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IN-DEPTH EVALUATION OF SELECTED UNIDO ACTIVITIES ON
DEVELOPMENT AND TRANSFER OF TECHNOLOGY

Common Issues and Conclusions

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Abstract

The report describes first the context and evolution of Programme evaluation in UNIDO and how this particular evaluation on development and transfer of technology concentrated on five components namely:

- The UNIDO/UNEP National Cleaner Production Centers (NCPCs)
- Technology Centers
- Technology Business Incubators and Technology Parks
- Transfer of Technology on Subcontracting
- Information Services in Support of Development and Transfer of Technology

In the context of this evaluation, we define technology as **technical information relevant to production**. This definition, which follows Teitel (1993), also has the advantage of avoiding complicating distinctions between technology which is embodied (as hardware), or disembodied (for instance as blueprints), distinctions between know-how and know-why, etc, which arise in some definitions of technology. In the final analysis, hardware and software, know-how and know-why, can all be boiled down to the information of which they and their components are comprised.

The accent of the evaluation is on transfer rather than development of technology since, under all five components the majority of activities relate to transfer.

Despite the validity of the concept behind each component, their applications cannot be indiscriminate. The concepts are particularly applicable in higher strata of industrialization and should respond to market needs. On their own, they cannot create the demand. At any rate the relevance and applicability in each case has to be carefully analyzed.

Sustainability is another common critical issue. It was found that by and large the institutions established/supported even in well functioning market oriented economies cannot survive if their services, particularly to SMEs are not subsidized.

The scope of technology actually transferred by interventions in any of the components in isolation is limited. This should not be construed as a negative conclusion since the technology used by industrial enterprises originates in the combination of a number of actions, such as joint ventures, licensing, purchase of machinery, consultancy and technology originated in the enterprises themselves. Given the scope of resources deployed by UNIDO, the impact achieved through UNIDO interventions can hardly be visible at the macro level where foreign direct investment and trade are the dominant factors of technology transfer and technology change.

Implementation of technology changes recommended by technical cooperation projects and institutions established under these projects (in particular NCPCs, TCS and TBIs) usually involve investment and consequently financing. A common barrier to the introduction or upgrading of technology is the lack of or insufficiency of adequate financial instruments.

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Acronyms

| | |
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| ICGEB | - International Center for Genetic Engineering Biotechnology |
| ICS | - International Center for Science and Technology |
| NCPC | - National Cleaner Production Center |
| TC | - Technology Center |

1. BACKGROUND

1.1. Context and evolution of Evaluation of UNIDO programmes

1. "Evaluation is a technique for establishing if and how well goals have been attained. It is a process which seeks to determine as systematically and objectively as possible the relevance, effectiveness and impact of work in progress, or of work completed, by measuring accomplishments against the original objectives and by revealing the reasons for any significant deviation"¹. In evaluating whether and to what extent goals have been attained, evaluation exercises are also designed to be forward-looking, by focusing on lessons learned from past experience and transforming these into useful recommendations for the future.

2. Evaluation is an element of the concept of the "Learning organization"². Learning is the basis for change (improvement and innovation). Learning is supported by information received through the feedback mechanism from the monitoring and evaluation function. Feedback allows for changes by management as well as for transparent and independent accountability to member countries (policy making organs and project counterparts) and to management. Learning by experience is supplemented by intelligence systems that plug the Organization into the worldwide industrial net so one can identify and anticipate the problems our potential clients are or will be having - a strategic planning function.

3. The use of the results of the Evaluation in the Field of Manufactures in the reorganization of the UNIDO Secretariat of 1986 is a good example of the application of the above concept. Such an approach was welcomed at the time by the Committee for Programme and Coordination of the ECOSOC and by the IDB.

4. During the 1980s, the evaluation function of UNIDO covered the totality of its technical cooperation. As a natural development, the then Director-General decided to move into the so-called Headquarters Programme evaluations to cover specific segments (programmes or subprogrammes) of the Programme and Budgets. This was to be undertaken by in-depth evaluations complemented by a self-evaluation system. This is the approach followed in the UN system. It allows for accountability (inter alia, through individual in-depth evaluation reports and the periodic Performance Reports of the Organization) and for learning lessons for the re-shaping of the programmes under evaluation. A start was made with the evaluation of the then System of Consultations. The related report was submitted to the 5th session of the IDB³ which took note with appreciation of the report and requested the Director-General to undertake further in-depth evaluations of the important activities of the Organization, giving priority in particular to:

- Development of industrial human resources;
- Economic Cooperation among developing countries, inter alia, solidarity meetings;
- The industrial investment activities of UNDO, namely (i) investment project identification and preparation and (ii) investment promotion projects including the Investment Promotion Services;
- Development and transfer of technology;
- Special Trust Fund projects.

5. In accordance with the availability of evaluation staff and extra-budgetary funds, the above evaluations were gradually undertaken.

¹Evaluation Manual of the United Nations New York, October 1986.

²This text is based on the methodologies of the Management for Development Foundation at Ede, the Netherlands.

³GC.3/9 of 13 July 1989

1.2 Work carried out under the Technology Evaluation up to the beginning of 1997

6. The last and most challenging evaluation of those indicated above was the one on Development and Transfer of Technology. After the preparation of terms of reference and approaching several donors, a financial package was engineered and obtained, consisting of contributions of:

| | | |
|---|-----------------------------------|--|
| - | The Government of Switzerland | \$ 60,000 |
| - | The Government of the Netherlands | \$ 60,000 |
| - | IDF/UC | <u>\$ 11,080</u> |
| | | <u>\$131,080</u> (including support costs) |

and the related P.A.D. was issued on 30 March 1995 (under project US/GLO/94/009), date when the evaluation formally commenced.

7. This evaluation, following a well established procedure developed for the other Headquarters Programme evaluations, was divided into three phases, with some natural overlaps between them. The first phase consisted essentially of desk work involving the collection and analysis of relevant literature. Of particular importance was the analysis of the evolving nature and importance of technology in the context of industrial policy and enterprise competitiveness, the different instruments involved and the respective roles of the private and public sectors. This first phase culminated in the preparation of a paper entitled "Conceptual Framework" which elaborates on the current thinking and practice on the subject under evaluation. This paper was continuously added to and improved during the other two phases of the evaluation⁴.

8. The second phase, the evaluative phase proper, consisted of several desk and field analyses which can be summarized as follows:

- Preparation of three country case studies, in Kenya, Brazil and Sri Lanka where the policy framework as well as UNIDO interventions related to industrial technology were analyzed.
- A desk review of the PMO's mandates and management decisions dealing with industrial technology, up to and excluding the Draft Business Plan⁵.
- An analysis of the organizational structure to respond to the mandates indicated above and how it evolved over time, up until June 1997.
- An analysis of the role of technology intensive enterprises supported by various mechanisms inter alia business incubators⁶.
- Participation in selected technology related meetings organized by UNIDO, particularly in Vienna.
- Visits to UNCTAD, UNIFEM, the German Development Institute in Berlin and the World Bank to enquire on their activities and on the results of similar evaluations conducted by the two latter

⁴In view of the eventual interest of the conceptual framework even in the changed scope of the present evaluation, the document is included in annex 1.

⁵As included in IDB.17/25 of 23 June 1997.

⁶As a spin-off of this analysis, a project for the establishment of business incubators in Eastern Europe, using the know-how available in the respective Academies of Science, was developed under the evaluation. Financing (\$1,500,000) was obtained from the Government of the Netherlands (Ministry of Economy) in addition to the contribution normally earmarked by that government to UNIDO. The project is presently under implementation.

organizations. It was of interest to note that these evaluations followed a similar approach to that of UNIDO, took a long time to be completed [-over two years-] but were undertaken against a more stable institutional framework than UNIDO=s.

