as Japanese) need for low-pollution automobiles [16] and which contributed significantly to Honda's share of the world's automobile market. In the same vein, Gerardin of France has urged multinational companies to take an active and creative attitude to assume the social consequences of new technologies instead of responding passively in compliance with government-imposed regulations [17].

Institutionally, by far the largest sponsorship of TA projects conducted in the industrialized market economies has come from the executive branch of national governments. The most visible TA institution in the legislative branch has been the U.S. Congressional Office of Technology Assessment (OTA), with bicameral and bipartisan support and control. Other countries have been less successful in institutionalizing TA in the legislative branch. For example, a bill introduced in 1973 to establish an "Office for the Evaluation of Technological Development" in the West German Bundestag [18] was defeated in 1975, and a similar bill introduced to the French Parliament in July 1976 has not precipitated any speedy action [19]. A major roadblock can be traced to the Western European "monistic" system, in which, unlike the U.S. system, there are close links between the executive and the parliamentary majority. Thus the demands by the opposition to receive information (nontechnical as well as technical) that it is traditionally denied, and to an equal number of seats in the political steering body of the proposed parliamentary TA institutions, are naturally resisted by the majority. It has also been observed that, because of the highly political environment in the U.S. Congress, many OTA projects have supplied technological information for short-term legislative deliverations, in contrast with tbe long-term holistic TA studies sponsored by agencies in the executive branch.

In Japan the traditionally close relationship between industry and government has set the operational pattern of TA activities in that country. A list of TA projects compiled by the Japanese Science and Technology Agency[2] indicates that over half of the TA projects in Japan have been conducted by industry. At the request of the Ministry of International Trade and Industry (MITI), the Japanese Industrial Technology Council set up a Technology Assessment Panel, which recommended in 1975 that TA should be done by the entities engaged in development of the technology and its application, usually the private sector industries, and that the government should both conduct TAs and "enforce measures to encourage the execution of technology assessments by private enterprise" [20]. One of these measures has been described by Hoashi of the Japanese National Institute for Research Advancement as a form of coercion: "the government affiliated organizations

[2] The list, obtained by Kan Chen in August 1976, showed 27 TA projects sponsored by government and 48 by industry.

which are being engaged in the R&D should make the results of TA public in principle before carrying out the experiments, and also the private corporations which are partly responsible for R&D projects of the government and have received government support or loan have to carry out TA'' [21]. As a result of such policy of institutionalizing TA, the Science and Technology Agency reported in March 1977 that out of 521 representative corporations in a survey, an overwhelming majority (72%) had applied, or had scheduled to apply, TA in their research and development (R&D) planning. There is a widely held concern in Japan that TA as practiced in industrialized market economies may have overemphasized the negative impacts and hence might become an inhibitor to technological innovation. The stress on the involvement of the innovators in industry to conduct TA is the Japanese way of implementing the social dynamics of TA idealized in Fig. 1.

The heterogeneity in defining and institutionalizing TA has made it difficult for industrialized market economy countries to cooperate in conducting transnational technology assessments. Blessed with the visible success of its 1972 international seminar on technology assessment [23], OECD tried to enhance international cooperation among its member countries by initiating both methodological and substantive TA studies. The former proved easier as methodological guidelines [24] are more theoretical and politically less sensitive than policy-oriented substantive TAs. Of the three substantive topics chosen by OECD for transnational cooperation in TA, namely, new urban transportation systems, humanized working conditions, and telecommunications technologies, only the first study has continued. Even that study (on transportation) has taken the form of ''coordination'' by pooling available national resources in a common effort.

A review of the OECD difficulties in transnational cooperation of TA [25] revealed that the crucial problem is the often changing interpretation and defense of national interests, which must be served by any international cooperation. Real policy decisions have to be made between competing and conflicting interests and values. Internationalization of other than direct technical and economic effects implies a deep change in social and legal structures, the kind of change no country is ready to make blithely. In addition to the lack of appropriate TA institution to represent each country (with the exception of the United States), as discussed previously, the industrialized market economies in OECD also face the impasse of sharing technological information (necessitated by transnational TA) in the ambience of international competition where secrecy during the phase of development is paramount.

Centrally Planned Economies

In centrally planned economies, including all the CMEA countries,[3] activities in science and technology are largely determined by sociopolitical goals. Science and technology goals are subordinate to the higher-level ideological and national goals. Historically the levels of economic affluence and technological advancement of the centrally planned economies have lagged behind those in some industrialized market economies [26]. Also, the management systems for economic and technological progress are generally considered less experienced and less developed. For these historical reasons, management effectiveness for the national economy ranks very high at present as a national goal for the Soviet Union and other CMEA countries [27].

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[3] These countries are members of the Council for Mutual Economic Assistance. They include the Soviet Union, the East European countries of Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, and Romania, and the non-European countries of Cuba and Mongolia.

