PN-ABH-133

THE ECONOMICS OF TECHNOLOGY
WORKING PAPER NUMBER 5

EMERGING ORGANIZATIONAL ARRANGEMENTS FOR APPLYING TECHNOLOGY TO DEVELOPMENT

By: Rustam Lalkaka
Northwestern University

December 1990

Bureau for Program and Policy Coordination
U.S. Agency for International Development

Technology Assessment Policy Analysis Project
A.I.D. Contract No. PDC-0091-C-00-9092-00
SRI International

CONTENTS

I. BACKGROUND 1

II. OBSTACLES TO TECHNOLOGY DEVELOPMENT PROCESS 2

III. TECHNOLOGY DEVELOPMENT PATTERNS 5

IV. SOME LESSONS OF THE LAST DECADE 7

V. TECHNOLOGY PLANNING MODEL 10

VI. NEW ORGANIZATIONAL ARRANGEMENTS 13

VII. IMPLICATIONS FOR DEVELOPMENT ASSISTANCE 16

VIII. CONCLUSION 21

REFERENCES 26

I. BACKGROUND

Since attaining political independence in the mid-1940s, developing countries have established a variety of institutions to develop and apply technology to their economic growth. These have initially included state-sponsored agricultural and multi-sectoral industrial research and ministries or councils to administer, rather than promote, S&T activities. As the economy has matured, support systems have been set up for information and small enterprise promotion as well as for attracting foreign know-how and investment. Today many such institutions are not performing well and need major restructuring, while some more imaginative arrangements need to be established in a vastly changed global situation.

Technology to date has generally remained outside the mainstream of economic life. The adverse trade environment, together with acute problems of debt and drought in Latin America and Africa in the 1980s have caused major setbacks to their economies. A few countries in east Asia have fared better due partly to their export-led strategies linked to explicit market-oriented technology policies.

The start of the 1990s is therefore an opportune time for all developing countries and for development organizations to draw lessons from the past and to redesign their strategies and structures for the future. Two new factors made this task even

more urgent: First, the accelerating growth of informatics and emerging bio-technologies is redefining the competitive advantage among countries. For a select few among the late-comers, the frontier technologies offer real opportunity. These countries can progressively move away from reliance on abundant raw materials and low-cost labor, towards more knowledge-intensive, high value-added activities. Most others, however, face a bleak future, one that is exacerbated enormously by the recent crisis in the Gulf States. Second, the changing relationship between the First World and the Second requires that the countries of the Third World -- no longer a monolith -- learn to rely more on themselves and on each other. The new structures for technology development must take full account of these harsh realities.

This paper reviews the challenges in technology development and some emerging organizational arrangements, based on the author's experience with the UNDP/UN Fund for Science and Technology over the last decade, when technical assistance projects were designed and implemented in some 60 countries covering the full development spectrum.

II. OBSTACLES TO TECHNOLOGY DEVELOPMENT PROCESS

Each country is a unique socio-cultural entity and generalizations are dangerous. Nevertheless, the underlying factors hampering the needed technological transformations are

remarkably similar. The main obstacles to the innovation process are considered to be as follows:

1. Inadequate political commitment to developing and applying science and science-based technology to basic needs. There has been considerable rhetoric during and since the UN Science and Technology Conference at Vienna a decade ago, but little understanding of the true role of technology in accelerating growth through innovation.
2. Misdirected eduction and training. The available technical human resources do not match the real needs for management of technology-based operations. We thus have a situation, as in Pakistan for instance, where there is widespread illiteracy concurrent with unemployment among scientists.
3. Lack of domestic financial resources for upgrading technology in the productive sectors as well as for scientific research. Dependence on external assistance inhibits local initiatives. In countries such as Bangladesh and Kenya, donors have compulsions to give massive aid and recipients to grab it, but very little of this assistance ultimately reaches the target group (only 20 cents per dollar of aid, according to a recent estimate) and it hardly adds anything to local self-reliance.
4. State-sponsored research suffers from sub-critical funding, inadequate autonomy, unmotivated researchers and poor linkages to the market-place. In all developing countries (except Korea) the productive sector, private or public, does little research itself and, in protected markets, feels no compulsion

to use the state laboratories. Countries such as Turkey and Thailand now have the acquisitive capability to negotiate and use imported know-how but lack the innovative capability to adapt, improve or invent.