- Analyses of in-depth evaluations and project performance evaluation reports undertaken in the past nine years of technical cooperation projects dealing with industrial technology.
- Analyses of various progress reports of the ICGEB and the ICS and of the "Forward Looking Assessment" carried out in 1994 of the ICS.
- The preparation of a study on "Technology -related industrial information activities of UNIDO".

9. The third phase relates to the preparation of the report carried out after all evaluative work and analysis was completed. This report was in an advanced stage at the beginning of 1997 when a number of fundamental changes affecting the future of the organization started to emerge.

1.3 Constraints, including external factors affecting the evaluation

10. Any evaluation has to focus on a specified time frame and a relatively stable shape of the Programme under review. While it is assumed that a programme design will not remain static during the period of its evaluation, there are limits to the changes that the programme can absorb to allow a meaningful evaluation. The changes which this programme in UNIDO had to cope with in the past five years, both substantive and structural, became the single most important factor affecting the continuity of the evaluation. It became much more difficult if not impossible to undertake an evaluation against an almost continuing changing backdrop both of substantive and structural nature.

11. At the beginning of 1997, the evaluation report was in an advance state of completion. At that time, opinions expressed by some member states led to wide ranging discussions between the Secretariat and the member states on UNIDO=s future in what regards coverage of activities and a reduction of total Regular Budget appropriations. This made it very difficult for the evaluators to have a relatively stable framework against which conclusions and recommendations of the evaluation could be based on. As a consequence, the previous Director General of UNIDO decided to postpone the completion of the exercise to the end of 1997 when more clarity on the future of UNIDO could be expected. However, the subsequent preparation of the Business Plan, set another scenario to the organization and consequently to the exercise, breaking with the past in the sense that activities of the Organization in the field of technology were to be concentrated on environmental and agro-industrial aspects and that the former Technology Service was to be merged with Investment Promotion.

12. The evaluation was being done against a different backdrop - including external - than the evolving scenario. Furthermore, UNDP financed traditional technical assistance, through which the bulk of activities in technology development and transfer was carried out by UNIDO in the past, was dramatically re-oriented and reduced. In addition, the Montreal Protocol Fund under which transfer of technology is carried out in a narrow, albeit environmentally important segment of industrial technology, became the single largest source of UNIDO delivery (around 50% -during the first half of 1999). The former UNIDO Technology Programme was amalgamated with the Investment Promotion Programme. As mentioned before, a result of such changes could be that the technology promoted by UNIDO be limited to the one associated with foreign investment, agro-industrial and environmental concerns. It was however too early to predict how the development and transfer of industrial technology was to take place under the transformed set-up. Under those circumstances it was questioned whether the evaluation was still actual and needed. Therefore, at the end of 1998 the evaluation was discontinued.

1.4 Resumption of the evaluation under a different framework

13. Shortly afterwards, upon the initiative of the Government of Switzerland, UNIDO conferred with the other main donor financing the evaluation on the future of this task. It was decided that in order to make use of the information gathered so far, the evaluation should not be discontinued but rather be reoriented and focused to areas which were still relevant to UNIDO's work at the time. These were selected as follows:

- The UNIDO/UNEP National Cleaner Production Centers (NCPCs)
- Technology Centers
- Technology Business Incubators and Technology Parks
- Transfer of Technology on Subcontracting
- Information Services in Support of Development and Transfer of Technology

14. The issues to be covered by these individual evaluations were given as follows:

National Cleaner Production Centers: Validity of the methodology and approach followed by the NCPCs; types of technology changes at industry level resulting from NCPC interventions; transfer of technology, particularly from abroad; relation and/or integration with other extension services.

Technology Centers: The role that such centers have played in the transfer and development of industrial technology. This role has to be analyzed in an evolving context which started on import substitution models under which many of such centers were established and changed to a more globalized context where technology can be "imported" freely under a variety of mechanisms such as joint-ventures, licensing, etc. or in other words in accordance to choices on the so called make/ buy paradigm.

High Tech Business Incubators and Technology Parks: The role of technology parks and technology intensive business incubators in ensuring that know-how, available (at certain sources like universities and academies of sciences) or obtainable, can be used in productive projects. The availability of know-how, the financing of the emerging businesses and the advisability/need for incentives to support such schemes need to be particularly analyzed.

The transfer of industrial technology through national and international subcontracting. The role of clusters of small and medium enterprises should be also analyzed in this connection.

Information: Supporting role of technical information in transfer of technology; possibility of building up capacities in the target countries providing information services to SMEs; application of networking in capacity building⁷.

15. After some preliminary consultations in the house, the originally selected item BINAS was deleted from the TOR. BINAS as a source of information and platform for networking deals primarily with issues of biosafety and its relation to transfer of biotechnologies is very indirect.

16. The work resumed at the beginning of 1999 and rather than covering the totality of UNIDO activities in the area of Development and Transfer of Technology, it was focused on the five components indicated above.

17. The evaluation was managed by Oscar Gonzalez Hernandez, assisted by Jaroslav Navratil, both UNIDO staff members. Specialized consultancy was obtained from:

⁷This component was selected instead of the original Atechnology component of investment promotion activities@since at the beginning of 1999 the integration of technology and investment promotion activities in UNIDO was not yet complete.

- Karel Klusacek, in the area of technology intensive enterprise incubation,
- Vincenzo Ziliotti, in the area of subcontracting,
- Rudolf Stefec and Nilgun Tas in the area of industrial information.

The first draft of the conceptual framework was prepared by Caroline Heider and the second draft by Alistair Nolan, both former staff members of UNIDO.

The six reports covering this evaluation are the product of the two evaluators named above who therefore take responsibility for the contents of the reports. These reports do not necessarily represent the official views of UNIDO.

The evaluators wish to acknowledge with thanks the inputs and advice provided by colleagues in the house as well as from several external contributors.

2. SELECTED ISSUES

18. At this stage it would be convenient to recall what is defined as Technology in the conceptual framework in Annex 1. We define there technology as **technical information relevant to production**. The definition of technology is sometimes contentious. The above definition, which follows Teitel (1993), is clear, tractable and comprehensive. It also has the advantage of avoiding complicating distinctions between technology which is embodied (as hardware), or disembodied (for instance as blueprints), distinctions between know-how and know-why, etc, which arise in some definitions of technology. In the final analysis, hardware and software, know-how and know-why, can all be boiled down to the information of which they and their components are comprised.

19. The development and transfer of technology is at the core of industrial development, although this theme cannot be treated in isolation. At policy level, technology policy should be seen in the context of industrial policy and often the latter subordinates itself to macro policy. At the enterprise level, technology management is part and parcel of the management of the enterprise itself.

20. Macroeconomic stability is needed for governments and enterprises to invest in technology. Growth also helps. In periods of no growth or decline, enterprises in developing country conditions, rather than upgrading the technology they use to become more competitive (which represents a “developed state of mind”) tend to retrench themselves and diminish all types of expenditures including those technology related.

2.1 Accent of the evaluation on transfer of technology

21. The process of globalization is accompanied with increased trade and investment flows which also contain technology. At the same time the process of concentration of R&D in a limited number of world centers and the diminishing public support for industry-related R&D in the developing countries and countries in transition are contributing to a growing gap in R&D intensity between different countries and regions. Thus, at developing country level, the globalization favors transfer of technology over local development.

22. This is also reflected in the evaluation. The five topics selected under this evaluation imply that accent of the evaluation is on *transfer* rather than *development* of technology. In fact, only the Technology Centers used to be significantly involved in the development of technology. As the evaluation proceeded, a

question arose on how to define the boundaries of transfer of technology. In the UN and international discussions the transfer of technology has been associated with the transfer of technology from *developed* to *developing* countries, therefore with a North-South orientation. This understanding is particularly strong on the part of “development politicians”. When the transfer takes place within the country literature often refers to this process as *diffusion*.