Science and technology have been considered by centrally planned economies as major instruments for economic development. Karl Marx repeatedly synonymized the growth in labor productivity with technological progress [28]. It has been estimated that 75% of the increase in U.S.S.R. national production will be due to the use of the fruits of scientific research [29]. Thus the higher goal of national economic efficiency can be translated to the subsidiary goals of acceleration of technological development, intensification of production activities, and growth of labor productivity. Currently the overall U.S.S.R. national five-year plan contains a "Science and Technology Development Plan" as a component, which covers basic research and development of major science and technology, introduction of new technologies and innovations, automation of production processes, development of new products, and standardization and industrial engineering [30].

Within the all-encompassing framework of central planning, it is easy to view technology assessment as another tool for social management of technology. As such, TA is defined as evaluation of the consequences of the development of technology, and is separated from technological forecasting (TF) and policy options generation in response to the projected consequences. Thus TA is parallel to TF and several other management tools, and all of these are put under an umbrella called SANT [31] (systems assessment of new technologies), as shown in Fig. 2.

Precisely how much of SANT is TA and how much TA in practice overlaps with the other management tools, are not as important as the major concerns shared by the centrally planned economies in their social management of technology. Dobrov pointed out three significant trends in technological change: (1) increasing rate of substitutions of technology generations (doubling every 20 years), (2) increasing time and cost of R&D parts of the technology life cycle (cost doubling and time lengthening about 50% in the last 5-7 years), and (3) increasing time spent on systems analysis and decision making (toward one-third of the total technology life cycle). Thus, a major concern in the social management of technology is the long lead time between R&D and production. It is hoped that TA or SANT applied as a management tool can help the understanding of technological change as a dynamic system and provide the necessary management information to speed up technological development and technology diffusion in the national economy.

Other major concerns in the centrally planned economies stem from their historical lag in economic and technological development behind the industrialized market economies. One of these concerns relates to possible detrimental effects resulting from the importation of advanced technologies from the industrialized West, and TA is considered as a possible tool for evaluating these side effects. Another concern relates to the traditional laissez faire tendency in science and basic research. In view of the demanding national goals and the decreasing rate of expansion of scientific resources, however, this laissez faire attitude toward science can no longer be permitted [29]. To make science

SANT = TF + TA + AT + ERD + STP
SANT = Systems assessment of new technologies
TF = Technology forecasting
TA = Technology assessment
AT = Alternative technologies ("evaluation of variants for technology policy")
ERD = Evaluation (of "usefulness") of R&D
STP = Science-and-technology potential indicators

Fig. 2. Composition of SANT (from Ref. [3]).

more manageable, TA is expected to apply the principles of the "Science of Science" [32], a new discipline whose objective is a systematic theoretical analysis of scientific and technological efforts.

Given these concerns, TA as practiced in the centrally planned economies has very different thrusts than those of the industrialized market economies. First of all, TA, as the application of the science of science, attempts to anchor itself on theoretical principles of organization, objective measurement of performance, rational analysis for multilevel planning, and cybernetics of technological change. This theoretical, objective, rational orientation is exemplified by the use of "goal trees" in the analysis of the hierarchy of planning goals and by the inclusion of the whole chain of elements: education-science-technology-production-consumption in the technological development process [27]. Specific TA approaches are represented by newly approved methods [33] that stress the technical and economic dimensions. However, the economic effect calculations are quite comprehensive, including the entire lifetime of a given innovation with regard to the consumer and estimates of economic effect of new technologies with improved quality parameters. An even more comprehensive assessment approach that includes social as well as economic effects will be used by numerous Soviet research organizations from 1977 on [34]. Interestingly, the social effects will include such intangibles as greater opportunities for the comprehensive spiritual development of the individual, the collective, and the whole of socialist society, as well as conservation of the environment. Again, the rational and quantitative orientation in the TA approach is evident here, as represented by the current effort to use several groups of quantitative indices for the various effects, and the hope to reduce all the effects to a common integral index for setting project priorities.

The theoretical and scientific thrust is evident even in policy related activities. Academician M. D. Millionshchikov, Vice President of the U.S.S.R. Academy of Sciences, expected the science of science to eventually lead to recommendations about the optimum means of development of science [35]. In discussing the purpose of science-policy studies, D. M. Gvishiani, Deputy Chairman of the U.S.S.R. Council of Ministers State Committee for Science and Technology, stated that such studies are concerned with the general laws of development of science and technology and would become the theoretical basis in which the fundamentals of science policy are worked out [36].

Other interesting comparisons can be made between TA as practiced in centrally planned economies and TA as practiced in industrialized market ecnomies. Both groups of countries bave defined technology broadly for the purpose of TA. Recognizing the important interaction between technology and society, especially from the standpoint of social management of technology, Dobrov defines technology as a system consisting of a set of technical means *(hardware)*, methods and procedures to use those means effectively (*software*), and special organizations (*orgware*) designed to provide the utilization by the decision makers [31]. This definition of technology resonates with the three kinds of technologies (physical, social, and organizationsl technologies) that have been assessed in the United States [37].