5. No recognition of the role of scientists and engineers. Even in India and China, with well trained technical manpower, the strategic decisions concerning S&T are usually taken without involvement of the scientists or of the end-users. Eventually, the scientist loses all self-confidence, and ends up as a "brain-drainee", or worse a "drained-brain"!

6. A dichotomy between an affluent urban sector based on foreign know-how and lifestyle, and a large rural under-class whose traditional technology is in decay. Such contradictions are all too apparent in many Latin American countries such as Peru, Mexico and Argentina. The metropolitan centers tend to attract a disproportionate share of financial and educational resources, and the resultant benefits rarely trickle down to the periphery. Most of the technology imports are for urban industries and has little relevance to the rural sector which continues to be mainly agricultural.

7. Weak technical infrastructure. Without proper communications, quality management, technology sourcing and information, consultancy services, and other support systems, technical innovation is impeded. The near-total lack of supportive structures and services is a characteristic of the least developed countries, many of which are in sub-saharan Africa.

8. Constraints of colonization and culture; the lack of equity in the global power structure. It is true that the late comers have made some significant progress by avoiding mistakes already made and building upon technologies already developed -- for instance, average life expectancy in the South is now 80 per cent of that in the North. But, on the other hand, the late comers do <u>not</u> have the technical infrastructure which took two centuries for the others to develop. They do not have "colonies" for markets, nor equitable access to the advanced technologies which can change their lives. While their political and economic revolutions are still incomplete, they have been thrust into revolutions of new ideas and high expectations.

III. TECHNOLOGY DEVELOPMENT PATTERNS

As noted, among developing countries themselves there is increasing differentiation in technology development capabilities. A measure of a country's technical level could be of great interest to national planners as well as external donors in the allocation and efficient use of scarce resources. Such a Technology Development Index should incorporate the inputs such as S&T expenditures and scientific personnel as well as outputs in terms of citations in world scientific literature, patents, exports of technology and technology-embodied equipment; also perhaps such intangibles as the autonomy of scientists and the quality of

infrastructure services. But data on S&T indicators is extremely incomplete and incompatible.

Further, co-relationships between levels of technological capability and of economic or human development are quite weak. The classic case is that of India which has an impressive technology establishment but ranks amongst some of the poorest countries in per-capita income terms.

Attempts to categorize the stages of technology development have viewed it as the process of learning by doing, adapting, designing, producing and innovating; or as the "backward integration" from production engineering, through project execution, capital goods manufacturing and on to R&D; or as patterns of technology acquisition from initiation, internalization to generation; or even as a struggle for mastery and movement away from a protected to a competitive market.

Another approach would be to compare the extent and maturity of the scientific and technological infrastructure, that is, the technical support services such as quality assurance, consultancy, sourcing and intelligence, venture capital, R&D systems and related mechanisms for promoting innovation. Table 1 attempts a preliminary typology of countries at escalating levels in the technology development process, based on empirical observations of their comparative S&T infrastructures.

Thus, technology development is seen to take place as a progression through six stages: Initially, the economy is based on traditional technology and there is practically no formal

support system. In the next stage, small industry and the informal sector prosper and mechanisms are initiated for standardization, testing and trouble-shooting. Then, modern industry emerges and the support measures begin to improve in quality and extent. As the country develops, the co-ordination of research and its linkages are strengthened, computer-based information systems and consultancy organizations set up. In later stages, as systems mature, new organizational arrangements have to be created in order to develop top technology managers, innovation centers for advanced products and processes, technology sourcing systems, special spaces for start-up of technology-based ventures, improved productivity and quality, and risk capital.

IV. SOME LESSONS OF THE LAST DECADE

The technological landscape has changed quite dramatically since the UN Vienna Conference 1979, when developing countries still had high hopes of narrowing the gap between themselves and the industrialized world and also of significant financial resource transfers to help in this process. Some clear lessons can be drawn from the disappointments of the last, lost decade.

First, technology policy is only one factor in economic progress, and needs to be fully integrated with the whole development process through a wide dialogue with all key players - universities, financial institutions, private and state enterprises, research laboratories, the urban and rural

stakeholders. Market-oriented technology strategies are now required together with economic policies to stimulate competition, upgrade quality and increase productivity. The overall objective must be higher growth but with greater equity.