23. In order not to add to proliferation of terms but to reach a consensus on the term *Transfer of Technology*, a small discussion group was convened in UNIDO. The group acknowledged the above mentioned dilemma. It was mentioned that in the context of the first Government Review for the Global Convention on Climate Change, the process of technology change was described in five stages which however do not differentiate between *imported* and *local* technologies although in the ensuing explanations a breakdown is made between technology transfer *within* and *across* countries.

24. In the conceptual framework prepared for this evaluation the term technology transfer is used indiscriminately for the two types of transfer. In the context of the increased globalization of the world=s economy this distinction becomes more blurred. Finally, we are interested in this evaluation at impact at the enterprise level and here the distinction is seldom relevant.

25. Therefore, for the purposes of this evaluation it was agreed that the term *Transfer of Technology* is used both for transfers within and across countries. When necessary a breakdown according to the two types may be made but then this distinction is so identified.

2.2 Level of development

26. In development co-operation there is a tendency to classify recipients according to the level of development of the related country. Thus, one speaks of *least developed countries*, *economies in transition*, *newly industrialized countries*, etc. We find that for the purpose of this evaluation which relates to the industrial sector it is preferable to speak of level of development of the particular industrial sub-sector, region of a country or even specific plants or clusters. This is because one can find quite advanced industrial industries in LDCs as well as backward companies or regions in more developed countries. The type of interventions should therefore not be geared solely to the level of development of a country but more to the development conditions as indicated above. As a consequence, when we speak in this evaluation of “more developed conditions” or a tighter industrial fabric we do not refer to the classification of recipient countries indicated at the start of this paragraph but rather to the level of development of the specific region, industrial sub-sector or cluster.

27. OECD classifies industries in groups based on technology, wages, orientation and skills. This classification is made according to data from OECD countries. Its applicability to developing countries may not coincide. However, for the purpose of this evaluation we found this classification as relevant, if not by the lack of a better one (see Annex 2).

2.3 Gender issues

28. The Gender Working Group of the United Nations Commission on Science and Technology for Development, with the assistance of UNIFEM published in May 1995 a paper entitled “Gender, Science,

Technology and Development” which basically reviews the related activities of selected United Nations agencies and organizations. The paper concludes that “UNIDO should clarify its approach to technology in general and gender and technology in particular” without offering specific lines of action in the latter respect.

29. The five components of transfer of technology studied do not show much coverage on gender issues by the related UNIDO activities. Although gender issues are not central to these five components, one cannot say that they are not relevant. A study undertaken in a Technology Center (TC) in Chile shows that women comprised 25% of the total workforce and 50% in the Chemical and Food Analysis Division. The management of this TC had strong feelings about the particular gifts of women to perform the type of services carried out. They felt that women are usually well organized, methodical, careful about contamination of test materials, precise with details and do not get bored with routine or repetitive work. Activities of UNIDO under the five components analyzed usually relate to institution building projects where such principles may apply. So it is not out of place to consider in such institution building projects a gender issue component to ensure that these particular gifts of women are utilized and rewarded and that adequate training where needed be provided to avoid the problems indicated in the UNU/UNIFEM study.

3. COMMON CONCLUSIONS OF THE EVALUATIONS ON THE FIVE COMPONENTS

30. The five evaluation reports were prepared to stand on their own. In each report, the specific concepts, trends and applicability to developing countries are presented as well as the issues affecting the role of the component in the development and transfer of technology. Selected issues, such as sustainability are discussed, particularly in the context of the needed subsidies to correct market failures or to provide social services, specially when the target groups are small enterprises.

31. It is difficult to generalize from these individual reports conclusions to the development and transfer of industrial technology in developing countries following a holistic approach. However some common issues and conclusions emerge from the study of the five components.

32. Only NCPCs, Information and Subcontracting are handled in UNIDO as programmes. The other two have been implemented usually in isolated interventions without much synergy. Taking advantage of the new UNIDO “Integrated programmes” we believe that, provided adequate financing, internal and external, is secured, there are advantages of integrating some of these components with other type of interventions. This would also allow for the related institutions to provide more commercial type of services, thus helping to subsidize the more social type of services. For instance and just to name a few cases where such an integration is possible:

- NCPCs can be integrated into wider type of extension or consultancy services to industries.
- Information Services can be components of Technology Centers.
- Technology parks may have a component of foreign investment promotion or vice versa.
- Subcontracting exchanges, as indicated in the related evaluation report, can include elements of training to enterprises to enhance technology development and of enterprise clustering.

Other proposals are included in the reports on the specific components.

3.1 Validity and applicability/relevance of the five components

33. As the reports indicate, the concepts behind the five “programmes” evaluated are valid and play a role in the development and transfer of industrial technology. They are not the only answer to the needs in terms of technology but they help, particularly if integrated with other instruments.

34. Despite the validity of each concept, its application cannot be indiscriminate. It was already mentioned in the reports that the concepts are particularly applicable in higher strata of industrialization and should respond to market needs. On their own, they cannot create the demand. At any rate the relevance and applicability in each case has to be carefully analyzed. Interventions cannot be simply replicated from one case to another.

35. We are living in a fast changing world and if UNIDO wants to be active and competitive in each of the five components evaluated it cannot do it on the basis of field activities alone. A minimum amount of research or supporting activities needs to be continuously undertaken to analyze how these concepts evolve, to exchange experience between stakeholders and to study applicability under different conditions. To a certain extent this is being done in the areas of Incubators, Subcontracting, NCPCs and Information but more intense conceptual work, making use of expert group meetings, panels, teleconferencing, networking with other organizations etc. is needed to strengthen professional competence of the organization in those areas.

3.2 Sustainability

36. One issue which is present in interventions under each of the five components is sustainability or lack of it. UNIDO interventions under the five selected components are usually of an institution building type and therefore require sustainability of capabilities at the end of the intervention. This is amply discussed in each component report and we will not repeat it here. Sustainability in terms of capabilities is intimately linked to financial sustainability. The two cannot be separated. As mentioned in each of the reports the “institutions” developed, be them NCPCs ,TCs, or subcontracting exchanges, provide services to enterprises, usually small, to correct market failures and to provide social type of services. They usually cannot fully recover costs and an element of subsidy is justified. Even in developed countries the related institutions benefit from public subsidies which guarantee its financial sustainability. As conditions evolved over the past twenty years these institutions have had to move from total public funding to a more market orientation and (partial) self-financing. How partial this self financing should be has to be analyzed on a case by case basis. As a rule of thumb the higher the proportion of social type of services the institution has to provide , the higher a subsidy is required.

3.3 Impact of the five components on DTT

37. The impact of the interventions analyzed under the five components should be measured in terms of actual industrial technology developed and/or transferred and finally used by the end users that is the enterprises. There is more experience of UNIDO on this in NCPCs and TCs so the conclusions regarding impact

are particularly valid for these two components. TCs, now somewhat discredited, together with extension services, if properly managed and oriented can be an important source of subsectoral technology to its end users. Regarding subcontracting, despite a relatively large UNIDO programme, practically all the interventions regard the establishment of subcontracting exchanges promoting matchmaking for subcontracts either related to excess capacity or specialization, where transfer of technology is not significant. However, in such cases subcontracting may be a driving force for enterprises to upgrade technology.

38. Assessment of information services indicates that they contribute to transfer of technology probably more indirectly through provision of business information (for which there is demand) than through databases on technology which are little used by SMEs, the use of which needs to be complemented by other (advisory) services.

39. Under business incubators, particularly those aimed at technology intensive enterprises, the transfer of technology occurs in more advanced conditions of development therefore where applicability to developing conditions is more limited.