The identification of potentially detrimental side effects of technology, so emphasized by TA in industrialized market economies, is not very pronounced in TA practiced by centrally planned economies. In fact, Dobrov makes a distinction between "managerial TA" and "alarm-oriented TA" and considers the former to be more important [38]. Surely the protection of environment is occasionally listed as a national goal, and the possible negative socioeconomic implications are sometimes listed as constraints placed on science and technology programs, but they are generally swarmed by the more direct and tangible goals of technical and economic developments. Also the *distributive* costs and benefits of new technology to various social groups within a country are never mentioned, let alone to be studied.

Since TA in centrally planned economies is embedded in the social management system for those countries, it is not surprising that TA as practiced in those countries face a couple of dilemmas in central planning in general. One is the conflict between central governments' authority and local individual initiatives. The other is the handling of disparate views on specific technologies, especially when such views are held by those perceived as political dissidents. These dilemmas are inherent contradictions accompanying socialist transformation and are among the most basic policy issues acknowledged and discussed by some centrally planned nations [39]. Of course, central planning is theoretically a top down (i.e., hierarchical) approach, which has imperfect power in actual practice. A great deal of anticipation and feedback from bottom up keeps central planning practical, leading to successive changes, adaptations, and readjustments in various aspects of the actual decision-making system. These practical needs have led to the introduction of economic incentives in some centrally planned economies so that both managers and workers of the socialist enterprises are interested in the profitability of their economic performance [40]. In the Soviet Union, the planning for technological program is "polyhierarchical" in nature, since linear relationship does not always exist between organizations responsible for technological program (e.g., the U.S.S.R. Academy of Sciences) and the entire system of national economy management. Decisions at the highly centralized level, decisions at the lower planning levels, and decisions by mainly technological organizations are not always well correlated [41]. It is also important to consider the factors that will affect the implementation of plans after they are formulated and adopted. The effective implementation will depend critically on operative incentives as well as authorities. In the Soviet Union, creative work in science and technology is the province not only of full-time scientists, engineers, and specialists working in various State scientific organizations, but also of numerous qualified workers in industry, culture, and social management. Thus there are "voluntary research institutes," which organize and direct the efforts of engineers, technicians, and workers to find new ways of solving current problems of technical progress in collaboration with professional scientists. Those engaged in the voluntary sector of Soviet science are motivated primarily by moral factors arising from a love for creative work in science and technology [42]—which may or may not correlate well with immediate national economic goals at the central planning level.

There are certainly environmentalists in centrally planned economies, and the environmental dimension of TA has its place in multidimensional planning and assessment procedures. It is recognized that degradation of natural and human environment, rise of technocracy, and discrepancy between technological and social changes could adversely affect centrally planned economies as well. Although there are State Committees for Environmental Protection and Development in the Soviet republics, public debate through open adversarial processes is simply not done in centrally planned economies.

Although "the State and its responsible organs, boards of management and individual managers do not want disparate and frequently contradictory assessments and recommendations from the isolated standpoint of economics, information science, psychology, etc." [29], disparate views do exist within the socialist systems such as between labor and management. The differences are usually resolved through a process of social consultation, such as through Party leaders' consultations (direct talks and meetings) with the working class of big industry [26].

Since TA is a part of the social management of technology in centrally planned economies, institutionally TA has permeated the organizational structure of science and technology management, such as the one for the Soviet Union (see Fig. 3), and the one for Poland shown in Fig. 4. It is interesting to note the close linkage between the legislative and the executive branches of Eastern European governments—similar to Western Europe but different from the United States. Unlike Western Europe, however, the legislative bodies in Eastern Europe are much more stable in terms of party control. It is also interesting to note the parallel status of the State Planning Committee and the State Committee on Science and Technology (above the U.S.S.R. Academy of Sciences), both under the Council of Ministers (see Fig. 3). Thus, assessments of technologies of national significance tend to have their locus in and around these institutes. In the case of Poland, the existence of the Research and Prognostics Committee "Poland 2000" provides a long-range planning link between the State planning commission and the Polish Academy