Second, the foundation for technological transformation is technical human resources. This starts with an awareness of the efficacy of science-based technology from the primary school onwards, particularly among politicians and government decision-makers. Knowledge and skills are required not only for science faculty and researchers, but also for technicians and trained workers to handle complex technical operations. Importantly, at the interfaces of governance, research and production, a new breed of managers of scientific research and technology transfer has to be developed.

Third, developing countries need to deploy larger financial resources to the whole range of technology development activities, particularly the infrastructure to support research, development and engineering. Laboratories which currently operate at sub-critical levels must first be strengthened before new institutes are started. The more advanced countries cannot afford to neglect basic scientific research, which is the knowledge base without which there can be no mastery of applied work. An important lesson of the recent past is that multilateral support to technology development will continue to decline, either because donors consider that S&T has important leverage in foreign policy and is best handled bilaterally, or because they do not consider it

important enough in the face of other priorities such as energy and environment - both of which of course are amenable to long-term technological solutions.

Finally, many of the dichotomies of the last decade should now be demolished. For instance, the debate on hi-tech vs "appropriate technology" should end with the realization that a technology carefully selected to optimize returns against consumption of scarcest resource (whether capital or energy or skills) is indeed the most appropriate. Even the poorest countries now need advanced techniques such as remote sensing or computer-based instruction as well as the technical capability to choose, operate and maintain them. But only a handful of developing countries today have the technological base to do any significant research work or experts in selected areas of competitive advantage. Typical examples are computer software developments in India, processed foods in Thailand and plant biotechnology products in Brazil.

There need be no further controversy on domestic research vs know-how imports. As Japan and the NICs have demonstrated so successfully, in many situations it is faster and cheaper to import the best technology, which itself requires enormous competence; then, the acquired know-how has to be adapted, absorbed and eventually improved, which again needs strong research capabilities. Again, only a few developing countries at advanced technical levels produce research results commensurate with the development of scarce national resources. This also gives them a certain standing in the international scientific pecking order.

But government-sponsored laboratories in most other countries are mainly engaged in trouble-shooting and testing. They could do better by applying process know-how already in the public domain or by importing technology purposefully and adapting it to local conditions.

Further, the arguments in some developing countries favoring a dominant role for the state (vs private sector) in production and research have validity in only very special situations. More often, such policies distort prices and suppress competition, affect the appropriate choices of technology, discriminate against small employment-generating businesses, and generally retard the development of technology. Recent events have clearly shown that market-oriented development usually allocates and utilizes resources more efficiently. The state's function should be to provide the enabling environment for private initiatives to establish viable technology-based activities which create quality products, exports, jobs.

V. TECHNOLOGY PLANNING MODEL

Under conditions of political uncertainty, internal and external pressures and systemic corruption, most developing countries are unable to prepare or implement sustainable policies for science and technology. An approach to such planning is shown in Table 2, assuming relative stability and based upon recent experiences in a range of developing country situations.

In the context of the national economic plan, the technology policy and policy instruments are developed with the objectives of strengthening acquisitive, absorptive, adaptive and innovative capabilities. The key inputs to this process are:

1. Technical human resources at all levels, for manufacturing, maintenance, research, and support services,
2. Financial resources for investments in upgrading the productive sector and the needed technological systems, and
3. Technology infrastructure of research, consulting, know-how sourcing and negotiating, technology assessment and forecasting. The overall objective is human development, that is, providing options to enhance health, employment, and well-being for the mass of the people.

VI. NEW ORGANIZATIONAL ARRANGEMENTS

The main difference between a technologically developed and a developing country is perhaps that one has S&T institutions that work due to good organization and team-work, while the other has institutions with similar functions (on paper) but which in practice do not work due to poor management and inadequate infrastructure. It is politically difficult to close down such institutions, but it may be possible to restructure them.

Furthermore, the changing times call for lateral ways of thinking and innovative forms of organization. Several emerging

organizational arrangements should be considered to meet the challenge of the 1990s.

1. Improve research productivity by enhancing skills, giving autonomy and accountability, and by ensuring that contract research meets at least 50 per cent of the laboratory's annual operating expenditures. Part of this income could go as incentive payments to research groups. Securing such contract work may call for a technology commercialization group to be run as a private, for-profit corporation.
2. Establish a foundation to promote research grants on the basis of matching contributions from private enterprises. This could help bridge the otherwise impossible gaps between state laboratory, university research and private business. The foundation could also help prioritize research needs through strategic studies on competitive advantage in selected export markets. The World Bank is presently appraising a major loan for supporting industry-university collaborative research to help raise technology to world-class levels in Turkey.
3. Adapt the technology park/incubator modality to local conditions. This offers advantages of providing focussed management/marketing assistance to start-up companies, the synergy of bringing like-minded entrepreneurs and researchers on one campus. UNFSTD is currently assisting China, India, the Philippines, Zimbabwe, Nigeria, Gabon Côte d'Ivoire and Poland in assessing the entrepreneurial environment and feasibility of setting up technology business incubators.