40. The scope of technology actually transferred by interventions in any of the components in isolation is not significant as explained in the individual reports. This should not be construed as a negative conclusion since the technology used by industrial enterprises originates in the combination of a number of actions, such as joint ventures, licensing, purchase of machinery, consultancy and technology originated in the enterprises themselves. Given the scope of resources deployed by UNIDO, the impact achieved through UNIDO interventions can hardly be visible at the macro level where foreign direct investment and trade are the dominant factors of technology transfer and technology change. UNIDO interventions aim primarily at strengthening local capacities to provide services to SMEs. Capacity building is a long-term process. However difficult it is to track its impact, strengthening local capabilities to meet demand for services to industry, particularly SMEs, is one of the recognized objectives that development agencies have in improving conditions for development. Effectiveness of these efforts depends also on the demand side, on the conditions which change potential needs into effective demand for services. In this context the capacity building programmes need to pay more attention to stimulating demand for services.

3.4 Financing mechanisms

41. Technology upgrading required by cleaner production measures, advice of Technology Centers, enterprise incubation, subcontracting and as a result of industrial information received, usually involves an investment and consequently financing. A common barrier in the five components to the introduction or upgrading of technology is the lack of or insufficiency of adequate financial instruments. While this seems to be a common constraint, it is particularly evident in NCPCs and in incubation. The subject is covered in the respective component reports.

Conceptual framework for development and transfer of Technology

1. Introduction

This chapter provides a conceptual framework for the evaluation of UNIDO's activities in the area of development and transfer of technology. It would be impracticable to attempt to cover here all issues in the field of technology, which is a complex and evolving subject. However, it is intended that this chapter provide a background to selected aspects of current thinking on technology issues most related to UNIDO's work in technical cooperation and supporting activities.

The chapter begins with a review of key concepts. An overview is then presented of the role of technology in development generally and in industrial development in particular. The chapter continues with a brief discussion of market failures in the creation and use of technology. It is held that these market failures provide a key theoretical argument for public intervention, and, by extension, for the work of an international agency specialized in this field. The chapter concludes with a review of the key institutions affecting technological development.

2. Concepts Used

In this section the following definitions of key concepts are proposed, with a discussion on each:

Technology: Technical information relevant to production. The definition of technology is sometimes contentious. The above definition, which follows Teitel (1993), is clear, tractable and comprehensive. It also has the advantage of avoiding complicating distinctions between technology which is embodied (as hardware), or disembodied (for instance as blueprints), distinctions between know-how and know-why, etc, which arise in some definitions of technology. In the final analysis, hardware and software, know-how and know-why, can all be boiled down to the **information** of which they and their components are comprised.

Industrial Technology: Technical information relevant to the production of industrial goods and services. This definition encompasses information (and activities performed using that information) beyond the operation of machinery, including the whole complex of human skills, physical assets, and organizational and institutional settings needed for industrial production.

Technology Transfer: A process through which technical information is acquired and adapted to the specific needs of the recipient. The need for a broad definition of technology may at least partly derive from the experience of failures and successes in transferring technology. As Dahlman and Westphal note "the shorthand expression 'transfer of technology' is misleading, to the extent that it suggests that technologies can in fact be transferred wholesale and in working order."⁸ Elsewhere, the same authors explain that much of the confusion about technology transfer arises from a too-restricted definition of technology (Dahlman and Westphal, 1983).

⁸ "Technological Effort in Industrial Development- An Interpretative Survey of Recent Research", C. Dahlman and L. Westphal, in Stewart and James (1982).

The transfer of technology involves a fundamental learning aspect requiring a considerable investment on the part of the recipient.⁹

Any transfer of technology has to take cognizance of, if not incorporate aspects concerning the setting (infrastructure) into which the technology is to be transferred. In a narrow sense this may imply that prior to selecting and transferring technology, its future environment in the recipient country needs to be analyzed and taken into account as one of the key determinants in the choice of technology. In a wider sense, an integrated technology transfer programme would have to include inputs and activities which are directed at establishing or improving the setting in which the technology has to operate.

Technique: A particular method of production requiring a specific combination of factors of production (capital and labor). This is an economist's definition. Economics considers a technique to be a point on a production function. The Concise Oxford Dictionary (1990) defines technique as a mechanical skill in an area or a means of achieving one's purpose, especially skillfully.

Appropriate Technology: A technology suited to the environment in which it is to operate. Proponents of the need for technologies "appropriate" to conditions in the developing countries argue, explicit or implicitly, that agents involved in the transfer and acquisition of technologies in those countries do not respond to market signals reflecting the relative availability of factors of production (or that these signals are distorted). Consequently, the technologies used tend to be more capital intensive than warranted. However, most detailed empirical evidence indicates that the contrary proposition tends to be true, i.e. technologies are generally adapted to local conditions and as a result are simpler, smaller, less capital intensive, etc. than in the originating industrialized countries. A corollary to the view held by those in the "appropriate" technology movement is that tools and equipment that meet the recognized conditions of scale, simplicity and labor intensity need to be specially developed for the benefit of local users. The danger thus arises of trying to introduce models developed "from above" in an ad hoc and normative manner.

Environmentally Sound Technology: Technologies which "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes". (UNCED, 1992, Agenda 21).

Technological Development: The increase in the ability to create, absorb, adapt and use production related technical information. This definition also accords with Lall's view of technological capability, which refers to the entire complex of human skills needed to establish and operate industries efficiently over time.

⁹ *"These learning processes include learning-by-doing, e.g. increasing the efficiency of production operations;learning-by-interacting, involving users and producers in an interaction resulting in product innovations; and even "learning-by-learning", whereby the capacity of firms to absorb innovations developed elsewhere depends on their learning experience, which in turn is enhanced by R&D and other related intangible investments" (Cohen and Levinthal, 1989).*

Technology development encompasses varying stages, from invention (defined as an idea, sketch or model for a new or improved device, product, process or system), innovation [understood in an economic sense to be accomplished when the first transaction involving a new or improved device, product, process or system takes place (Freeman, 1982)], and imitation (meaning the reproduction of with or without incremental changes to improve, alter or adapt, existing technology). Imitation may still demand an intimate understanding of the technology itself as well as of its operating environment (in a wide sense) so that it can be copied or sensibly altered.

Analysts have often tried to explain the process of technological change by means of models which assume that science and markets (applying industries) are connected through a sequence of events which follow a defined path. For instance, the so-called "science-push" theory argues that the development, production and marketing of new technologies originates in research activities and that, consequently, technological development will in some instances have to start from the science and research side. This may be so because in their development phase some technologies do not appear viable or commercially interesting, but later form the basis for major technological changes. In other cases, technologies may not be of commercial interest, but of social or humanitarian importance. The disadvantage of a science-driven approach is that resources might be spent on research activities which may be so remote from any demand that neither their application nor the recovery of costs is possible. The "market-pull" hypothesis, on the other hand, holds that the demand side stimulates and directs technological development, with research and development concentrating on those technologies which have a high likelihood of finding commercial application. In fact, simple unidimensional explanations of technological development are inadequate. Technological development results from a complex set of interactions between the demand for and supply of technology generally, between innovative and productive sections within firms, as well as between enterprises and technology-related institutions.

Technology Cooperation: Joint conceptualization, adaptation and deployment of technology. Many forms of cooperation are possible: firm - firm; public - private; university - firm; North - South; South - South; etc. The cooperative format is distinguishable from the transfer format since it provides different mutual benefits and is of a longer-term duration. It is important to emphasize to research teams and firms in emerging economies the importance of protecting intellectual property by filing patents. No industrial partnering is possible unless the firms involved can rely on commercial protection of the acquired or jointly developed technologies.

International cooperation primarily takes the form of joint research projects and shared institutions. In the private sector of developed countries international agreements on R&D are making research on high technology global. In the case of commonly run institutions, benefits may lie in sharing the cost of operating institutions as such institutions might be unaffordable by one country, or impractical for one country owing to a small national market. The question of regional as opposed to national institutions has to be carefully analyzed on technical and economic grounds, with economies of scale arguments regarding regional cooperation often being overstated. Furthermore, when the need for an institution - national, regional or subregional - has been ascertained, it may be more efficient to expand an existing institution than to create one from scratch.