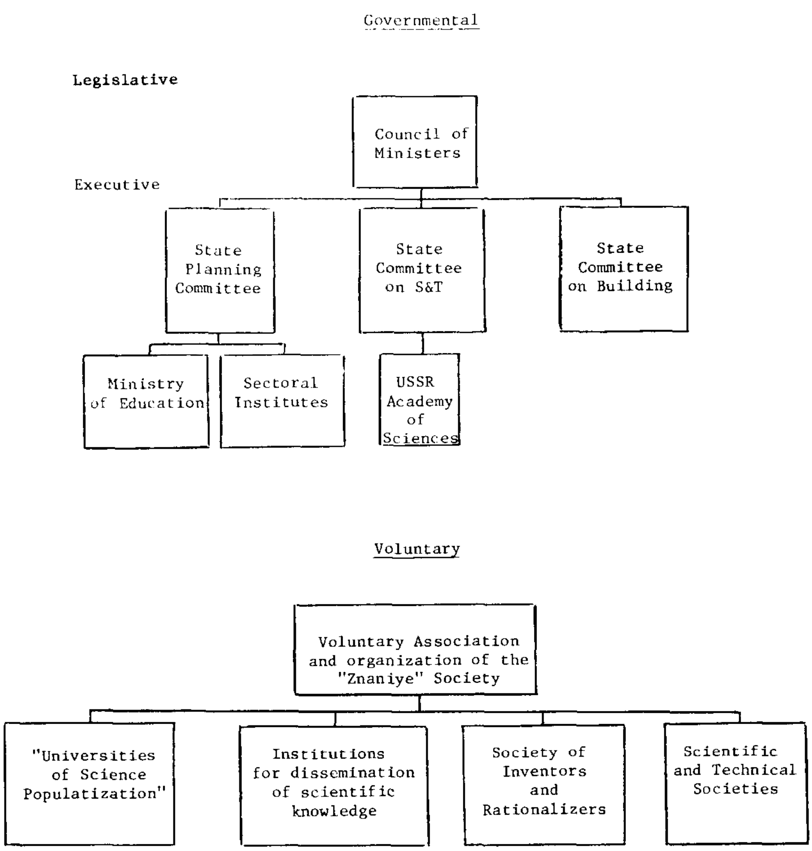

Fig. 3. Organizational structure of science and technology (S&T) in the Soviet Union [from Ref. 42].

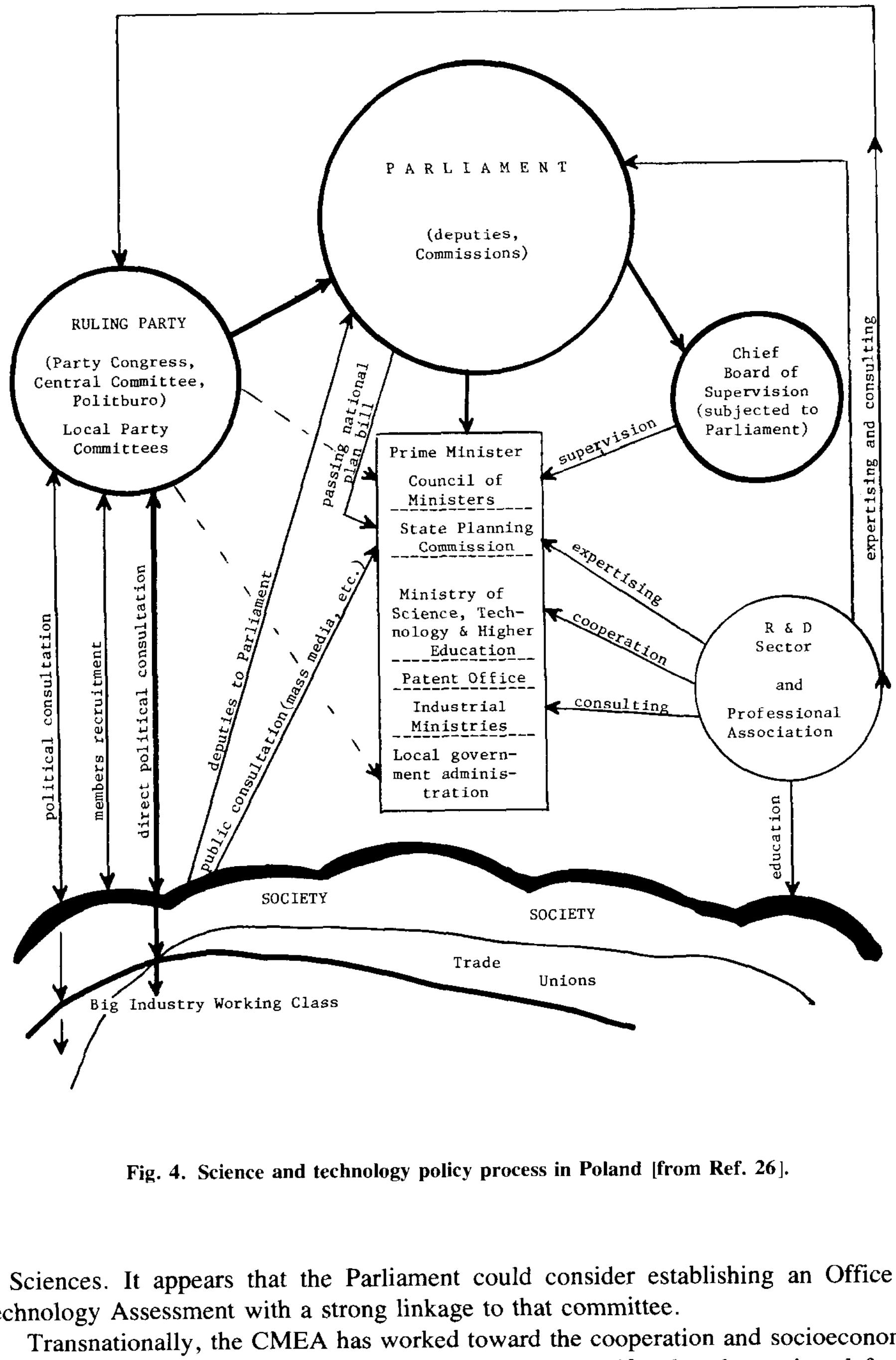

Fig. 4. Science and technology policy process in Poland [from Ref. 26].

of Sciences. It appears that the Parliament could consider establishing an Office of Technology Assessment with a strong linkage to that committee.