Logical extensions are to create an entrepreneurship development institute to train a new generation of business people as well as a venture capital company to take equity positions in high-risk enterprises, where conditions call for such operations.

4. Initiate a technology sourcing and brokerage mechanism. This is now a special discipline, which helps match the needs of firms in developing countries with the availability of know-how on proven products and processes. Small businesses in the industrialized countries which have such know-how would otherwise not be able or willing to find appropriate partners, due to the high transactional costs of doing business under conditions of uncertainty.

5. Mobilize expatriate nationals through programmes like TOKTEN. Such professionals have the knowledge and commitment to make a significant contribution to their countries of origin. They could also access funds to start small high-tech businesses. The UNDP programme has enabled 3,000 TOKTEN consultants from 28 countries to return home for short volunteer assignments.

6. Start technology assessment and forecasting as a specialized activity. In a fast-changing technological world, an incorrect choice could have long-term implications for competitive advantage, employment, trade and environment.

7. The practice of total quality management has to be made a national preoccupation, together with the required quality testing, monitoring, and legislative measures.

8. Introduce training in the management of scientific research and technology transfer.

9. Develop local design and engineering consultancy services. Giving meaningful responsibility to local industrial consultants is a most cost-effective way of acquiring technology and technical experience; opportunities to gain such experience are lost when external consultants are used indiscriminately.

10. Create a strong awareness of the role of science and technology in national development and enhance the status of scientists.

Table 3 on the next page indicates schematically the progression of institutional arrangements of increasing sophistication being set up in developing countries as their economies expand and technological infrastructures mature. Donor agencies need to direct their assistance to establishing such institutional arrangements as are appropriate and sustainable for the stage of technological development in a country. A transplant in the wrong season cannot thrive; an institution set up before its time will atrophy.

VII. IMPLICATIONS FOR DEVELOPMENT ASSISTANCE

The justification for increased international co-operation in science and technology may seem self-evident to some, but has yet to be fully established for the decision-makers in both government

and aid agencies. Specific studies are therefore needed on the costs-benefits of such co-operation, at national, sub-regional and global levels, through all financing channels, and in the key environmental, production and service sectors. This should lead to a validation and better awareness of the significant past (and probable future) contributions of S&T to human well-being, national income, international trade, employment and competitiveness.

Developing countries must make their case more cogently for continuing co-operation in S&T. They must now be prepared to design projects more carefully, keeping also in mind the agenda of the donor community, particularly its policy concerns for market-oriented growth, environmental protection and the role of women in development, as well as its internal problems of safeguarding trade, employment and intellectual property.

In the technology policy arena, development assistance could include endogenous capacity-building through training, analyses, and wide dialogues with all stake holders (a programme now initiated by the UN Center and UN Fund for Science and Technology); helping define the specific S&T priorities and needs of developing nations in the context of larger global issues in technology policy, such as oceans and climate, biological diversity, food security for the poorest one billion; in the least developed countries, assistance in setting up practical mechanisms to promote technological activity, building where possible on existing structures; in the more developed countries, providing access on equitable terms to advanced technologies (UNFSTD projects with

excellent impact have included computer software development and training in India, carbon fibre reinforced composites in Brazil and a national remote sensing center in China).

In human resources development, assistance continues to be needed in the least developed countries for design of curricula and facilities for science education at all levels, facilities that are both sustainable and responsive to the needs and conditions of the economy; training of technicians in such fields as repair of scientific instruments; popularization of science through fairs, media and museums; for the more developed countries, courses in industrial project preparation/appraisal, in the management of technology including know-how negotiations, research management, and entrepreneurship development.

To augment financial resources for S&T, the World Bank, regional and national development banks can be utilized more effectively. In the past such institutions have lacked the capability or interest for supporting technology development, but this is changing. Assistance is needed to establish technology-oriented risk capital. Direct foreign investment by transnational corporations can also be utilized more purposefully as a technology transfer mechanism. Of the US$1,000 million provided by UNDP in technical assistance annually, 20-25 percent is estimated to go to S&T related activities, and this proportion is rising.