Generic Technology: a concept or process that has the potential to be applied to a broad range of products and processes.

3. **Technology in development**

Technological change has been central to economic and social transformation throughout recorded history. Technological change has made possible enormous improvements in living conditions, agricultural productivity, health care, freedom from the physical drudgery of certain types of work, etc. Technology is critical to product and process development. The former make possible a supply of goods the consumption of which affords improved living conditions. The latter yield productivity increases which are key to economic growth. Consequently, the ability to apply and/or develop technologies is of major importance to acquiring or maintaining competitive standing. The pace of technological change also demands that companies and countries be able to react fast and flexibly to change. In the words of Barnett (1992):

"it is increasingly accepted by the mainstream of development agencies that the capacity of developing countries to manage these processes of technical change to their advantage increasingly defines the divide between industrialized and developing countries."

Industry is that sector of the economy most closely associated with technological development. Industry can be viewed, inter alia, as a source of technology supply for both the service and agricultural sectors. Any degree of industrial development requires technology. Furthermore, industrial development can itself facilitate technological change by providing a resource base for the development of skills and institutions.

There are areas in which technological change is particularly rapid, with enormous potential impact on technological advances in other sectors. These areas include biotechnology, new materials, micro-electronics and information/communication technologies. It is sometimes claimed that just as, in previous decades, the steam engine, steel, textiles and the internal combustion engine represented "heartland" technologies, having a broad influence on industry and the economy generally, so biotechnology, new materials, micro-electronics and information/communication technologies represent the heartland technologies of today. New materials technologies, for example, allow the design and composition of materials exactly according to the required specifications. Previously, the inherent properties of existing substances dictated limitations on their industrial application. New materials may allow products of higher quality with better performance and/or new characteristics and applications, with more efficient use of materials, less waste and lower energy consumption. The application of new materials can be found in industries as diverse as telecommunications, car manufacturing and metallurgy. New materials may also replace some of the traditional materials produced and exported by developing countries.¹⁰ Biotechnology, for example, has important implications for agro-industries, particularly food industries, pesticides, fertilizers, pharmaceutical and chemical industries. According to the OECD (1990), education and skill levels are inadequate to meet the challenges of new materials, even in OECD countries. Technological change has numerous social ramifications, one of which is its impact on employment. Many recent technologies are labor-displacing, at least in the industry's in which they are applied. In the developed world, the overall employment effect of new technologies probably varies from case to case (the software industry, for example, which supplies a key input to automation technologies, is itself labor intensive). The net employment effect of new technologies in the developing countries, which often do benefit from being suppliers of the new technology, may be more damaging. Technological development alone is unlikely to remedy income

¹⁰The issue of export losses is not new. It was already present when synthetic fibers and rubber largely displaced their natural equivalents. The lesson is clear. There is no point in fighting with subsidies and protection against materials which are generally cheaper and possess better properties (although market niches still remain for some traditional materials, in this case cotton and natural rubber). Such a battle is in the long-run a lost cause.

or gender disparities. While technological change can have a gender-specific impact, this impact is, arguably, not inherent to the technology, but rather is a function of the social milieu. Technologies can also have a distributional bias, favoring one income group over another.¹¹ However, in general, and in pursuit of efficacy, issues of income distribution and gender equity must be addressed primarily through social policy, rather than technology policy.

4. Technology and Market Failures¹²

Market failures are likely to exist in both the production and use of knowledge (information). The existence of such market failures constitutes an important theoretical justification for selective public intervention and, by extension, for support from development cooperation agencies. Three sources of market failure are usually pointed to in connection with the development of technology: uncertainty, externalities and indivisibilities.

Uncertainty exists in that the outcome of research and development cannot be foreseen. Research and development can be thought of as an investment to reduce the stochastic element in innovation. Unlike investment in fixed assets, firms cannot know beforehand what an investment in research will yield (otherwise the research would be unnecessary). Uncertainty is thus likely to cause under investment in research and development.

Externalities can arise in that the production of knowledge may create benefits for those who have not contributed to the costs of knowledge creation. Externalities of this sort are greatest where firms cannot appropriate the benefits of their investment in knowledge creation. Even with an effective system of patents the appropriation of benefits may be difficult, as knowledge about products can be contained in the products themselves (chemicals for instance). In a competitive market, externalities may again cause under investment in the production of knowledge.

A further source of under investment in knowledge production is the existence of indivisibilities. Indivisibilities exist if investment in research has minimum size requirements, such as numbers of research personnel and scale of research facilities. These indivisibilities give rise to scale-economy and entry-barrier effects, and as such may justify public promotion of private investment in research that would otherwise be stalled.

¹¹It is often claimed for example that better-off farmers have benefited disproportionately from the "green revolution" in parts of Asia. This, it is held, reflects the privileged access of such farmers to credit and a range of inputs which complement high yielding seed varieties.

¹²This section borrows heavily on Teitel (1993), Chapter 9.

There are also market failures in the use of technical knowledge. Teitel summarizes the economic aspects of the use of information as follows: (i) there are irreversibilities in the use of information as prior investment is required in its processing, possibly precluding more efficient uses of information in the future; (ii) depreciation begins as soon as the investment in acquisition of information is made. While depreciation occurs with any investment it will be greater if the acquired information is not used; (iii) there are decreasing returns to the human factor as an information processor -people can organize only so much information; (iv) there are increasing returns to the use of information. For example, the unit cost of an investment in information on semiconductor production can be reduced with increased output, and (v) information dissemination is not necessarily be uniform. While the literature on market failure in the use of information is still developing, the economic characteristics enunciated above are likely to give rise to under investment in the search for information.

The market failures noted above provide a theoretical rationale for policies and publicly sponsored programmes aimed at increasing research and development and information use. These might include research-inducing fiscal policy, sub-sectoral technical assistance and information dissemination, and related industrial extension services.¹³ It is in such areas that an international body such as UNIDO can justifiably assist in policy formulation, institution building, and information dissemination.¹⁴

5. Technology Related Capacity Building

The ultimate aim of development cooperation is to help develop capabilities in *recipient* countries which facilitate the pursuit of the recipient's economic and social goals. Technological capability is the ability to create, absorb, adapt and use production related technical information. A country's technological capabilities are determined by the degree to which it possesses skills (i.e. scientists, engineers and technicians), enacts appropriate policies and operates effective technology related institutions. Some refer to this arrangement of skills, policies and institutions as the *technological system*. The authors of this report find that terminology unhelpful - as it implies a set of clearly delimited institutions working together towards common goals -, and

¹³The argument has also been made that diversity in the sources of knowledge creation will lead to superior outcomes, simply because no source of information creation is omniscient. Publicly-sponsored subsidy of research in related areas is the suggested policy response.

¹⁴The United States Government applied a non-interventionist technology policy for almost a decade, which led to a loss of leadership in various critical technologies. Under the present administration the role of the government goes beyond issuing regulations and setting of policies to assisting corporate and academic R&D by sharing the financial risks of long-term projects that are of national interest (Science in the National Interest: August 1994. Executive Office of the President of the United States, Office of Science and Technology Policy).

refer instead to technology related institutions.

6. Technology Related Institutions

Technology related institutions operate at three levels: government, enterprises and intermediary bodies. These interact and stimulate innovation, development and diffusion of technology. In many developing countries the relevant institutions are often underdeveloped or non-existent, and their interaction weak.