Transnationally, the CMEA has worked toward the cooperation and socioeconomic integration of its member countries. There are both centrifugal and centripetal forces affecting this integration [43]. In the area of science and technology, an interesting CMEA project of multinational technology forecasting and planning started in 1972 and resulted in 1976 a set of recommendations with respect to the employment of joint forecasting methods [44]. The approach is so comprehensive that it contains at least some elements that would usually be considered within the realm of TA. The ultimate goal of this joint forecasting exercise was to do cooperative planning. Thus four basic groups of criteria were used to guide the selection of a manageable number of technological possibilities: forecast reliability criteria, policy criteria, technical and economic criteria, and criteria of systematic coherence. The policy criteria take into account the social structure, the internal and external policy of the individual country concerned and the CMEA as a whole, the ideology expressing the attitude of the state towards science, and the national goals (economic growth, defense, national prestige, etc.). Each participating country was asked to strategically recognize those technologies for which the country should not deliberately try to reach the state of the art but should be content with relying mainly on the application of international scientific and technical experience.

The lessons learned from this CMEA project included the importance of involving decision makers of various levels as well as scientists and engineers, and the need for continuing improvement of methodology—lessons quite similar to those learned elsewhere from TA projects. Furthermore, similar to the OECD experience discussed in the last section, the CMEA project led to the conclusion that taking into account the specific interests and priorities of each member country is a main precondition for successes in multinational projects in this area. In summary, the benefits of integration must outweigh the costs of integration in the long run and the national bodies must be convinced that they can preserve their sovereignty while being helped by multinational cooperation and consultation [45].

Developing Countries

The most persistent goal of the highest priority shared by the developing countries has been to close the economic gap between them and the industrialized world. In spite of a great deal of well-intentioned efforts from both rich and poor countries in the past three decades, this so-called north-south gap has been widening in terms of per capita gross national products. Turning from deference to defiance, the developing countries have demanded a new international economic order in which they will have at least equality of opportunity for future development and more proportional share of future growth. This demand has received global moral backing [46] and has received some serious support from the industrialized market economies and the centrally planned economies, as the industrialized countries themselves face unprecedented problems of energy and raw-materials shortage, economic "stagflation," and balance-of-payment deficits. Had the developing countries (the "South") not called for a new international economic order, the industrialized countries (the "North") would have pressed for one [47].

Parallel to this background, there has been a sobering understanding of science and technology for development. Until recently it had been the general belief that modern science and technology could lead to nothing but the improvement of the living standards of all people in the developing countries. The major concern was not whether all science and technology are beneficial to development, but whether the traditional values and institutions in the developing countries could undergo timely and sufficient changes to benefit from the fruit of science and technology. Now we have learned from experience that direct transfer of foreign agricultural and industrial processes can often aggravate unemployment in the developing countries, uprooting the rural unemployed as they migrate to urban ghettos. The benefits of science and technology have thus often been reaped by a small privileged minority without touching the masses living near the subsistence level. Large-scale irrigation projects such as the Aswan High Dam could lead to tremendous environmental problems, threatening public health and future land use [48]. High-yield grain monocultures, the kernel of the green revolution, could be ecologically unstable and can be maintained only by heavy use of fertilizers, pesticides, herbicides, and energy [49]. Consequently, the "green revolution" bas benefited only the rich farmers, leaving the poor farmers untouched and driving out the peasants who used to work for the rich farmers [50]. Multinational corporations, which have served as main vehicles for technology transfer from industrialized market economies to developing countries, have also been a source of undesirable foreign political influence [51]. The fact that much of modern technology is often unavailable to the developing countries except as part of a package offered by transnational enterprises (publicly as well as privately owned enterprises which deal with international flows of equipment, finance, technical know-how, and personnel) only reflects the technological overdependence of the developing countries on the industrialized world. As the developing countries have tried to develop their technical human resources, much of this effort has turned out to be irrelevant or unretainable to the development needs, resulting either in a mismatch between the demand for skilled factory workers and the supply of theoretical scientists, or in technical "brain drain" from the developing countries to the industrialized world.[4] For one reason or another, science and technology seem to have only helped the rich countries get richer and have not benefited the poorest in the poor countries. This perception has led to the demand of creating a "new scientific and technological order" within the new international economic order [52].