Compliance by the developing countries with new international treaties for the control of hazardous wastes, trans-boundary air pollution, and ozone layer depletion will cost billions annually.

The countries do not have such financial resources nor the technical capabilities to adapt and use environmentally-sound technologies for sustainable development. Clearly, new international arrangements are essential to provide the additional funding and the access to such technologies.

At the same time, a lesson from the experience of UNFSTD is that small grants of money (say $100,000) for well prepared research activities can have very significant results. In this context, the International Foundation for Science programme of micro-grants for scientific research has been very effective.

The building up of technological infrastructure remains a top priority for international technical assistance. Many existing institutions for training, research or support services are in a state of stagnation or decline, and should be restructured towards the needs of the user. At the same time, new arrangements (not necessarily new institutions) are required to promote collaboration between enterprises, between universities and enterprises, between development and research organizations, both domestically and abroad. A new type of "center for technological innovation" could serve as both a think-tank for strategic studies to identify competitive advantage and as a "gateway" for information on technology sources and needs.

Networks of research efforts through a coordinating focus can be cost-effective, provided each nodal point has some basic capability and resources. International NGOs such as the World Association of Industrial and Technological Research Organizations

can help through twinning of laboratories in the North and South, information dissemination and training. Research institutions in developing countries need sustained support over at least 10-15 years before showing useful results -- the success of the CGIAR effort in high yielding rice and wheat varieties is based in large measure on the massive support over a long duration.

Donor agencies rarely look beyond the end of the project being assisted. Greater emphasis is needed on longer-term impact and sustainability of a development relationship in the post-assistance environment.

VIII. CONCLUSION

As global technological change accelerates, the needs for technical assistance become larger, more sophisticated. This calls for a re-ordering of the roles of donor and recipient, with much greater responsibility assigned to national agencies themselves in the design and execution of international co-operation projects. It also calls for more imaginative approaches and creative ways of financing them.

An age-old way to stretch scant resources is to use them more effectively. This means, for instance, <u>less</u> meetings, <u>more</u> hands-on training. A consultant or researcher can best be trained on the job, not in a classroom or conference room. It also calls for more productive research, less prototypes and pilot plants, more effective diffusion and commercialization. And finally, it means

some sharing, some sacrifice. International co-operation does not have to be a zero-sum game. Everyone, rich and poor, can win.

Table 1 - Technology Development Patterns

S&T INFRASTRUCTURE	Little or none technology-base	Nascent emerging technology	Expanding market-based economy	Maturing exogenous development	Extensive technological self-reliance	Strong industrial compet.
EXAMPLE	Laos Haiti Uganda	Kenya Bangladesh Sierra Leone	Thailand Malaysia Jamaica	Mexico Argentina Turkey	India China Brazil	Korea Taiwan Singapore
MODE for TECH. ACQUISITION	Mix of un-coordinated modes	Foreign collaborations for state enterprises	Reliance on know-how & capital imports	Joint ventures; heavy external borrowing	Local R&D utilizing human & natural resources	Acquisition adaptation improvement of technology
OBJECTIVE	Breaking out of subsistence economies	Improving life of rural poor	Rapid growth thru low-cost labor & natural resources	Gradual build-up of local capability	Self-suffi-ciency in vast protected market	Export-led industrial development
GOVERNMENT ROLE	Low priority for S&T	Bureaucratic controls	Promotion of "foreign" investment	Explicit policies, poor implementation	State R&D, curtailment of imports	Active policy intervention against external threat
PROBLEMS	Severe finance constraints, lack of S&T personnel	Decay of institutions; loss of self-esteem among scientists	Dependency on foreign capital/ know-how	Inflation indebtedness Exodus of personnel	Slow pace of economic growth, bureaucratic bottlenecks, brain drain	Rising labor costs, transition to higher value exports