Key technology-related institutions include: (i) research and development institutions; (ii) patent offices; (iii) productivity and information services; (iv) quality control, standardization and metrology bodies, which ensure that the goods produced conform to expected standards; (v) industrial subcontracting institutions; (vi) universities, colleges, and training institutions, and (vii) finance and investment promotion institutions. Furthermore, industry associations (should) play an important role in the policy dialogue with government as well as fulfil some of the functions ascribed above to other institutions (for example, they may provide information, advice and training on technology issues). The roles of government, enterprises, and the institutions listed above, are briefly outlined in the following paragraphs.

Government

The potential role of the public sector in countering technology-related market failures was noted above. Some governments, following an active industrial policy, have gone further than the rectification of market failures and have sought to change the structure itself of a given industry. Allowing only limited entry has been undertaken to avoid price wars and bankruptcies in the presence of decreased demand, but also, it would appear, to foster the diffusion of technology, it being argued by some industrial economists that diffusion is most rapid in industries with an oligopolistic structure.

Governments also provide technological infrastructure and are generally responsible for human resource development. Broader government policies - such as tax, trade and financing regimes - will also affect technology development, for example by altering incentives to innovate.

Governments also exercise major influence through regulatory functions, by approving curricula for education and training, by setting a system of national standards and calibration, and by defining national patent policies. This requires interaction between government and industry.

Enterprises

Enterprises are the main producers and users of industrial technology. Most enterprises, particularly in the developing world, follow technological trends by means of imitation, adaptation and improvement of existing innovations. Technology adaptation is perhaps most relevant to developing country firms.

For most developing countries industrial technologies are imported, whether formally via licenses or patents, or informally by copying and "reverse engineering". However, in most cases technologies cannot be

implanted and successfully used without some technical adaptation to local conditions. While such adaptations are carried out, technological learning takes place about how a process, machine, or device, really functions and what the key technical parameters determining performance are. Thus, adaptation of a technology is best seen as part of a process of technology acquisition, modification (to adapt or improve), or creation of a new product or process.

Technologies transferred to developing countries often need to be adapted to scale, to locally available materials and skills, terrain and climate. Scaling down is necessary because market size, and many times plant size, are much smaller than in the country transferring the technology. In some cases the scaling down process is simple because the manufacturing process involves several parallel, identical, lines of production, but in others, machines, vessels and other equipment have to be redesigned or locally adapted in various ways. The question of material availability may arise when local materials are not exact, but close enough, substitutes and the work of adaptation required to maintain product and process quality requirements makes technical and economic sense. It is also common in developing countries to find skills gaps, for example in technical areas such as repair and maintenance. This may cause firms not to import machinery or process equipment with delicate electronic controls requiring qualified technical attention that firms cannot provide. Consequently, machines often need to be made simpler, sturdier and with fewer controls than in the technology-originating country. This is also the case with humidity and other weather conditions that may be quite different, and more extreme, than in developed countries. Terrain could of course be important in the case of transport and construction equipment.

The ability to adapt and absorb new technologies depends critically on the company's internal division of labor. In many small and medium-size firms the internal division of labor is minimal. This inhibits the undertaking of specialized technical work using employees of the firm. It also hinders the ability of the firm to search for appropriate external assistance and to interpret and implement any assistance received. In developing countries, there is a need to help enterprises, particularly SMEs, to specify their technology needs. The management culture of a firm is also important in technology adaptation and absorption, particularly the ability to manage change and define consistent company policies.

There is a variety of general technology selection criteria for firms which, most obviously, include financial feasibility, compatibility with existing facilities, environmental acceptability, and energy consumption. In technology choice, the accuracy of the selection depends both on the analytical ability of the evaluators, and on the availability of data on alternative technologies. In developing countries a focal point for information could possibly assist in this respect.

Contract negotiation may result in a legally binding technology transfer agreement (UNIDO has prepared manuals and guidelines for the preparation of technology contracts). The form of the chosen technology transfer arrangement can affect the degree to which technology is transferred. A close relationship between technology supplier and buyer, for example in a joint venture, ensures that equipment installations and training for operation of the new technology is likely to be adequate. In the cases of procurement or licensing the extent to which the technology supplier will install and customize the equipment and provide training depends on the details of the contract, as successful installation may be of less interest to the technology supplier.

Research and Development Institutions

Universities and other public research institutions are being increasingly compelled to set priorities and adjust their activities to the demands of industry. With public funds diminishing, other income has to be generated through research activities. Public research institutions thus have to become more client oriented. The difficulties this entails, such as adjustments in attitudes, are common to public institutions generally. Contract research organizations (CRO) provide specific research services to industry. The establishment of independent CROs or some form of commercial adjunct to public research institutions and universities could be explored by decision-makers in developing countries.

Industrial technology research institutes (ITRIs)¹⁵ and other science and technology organizations have been established in much of the developing world during the last two or three decades. Such ITRIs take a variety of organizational forms, and operate in both the public and private sectors, as joint public-private ventures and as a part of universities. Many provide valuable services to industry in areas such as quality control and product certification. However, the efficacy of such bodies is increasingly questioned. This questioning stems both from changes in the policy context, and from the manner in which many ITRIs are seen to operate. Symptomatic of the decline in status of ITRIs is the closure in recent years of the principal national industrial technology institutes in some countries namely Colombia, Guyana and Peru. Policy changes which undermine ITRIs can range from a general aversion to the funding of public bodies in a climate of economic liberalization, to changes in the demand for the services of ITRIs caused by policies which affect the rate of implementation of technology-intensive projects.

A paper prepared in 1993 by Araoz notes that many ITRIs have only weak linkages with users in industry.¹⁶ In some instances the pursuit of scientific goals has become an end in itself, divorced from the requirements of production. With some exceptions there appears to be only a limited involvement of ITRIs in acquiring foreign technologies and in adapting and diffusing these. Furthermore, in Latin America ITRIs have produced little that is patentable. The most common form in which ITRIs have assisted industry is through the provision of support services such as quality control. Commenting on the services usually offered by ITRIs, Araoz notes the finding of Machado that there is "a tendency towards vertical integration of services, rather than towards complementarity with other service providers....". Machado is also reported as finding that most ITRIs fail to assist firms in transferring technology through joint ventures.

However, there are also a number of ITRI successes. For example, ITRIs have played an important role in technology acquisition, adaptation and diffusion, and in basic research, in Japan, and later in Korea and Taiwan. It is also true that in these countries industrial policy generally has been far more statist, and sophisticated, than in most other parts of the developing or developed world. In the Latin American context Araoz cites the Chile Foundation as an example of an effective ITRI, describing this institution as one which "defined carefully its objectives and its field of action, adopted a legal and a managerial structure that allow it to conduct its operations with high efficiency and flexibility, established excellent relations with the productive sector, and achieved a high degree of maturity, including self-financing." There appear to be changing trends in

¹⁵ITRI is the designation used by WAITRO. In the context of this evaluation we have used the simpler designation of Technology Center.

¹⁶The Revitalization of Industrial Technology Research Institutes in Developing Countries: Guidelines for UNIDO, Alberto Araoz, October 1993.

the mix of services offered by some ITRIs. New services offered include: consultancy in technology management, technology transfer and production systems; the use by industry of ITRI installations; environmental services, and support in establishing new enterprises.

Araoz holds that the general features of a successful ITRI usually include: A sufficient size; a legal status which permits flexibility in operations and personnel management (the Chile Foundation is illustrative in this respect, having the autonomy to create and own demonstration companies using the most current imported technologies, with the purpose of selling these firms to the private sector); clear objectives and responsibilities, focusing explicitly on the needs of industry; the specialization on a limited number of technological areas and types of services to be offered, with services determined by market requirements; a periodic review of the ITRIs work, deselecting those services for which there is little demand and creating new services where demand is growing (for example Machado suggests that ITRIs might work together with consulting and engineering firms and producers of capital goods, and others, to assist firms in transferring technology through the route of joint ventures and strategic alliances); close and stable relationships with industry, including industry membership in the governing bodies of the ITRI, consortia with industry, the exchange of personnel, public relations efforts, etc.; the specialized marketing of ITRI services; adequate physical installations, and modern management practices, including systematic long and short-term strategic and business planning."