The significance of the new international scientific and technological order can be appreciated only from a historical perspective. In the 1950s a host of new nations emerged as numerous former colonies gained political independence. However, it was not very long before the new nations realized that political independence would not improve their human welfare enough without economic independence. The 1960s was the decade of technical assistance, mostly in the form of "turnkey projects" rendered by the industrialized world (OECD and CMEA countries) to the developing countries. Pretty soon the developing countries learned the lesson that technological independence underlies economic independence, and that the former cannot be attained through package deals. The byword for the developing countries in the 1970s is "self-reliance," which has been exemplified by the assiduous efforts of the Chinese people over two decades. After the oil embargo in 1973, many developing countries began to see two interrelated facets in the strife for a new scientific and technological order. The first facet is for those developing countries exporting raw materials to nationalize their natural resources and to bargain for the highest possible prices for their raw materials in the international market. The other facet is for all developing countries who must import agricultural and manufactured products to develop their own agriculture and industry, using technologies that fit their own development criteria. This latter facet implies the need for developing countries to do technology assessment.

According to Chatel [53], developing countries would assess technologies according to the following typical criteria:

1. Employment: with surplus of low-cost labor and often high unemployment (as high as 70% in some nations), it behooves most developing countries to consider

[4] The United Nations Conference on Trade and Development (UNCTAD) estimated that, in economic terms, the imputed capital value of the skill of technicians migrated to United States, Canada, and Britain from the developing world exceeded the aid from those three countries to the developing world by $4.6 billion for the period of 1960 to 1972.

labor-intensive processes, especially in such cases as road construction, instead of using Western capital-intensive labor-eliminating technologies.

2. Capital: being capital limited, especially in foreign exchange, most developing countries should consider capital conserving, inexpensive technologies, as exemplified by mini-cement factories in India.
3. Energy: with energy cost at a premium and rising continuously in the foreseeable future, most developing countries should consider energy conserving technologies where applicable.
4. Material: indigenous materials should be used wherever possible, not only to save cost but also to support local economy and employment (a good example is the use of bamboo instead of steel pipes for transporting irrigation water).
5. Environment: while the rich world is concerned about the impact of its pollutive activities on life-supporting systems, the poor world is more concerned with the pollution of poverty [52]—pests, epidemics, unsanitary conditions, and so on.
6. Culture: consideration must be given to the taste, need, habit, and tradition of the local people. For example, women in traditional Arab societies have very different work roles than Western women. Small electric grinders would be very useful to those women in African villages who currently spend about 3 hours each morning crushing cereal.
7. System: marginal changes in the total sociotechnical system may be more effective than revolutionary changes. Thus oxcarts may be good transportation substitutes for people carrying food on their heads. Incremental changes of local bureaucracy may accomplish higher efficiency than abrupt transplantation of Western administrative technology [54]. This is not to ignore the goal of eventual modernization of the entire technological and managerial system.

Presumably, technologies meeting such criteria would be "appropriate technologies," a term that has been popularized by Schumacher's seminal work [55]. Because of Schumacher's emphasis on criteria (1) and (2) in the preceding list, appropriate technologies have often been identified exclusively with "intermediate technologies" or "light capital technologies," characterized by labor intensiveness and capital conservation. This approach, in contrast with the direct transplantation of Western technology through turnkey projects discussed previously, has received increasing popular and official support.

Ironically the support for appropriate technology appears to be concentrated at present in the industrialized world, as evidenced by a number of new programs, research institutes, and even public laws stressing this concept.[5] Many developing countries have suspected appropriate technologies as second-best technologies that the industrialized countries are willing to share while keeping the most advanced technologies to themselves.

Actually appropriate technologies need not be exclusively intermediate technologies. The test of appropriateness, such as by the list of criteria given previously, sbould be based on national development goals and sectoral/local community needs. As developing countries are not a homogenous group, their goals and needs may be very different from each other. Since the oil embargo, differentiation has been made between the Third World

[5] Representative of the support are new programs in appropriate technology in U.S. AID, California State Government, U.S. and U.K. research institutes in appropriate technology, and U.S. Public Law 95-105 (August 1977), which requires the United States to place important emphasis on the development and use of light capital technologies in her participation in the 1979 U.N. Conference on Science and Technology for Development.

(developing countries with rich nautral resources) and the Fourth World (developing countries with little marketable resources). Some developing countries are rich in hard currency but deficient in technical skills, whereas others may have thousands of scientists but are overburdened with large poor populations. Some developing countries have had a great deal of experience in successfully dealing with transnational enterprises, whereas others may have stuck to stringent self-reliance as the basic development strategy. Given such heterogeneity, it is impossible and unwise to conlude that small-scale, labor-intensive, and decentralized technologies are always most appropriate to developing countries, although such technological options should be considered. In fact, certain developing countries may have a latecomer's advantage as compared to the industrialized countries in adopting the most advanced technologies. A case in point is the use of fiber optics in telecommunications, which may be very appropriate for developing countries that do not have to be concerned by the cost of writing off the capital of large copperwire telephone systems since they do not exist. Other examples include the use of plastics for automobiles and airplanes, the use of the most advanced steelmaking processes, and the use of satellites for communication, education, and surveying for vast areas without an industrial infrastructure.