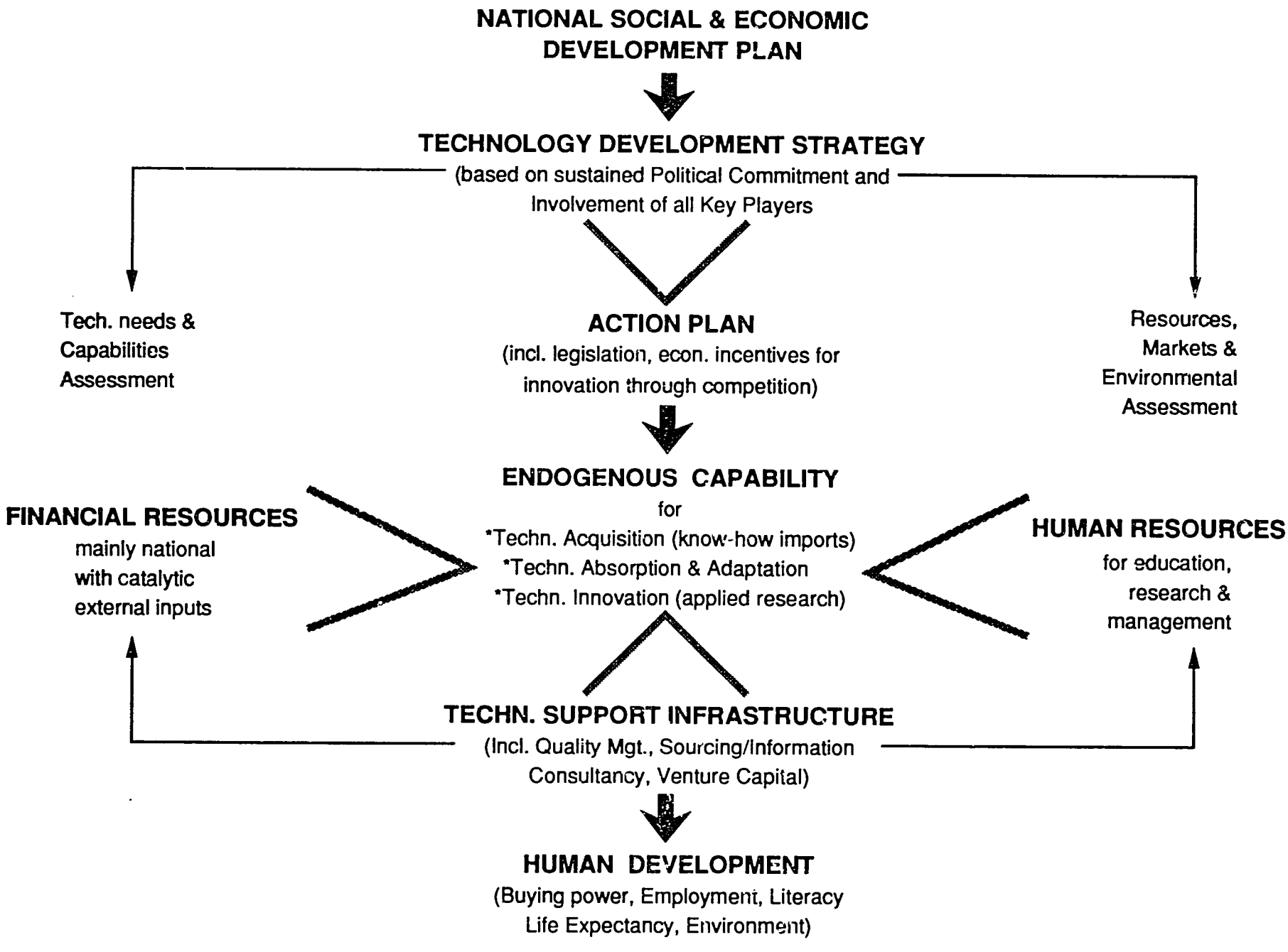

Table 2 – Technology Planning Model

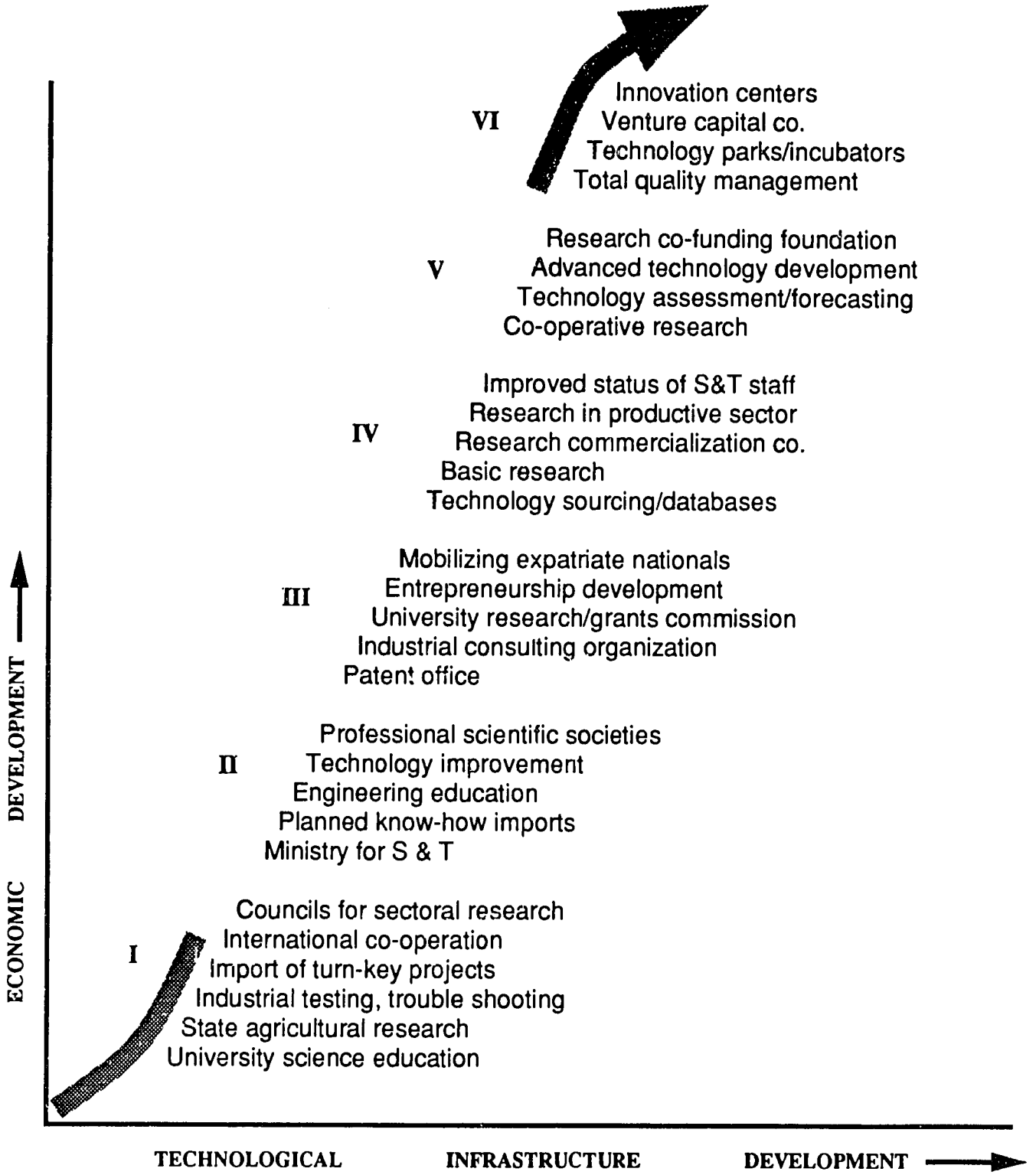

Table 3 – Progression of Institutional Arrangements

Bibliography

Center for Science and Technology for Development , State of Science and Technology for Development in the World: Options for the Future, United Nations, New York, 1989.

Dahlman C., Ross-Larson, B., Westphal L., Managing Technological Development: Lessons from the Newly Industrializing Countries, World Bank Staff Working Papers, No. 717, 1985.

Choi, Hyung Sup, Transition from Imitation to Creation, Technological Forecasting and Social Change, 36, Elsevier Publishing, 1989.

Lalkaka, Rustam and Wu Mingyu, Editors, Managing Science Policy and Technology Acquisition: Strategies for China and a Changing World; Tycooly, 1984.

Lalkaka, Rustam, "Is the United States Losing Technological Influence in the Developing Countries?," Annals, American Association of Political and Social Sciences, November 1988.

Lall, S., Developing Countries as Exporters of Industrial Technology, Research Policy, vol 9, 1980.

Lee, J., Bae, Z. and Choi, D. "Technology Development Processes: A model for a developing country with a global perspective," R & D Management, vol 1F, No. 3, July 1988.

Weiss, Charles "Scientific and Technological Constraints to Economic Growth and Equity,"

Wad, Atul, (ed), "Science, Technology and Development," Westview Press/IT Publications, 1988.