Patent Offices

A patent is a monopoly granted for a limited period of time (e.g. 17 years in the United States) by the state to an inventor for the right to exploit his invention. The purpose is to stimulate inventiveness and innovation which would otherwise be deterred if the benefits of the new knowledge could be appropriated by persons or companies other than the individual or corporate inventor. The other side of the coin is that once the new knowledge has been produced, it would be optimal to make it available to everybody that could use it since the costs of generating the invention have already been incurred and attainment of the expected benefits could be maximized by open competition. Thus patent regulations try to deal with the potential conflict of interest arising between the interest of society at large and that of the private inventor.

The importance attached to patent regulations will differ among countries according to their position as producers or users of inventions. The majority of developing countries, which are largely non-innovating, are not as keen to establish patent regulations as the advanced industrialized countries, which account for most inventive activity. In the not so distant past, developing countries were concerned about the prevalence of royalty overpayments for patent licensing and other forms of technology transfer. The issue arose in the context of generally restrictive norms for the repatriation of profits from direct foreign investment and it was sometimes argued that foreign transfers for patent royalties were inflated to compensate for the limitations imposed on the transfer of profits from capital investment. Some studies also revealed the existence of restrictive business practices in connection with technology transfer contracts, including licensing of foreign held patents. Such practices as required cross-licensing, limitations in exports, tied-in purchases of parts and materials, etc., were documented in several cases after royalties or licensing commissions were set up in some developing countries. Such situations are now generally of historic interest only. On the one hand learning and technological development reduced the previously existing asymmetry in information, and, on the other, the increased opening and liberalization of the economies of most developing countries has reduced the opportunity for such occurrences.

Present concerns of developed and developing countries also differ and revolve around the more general concept of intellectual property protection (IPP). IPP also encompasses the results of artistic creativity, like music records and tapes, book-printing, computer software, etc.. Advanced countries have made IPP a key issue in the discussions that led to the GATT Uruguay Round Trade Agreement and the creation of the World Trade Organization. The question of illegal copying is being pursued by industrialized countries through international trade regulations, and these countries are increasingly pressing for the adoption of laws to protect intellectual property rights in all countries desiring their foreign direct investment. Developing countries, being mostly users and not producers of such products, have not been equally interested in IPP, but must eventually comply to be able to fully participate in international trade and investment.

The concerns of semi-industrialized countries may in certain fields be different from those of the majority of developing countries. Countries like India, Brazil, Argentina, etc., that have already made substantial progress in industrial and technological development require a more qualified and detailed examination of how patents and IPP regulation affect them. For example, these countries have been producing pharmaceuticals for some time now, and possess the knowledge to manufacture antibiotics and other chemical drugs that might be protected by product patents using processes developed locally. They have thus argued that a distinction must be made in this field and that their production of certain products not be considered a violation of existing patents that only protect the product's formula and not the process by which it is produced. Another area of potential conflict is in the production of computer software. Countries like India, Chile, Mexico, and others, due to the lower cost of their programmers, can compete in the international market for such services, and in fact are already subcontracting work from international computer and software firms. Thus the possibility arises that they could circumvent copyrighted software by their own developments or by the adaptation of existing code used in similar computer applications.

It is sometimes claimed that patent documents constitute a large source of free technical knowledge available to everybody with access to the patent files in Patent Offices. While that kind of information could be of use to US or Japanese firms trying to learn what has been patented by one of their competitors, and how they could circumvent such a patent, it is of little or no use to developing countries or, in general, to anybody not deeply involved in the technical area being protected by a given patent. This is so because the language used and the information disclosed in the patent documents is prepared by legal and technical specialists to, on the one hand, protect what needs to be protected, thus making as general a claim as possible, while at the same time divulging as little as possible about the key scientific and/or technical innovation involved in order to avoid that competitors develop "around it".

It has also been suggested that patents could be used as an indicator of scientific and technological prowess. While this is essentially true, it must be qualified. In the first place, an overwhelming proportion of world patents are granted to a few industrialized countries, and very little is accounted for by developing countries. This is so when we consider total patenting worldwide or in any particular country, and holds for total number of patents as well as, a fortiori, for only national patents. Still, using patents as one indicator, together with others, of scientific and technological activity, it has been shown that the number of patents granted in a given country is correlated with its expenditures in R&D as well as its stock of scientific and technical personnel. There is also a strong correlation, between number of patents granted and two economic variables: level of income per capita, and country economic size as measured for example by population size.

Business Incubators

Business incubators provide facilities to new entrepreneurs in order to facilitate business start-ups. They seek to: provide preferential conditions for a specific industry or type of enterprise; pool resources in terms of services, facilities, and equipment, and concentrate geographically the supply of utilities. Some of these incubators focus on high tech industries, usually by their proximity to sources of knowledge such as Research institutions and Universities thus ensuring that technology is put to productive uses. A potential problem in the operation of business incubators is that industries set up on the premises of business incubators may remain there, excluding new entrants. Often these facilities become real estate operations.

Institutions Providing Productivity and Information Services

Institutions providing productivity and information services include extension services, productivity centers and management and engineering consultancies. Support may entail the provision of access to technologies through shared facilities, for example in productivity centers, advice on the integration of acquired technologies into existing operations, and the improvement of environment related performance.

In some circumstances, perhaps especially in mature industries, information may flow relatively freely, and the establishment of specialized information services may be unnecessary. The type and relevance of the information provided will be important. Details of financial as well as technical features of new technologies may be required. The relative costs and benefits of user access to information should likewise be considered, which relates to the question of how information services are to be financed. The costs of establishing and operating a technology information system will probably be greater - depending on the sophistication of the system -, where a country's level of informational infrastructure and research facilities is low. It may also be the case that use can be made of information which is not usually brought together in a systematic way. For example, information gleaned from marketing trips, conferences, and other overseas contacts might be collected by industry associations or other bodies. Whether to charge users for access to information services, by how much, should also be considered in terms of how a charge might affect the demand for and use of the service.

Quality control, standardization and metrology

Such institutions set norms and standards, carry out inspections, and certify compliance with established quality criteria. The increase in sophistication of measuring technologies results in the ability to detect even minor variations over desired specifications. Furthermore, expanding participation of manufactured products in the international market increases the need for standardization and quality control. Increasingly, suppliers have to meet requirements of ISO 9000, or similar norms. Highly protected economies could afford to operate under a set of national standards; however, liberalization makes it necessary to comply with international rather than national standards. This will make national standards differing from international ones redundant.

Human Resource Development Institutions

Development of skills is perhaps the most fundamental aspect technological progress. Skills are essential for effectively undertaking the gamut of operations required by enterprises to create, adapt and use technology. Skills are also essential to the operation of technology related institutions and the development, implementation and monitoring of policies. Human resources development has traditionally been the responsibility of the public

sector. Increasingly, however, private institutions, companies specializing in advising on and providing training programmes, and professional associations are engaging in training. Specific technology issues which arise in this connection concern the pace of technological change and difficulties in adjusting curricula accordingly, as well as feedback between training institutions and employers.

Finance and Investment Promotion Institutions

Investments in research and development and other areas of technological change require commercial and development finance institutions. However, development finance institutions often cannot properly assess the viability of the technological content of a loan application. The World Bank suggests that financing institutions are not suitably equipped to undertake lending in this area, partly because of their limited knowledge and partly because of their risk aversion. Instead it is recommended to "look for intermediaries that understand R&D, have technical expertise, are knowledgeable about various industries and are committed and willing to take risks."¹⁷

Investment promotion agencies can facilitate both the inflow of resources and transfer of technology. However, investment promotion agencies usually have little capacity to assess the technological implications of investments. As a result they usually concentrate on the funds mobilization aspects of their work.