The preceding discussion suggests that the major thrust of TA for developing countries would be the selection of appropriate technology (AT) on the basis of national development goals and sectoral/local community needs. Although TA has not yet been widely practiced or even understood by most developing countries, the early discussions certainly have pointed in the direction of linking TA with AT [56, 57]. Conceptually, this linkage may be represented by Fig. 5, which may be compared with TA for industrial market economies represented by Fig. 1.

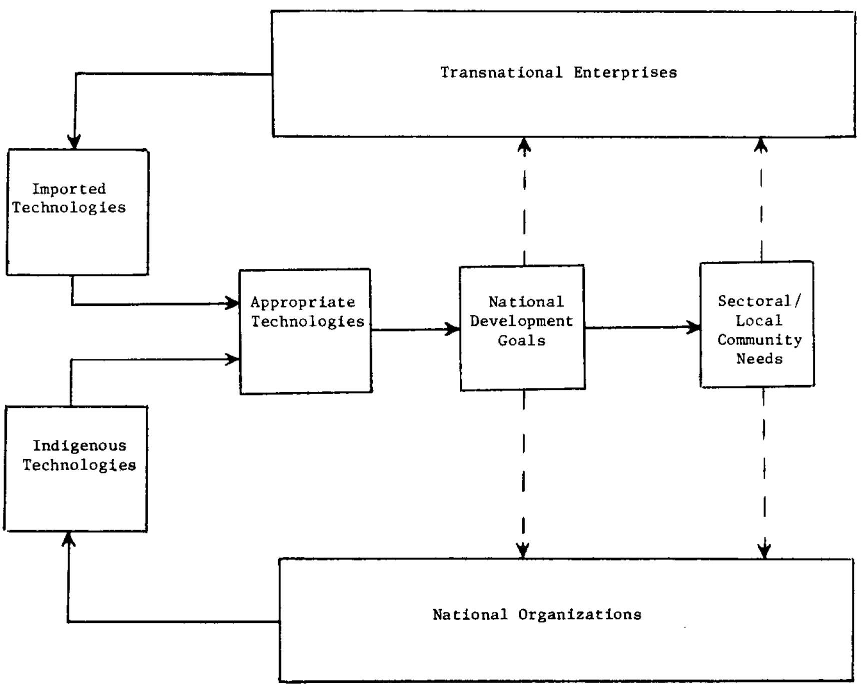

Fig. 5. Technology assessment for developing countries.

Technological choices by developing countries are usually perceived to be of two basic types: (1) imported technology and (2) technology A or technology B [58]. This is frequently the case at present, and the technological options for developing countries are therefore rather limited. Two ways of broadening the options are suggested by Fig. 5. First, combinations of imported technologies and indigenous technologies should be considered. However, any intricate combination would require an in-depth knowledge of the imported technologies, a knowledge that may not be accessible to many developing countries. The second way is to develop the skill and institutional arrangements so that the transnational enterprises would be motivated to create and modify the technologies they intend to import, and the national organizations would be capable of creating and modifying the indigenous technologies, all based on the national development goals and sectoral/local community needs of the developing country in question. This second approach is more difficult because developing countries, and even the smaller industrialized countries, are generally consumers or receivers, rather than generators, of technology [59]. Moreover, some developing countries may be too weak and too soft to deal effectively with large transnational enterprises whose sales volume may be comparable or much larger than the developing country's GNP [60].

Although the suggested ways of broadening the technological options for developing countries are very ambitious undertakings, some specific measures have been proposed to improve the access of developing countries to technological know-how, to increase the applied research capacity of the developing countries, and to encourage the industrial countries to develop appropriate technologies tailored to the needs of developing countries [61]. The institutional capability and arrangements will take time to build. Meanwhile, the developing countries need to develop their own capabilities and institutions for TA so that TA *by* them as well as *for* them will become possible. Until developing countries are themselves involved in technology assessment, creation, and selection, they will not gain the technological independence they desire.

Transnationally, the United Nations have been an active catalyst in introducing TA to the developing countries [56, 57]. Significant international efforts have been made to assess the environmental impact of certain technological projects [48, 62]. Some bilateral discussions and exchanges of information about TA have taken place between individual developing countries and industrialized countries. However, to our knowledge, there has been no full-fledged TA projects involving a group of developing countries, analogous to the OECD and CMEA projects discussed previously.

The United Nations Conference on Science and Technology for Development (UNCSTD), scheduled for 1979, is supposed to help build programs supportive of the self-reliant and equitable principles of the New International Economic Order [63]. It remains to be seen to what extent TA by the developing countries will be facilitated by the UNCSTD and its follow-up activities, and to what extent TA by the developing countries will help shape and bring about the New International Scientific and Technological Order.

Toward Global Technology Assessment

With its increasing power, scale, and complexity, technology and its impacts respect no national boundary. Assessment of certian powerful, large-scale, and pervasive technologies must be conducted on a global basis involving all country groups. The assessments of nuclear power, earth-orbiting satellites, and energy technologies having global environmental impacts are just a few examples.

		Premises		Processes	
		Social Values	TA Thrusts	Major Concerns	Conflict Resolutions
Differences	I	Diversity	Side Effects	Control of Private Sector	Open Adversary
	II	Efficiency	Social Management	Efficiency of Public Sector	Social Consultation
	III	Equity	Appropriate Technologies	Influences of Transnational Enterprises	Demand for Self-determination
Similarities		Reduced laissez-faire attitude Social management of technology		National government controlling large-scale technology Two-community theories in TA utilization No international government	

Fig. 6. Elements of similarities and differences in TA premises and processes among the three groups of countries (I—industrialized market economies; II—centrally planned economies; III—developing countries).

It has been argued previously [64] that a cross-national understanding of technology policy decision *processes* and basic *premises* underlying TA must be established before effective international TA can be accomplished. Therefore, before any global TA is attempted, it behooves us to compare the differences and similarities in TA premises and processes of the various countries in the world.

In the previous sections we have discussed the differences in TA as perceived and practiced by the three country groups of industrialized market economies, centrally planned economies, and developing countries. These differences are further expanded and summarized in Fig. 6. From the standpoint of basic social values, we see tbe difference in major emphases being placed on diversity [65][6], efficiency, and equity, respectively. Interestingly, this difference in values seems to reflect more the different social needs at various technoeconomic development stages rather than different ideologies. In terms of TA, we see the difference in major thrusts being directed to the anticipation and control of negative side effects of technology, to the social management of technology as part of central planning, and to the development and selection of appropriate technologies.

Under the "process" column in Fig. 6, differences among the three country groups lie first in their concerns about their respective traditional processes through which technologies are developed, adopted, and diffused. Thus the industrialized market economies are concerned about controlling the private sector without stifling its creativity

[6] The term "diversity" here refers to the coexistence and simultaneous expression of disparate rankings of social values by a variety of social groups.

and initiatives in technological change. The centrally planned economies are concerned about efficiency in their public sector, which has traditionally planned and managed their technological change, whereas the developing countries are concerned about excessive influence of the transnational enterprises instrumental in bringing modern technology to the developing countries. The three groups of countries also differ greatly in their processes through which conflicts about technological issues are resolved. While the industrialized market economies are accustomed to the open adversarial process in public debate, the centrally planned economies generally resort to social consultation within the planning process. A mixture of these two kinds of conflict resolution processes is usually found in most developing countries. However, the more important factor in the developing countries is their aspiration for true self-determination in science and technology, which can be achieved only by gaining access to technological information that they do not now have.

In spite of such profound differences, there are basic similarities among all country groups. As shown in Fig. 6, a central element of similarity in TA premises among all country groups is that technologies that have broad social implications should be brought under social control. Thus, as has been discussed previously, all three groups have a reduced laissez faire attitude toward science and technology, and social management of technology is becoming an increasingly accepted concept, even in the industrialized market economies [66].

There are also basic similarities among all three groups in their policy making processes within which TA must operate. For example, large-scale technological developments—space exploration, nuclear power, and so on—are largely under the control and regulation of national government agencies. The two-communities theory—that TA doers and users live and operate in separate worlds with different and often conflicting values, different reward systems, and different languages—probably bave equal validity in explaining and predicting the difficulty in effective use of TA in real policymaking in all countries. Finally, the absence of a powerful international governing body having the authority to legislate and enforce international laws makes global and international TA equally difficult in this respect for all countries.

Although we should emphasize the similarities in the development of effective global technology assessment methodologies, we maintain that we should also be aware of and sensitive to the differences in order to avoid unnecessary snarls. Moreover, the differences could also provide an opportunity for mutual learning. For example, the experience of industrialized market economies in dealing with diverse goals and values in technology assessment would be helpful when there are conflicting goals and values between countries participating in global technology assessments. On the other hand, the experience of centrally planned economies and developing countries in linking TA to social goals can be exploited once sufficient agreement on some specific goals and criteria for a global technology assessment is reached.

In conclusion, we believe that global TA is needed for the future of mankind on spaceship earth. Global TA is difficult, but not impossible. The experiences of transnational TA within the OECD and CMEA are useful initial steps. To work across country groups, we believe that an in-depth crossnational understanding of TA premises and processes is a prerequisite for global TA. Appropriate and effective common methodologies can then be developed for global TAs involving more than one group of countries, without a complete agreement on premises and processes. Eventually new and effective methodologies and institutions for global technology assessments can emerge after sufficient learning from the actual experience through international collaborative efforts across groups of countries.

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