Industrial Subcontracting

Industrial subcontracting may not require specialized institutions, although subcontracting exchanges can facilitate the process. Industrial subcontracting can serve as a channel for technology transfer. The transfer of technology through subcontracting may occur when the relationship between the contracting firm and the subcontractor becomes more stable and integrated than the standard and occasional buyer-seller relationship. In addition to the transfer of technology, potential benefits of industrial subcontracting include improvements in the competitiveness of both partners, and greater flexibility for the contractor in meeting market demand fluctuations. Industrial subcontracting is widespread in much of the OECD and in many of the fast-growing economies of South East Asia, with specialized institutions and legislation operating in many cases. UNIDO data indicate that in a number of mainly upper-middle-income developing countries subcontracted components and parts account for up to 25% of total exports.¹⁸ Industrial subcontracting is particularly common in the automobile, electronics and aerospace industries.

There has been a progressive change in the nature of industrial subcontracting. Industrial subcontracting originally entailed the simple use of spare capacity. However, this evolved to include reliance on more specialized know-how and equipment, and, more recently, the development of relatively stable industrial partnerships based on an ability to rapidly and reliably supply products or systems of high quality, with minimal

¹⁷Report No. 12138

¹⁸Expert Group Meeting on Industrial Subcontracting Exchanges and Policies, Doc. IO.56 (SPEC), November 1991.

stocks held by the contractor. The emphasis on the quality of subcontracted production often requires a close relationship between contractor and subcontractor, with joint teams sometimes working on design, engineering and the manufacture of prototypes.

International subcontracting has become more common in recent years, often as a consequence of restructured operations within multinational companies. Most international subcontracting occurs as yet between firms in developed countries. Problems to be overcome in international subcontracting include the distances separating the firms involved, which can pose physical and financial obstacles to achieving the desired cooperation. The need for a degree of parity between potential partners may also pose obstacles to international subcontracting between firms in developed and developing countries.

As noted above, technology transfer through subcontracting requires that some degree of partnership be developed between the firms involved. However, the subcontracting relationship has at times tended to favor the contractor, with unequal sharing of the benefits of the relationship. The question of asymmetric market power may also arise in the national context between the large contractor and the smaller subcontractor. Moreover, assembly or "marginal" operations may provide only temporary benefits in the form of unskilled labor employment, particularly when local value added is limited and there are few backward linkages and opportunities for technological learning. The subcontracting relationship may be formalized, with the obligations and rights of both parties being specified for an agreed duration. Formal agreements may cover, *inter alia*, issues such as the specifications, quality, quantity and delivery schedules of specific products, the establishment of emergency stocks, preferential sales clauses, payment terms, consultation and, if necessary, conciliation arrangements. Technical assistance and investments may often be required to upgrade enterprises attempting to become subcontractors.

Classification of manufacturing industries according to OECD

Technology: Industries are grouped on the basis of their R + D intensity in the OECD area as a whole, defined as the ratio of business-enterprise R + D to production. The following high-, medium- and low-technology groups emerge.¹⁹

High-technology. Aerospace (ISIC 3845), computers and office equipment (ISIC 3825), communication equipment and semiconductors (ISIC 3832), electrical machinery (ISIC 383-3832), pharmaceuticals (ISIC 3522) and scientific instruments (ISIC 385).

Medium-technology. Chemicals (ISIC 351+352-3522), excluding drugs; rubber and plastic products (ISIC 355+356); non-ferrous metals (ISIC 372); non-electrical machinery (ISIC 382-3825); motor vehicles (ISIC 3843); other transport equipment (ISIC 3842+3844+3849) and other manufacturing (ISIC 39).

Low-technology. Food, beverages, tobacco (ISIC 31), textiles, apparel and leather (ISIC 32), wood products (ISIC 33), paper and printing (ISIC 34), petroleum refining (ISIC 353-354), non-metallic mineral products (ISIC 36), iron and steel (ISIC 371), metal products (ISIC 381) and shipbuilding (ISIC 3841).

Orientation: This classification is based on the primary factors believed to affect competitiveness. Industries are classified into resource-intensive (access to natural resources), labor-intensive (labor costs), scale-intensive (length of production runs), specialized-supplier (differentiated products) and science-based (rapid application of scientific advance).²⁰

Resource-intensive. Food, beverages, tobacco (ISIC 31), wood products (ISIC 34), petroleum refining (ISIC 353+354), non-metallic mineral products (ISIC 36) and non-ferrous metals (ISIC 372).

Labor-intensive. Textiles, apparel and leather (ISIC 32), fabricated metal products (ISIC 381) and other manufacturing (ISIC 39).

Specialized-supplier. Non-electrical machinery (ISIC 382-3825), electrical machinery (ISIC 383-3832), communication equipment and semiconductors (ISIC 3832).

¹⁹See OECD (1992), Industrial policy in OECD countries: annual Review, 1992.

²⁰See OECD (1987), Structural Adjustment and Economic Performance

Scale-intensive. Paper and printing (ISIC 33), chemicals (ISIC 351+352-3522) excluding drugs; rubber and plastics (ISIC 355+356); iron and steel (ISIC 371 and shipbuilding (ISIC 3841), motor vehicles (ISIC 3843) and other transport (ISIC 3842+3844-3849).

Science-based: Aerospace (ISIC 3845), computers (ISIC 3825), pharmaceuticals (ISIC 3522)

Wages: The classification of industries into high-, medium- and low-wage groups is based on the average labor compensation (calculated in US \$ PPPs as labor compensation per number engaged) across nine-countries (Australia, Canada, Finland, Germany, Japan, Norway, Sweden, United States and United Kingdom) for 1985. The high-wage grouping then defined as industries in which the wage was more than 15 per cent above the median, the medium-wage grouping as industries within 15 per cent of the median and the low-wage grouping as industries with wages at least 15 per cent below the median. The groupings appear to be quite stable to two other time periods (1975 and 1980) and for additional countries.

High-wage. Chemicals excluding drugs (ISIC 351+352-3522), aerospace (ISIC 3845), pharmaceuticals (ISIC 3522), petroleum refining (ISIC 353+354), computers and office equipment (ISIC 3825) and motor vehicles (ISIC 3843).

Medium-wage. Paper and printing (ISIC 33), rubber and plastics (ISIC 355+356), non metallic mineral products (ISIC 36), iron and steel (ISIC 371), non-ferrous metals (ISIC 372), metal products (ISIC 381), shipbuilding (ISIC 3841), non-electrical machinery (ISIC 382-3825), scientific instruments (ISIC 385), communication equipment and semiconductors (ISIC 3832).

Low-wage. Food, beverages and tobacco (ISIC 31), textiles, apparel and leather (ISIC 32). Wood products (ISIC 34), electrical machinery (ISIC 383-3832), other transport (ISIC 3842 +3844 +3849) and other manufacturing (ISIC 39).

Skills: Manufacturing industries are classified into skilled and unskilled on the basis of estimates for the proportion of production workers in manufacturing employment by industry.

Skilled. Food (ISIC 31), paper (ISIC 34), chemicals products (ISIC 351+352-3522), pharmaceuticals (ISIC 3522), petroleum refining (ISIC 353+354), fabricated metal products (ISIC 381), office and computing equipment (ISIC 3825), communication equipment and semiconductors (ISIC 3832), aerospace (ISIC 3845) and scientific instruments (ISIC 385).

Unskilled. Textiles (ISIC 32), wood products (ISIC 33), rubber and plastics

(ISIC 355+356), non-metallic mineral products (ISIC 36), ferrous metals (ISIC 371), non-ferrous metals (ISIC 372), non-electrical machinery (ISIC 382-3825), electrical machinery (ISIC 383-3832), shipbuilding (ISIC 3841), motor vehicles (ISIC 3843), and other transport equipment (ISIC 3842+3844+3849).