THE EARTH SUMMIT AND THE PROMOTION OF ENVIRONMENTALLY SOUND INDUSTRIAL INNOVATION IN DEVELOPING COUNTRIES

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Introduction

With the end of the cold war, issues of environment and economic development are assuming greater international salience. The linkages and overlaps between these two issue areas are already dense. They promise to become even denser in the future, increasing the complexity of the environment and development agenda.

By the 1970s, over 100 countries had established some variety of national environmental protection agency. But environmental degradation was becoming pervasive, with growing global effects. The Brundtland Commission's report (1987) produced distressing evidence of planetary decline: "the annual loss of an area the size of Saudia Arabia to the march of the deserts, the loss of over 17 million hectares of tropical forests per year, the destruction of the earth's ozone shield by chlorofluorocarbons (CFCs) and halons, and the possibility of a warming of the earth's climate over the next fifty years, greater than that experienced over the previous 10,000 years" (Runnalls 1993: 134). The United Nations Environment Program (UNEP) estimates that, with expected growth and industrialization in the South, the developing countries' world share of carbon dioxide emissions will increase from 25 % to 40 % between 1985 and 2025, and their share of sulfur dioxide emissions will grow from 30 % to 70 %.

Some now believe that the world-wide environmental crisis that threatens the first half of the 21st century "can only be compared to the 14th century catastrophe which annihilated one-half of the population of Europe" (Lipietz 1993: 111). At the same time, the unfortunate view is gaining ground that the Post-World War Two international development effort has largely failed and deserves to be abandoned – even though between 1960 and 1980, average annual economic growth in the countries of the South exceeded that of their Northern counterparts. "During that same time period, we witnessed gains in developing countries in life expectancy, child survival, nutrition, agricultural output, education, disease eradication, and industrial output that are without parallel in all of human history" (Bezanson 1993: 3). But the international context of development is suffering major discontinuities and the prevailing development paradigm – the "infinite growth, material progress paradigm" – enjoys decreasing plausibility.

Global and emergent globalized problems are forcing environmental interdependence on the world (1). Transboundary threats cannot be addressed unilaterally by any single country or group of countries. Such problems must be addressed by international and national policies but "there are major uncertainties about sources, processes, consequences, and viable modes of response" (Choucri 1993: 114). The global environmental agenda is reviving the North-South debate and rejuvenating the Third World coalition in international fora. North-South issues "are inscribed in the international environmental agenda at two structural levels: in the equality of responsibility for environmental degradation and in the relative abilities to cope with these problems" (1993: 25). The encouragement of environmentally sustainable forms of industrialization in the South requires expanded and improved international cooperation. However, the North's greater resources and greater responsibility in causing global environmental degradation require its continuing involvement in the search for solutions, including ones applicable to newly industrializing countries.

In June 1992, the largest intergovernmental conference ever held was convened in Rio de Janeiro to address these issues. The United Nations Conference on Environment and Development (UNCED, or the Earth Summit), attracted 105 Heads of State or Government, 8,000 journalists, and 15,000 participants from non-governmental organizations (NGOs) at UNCED or at the parallel conference held simultaneously in Rio. It produced a consensus action plan of about 700 pages: Agenda 21.

Agenda 21 presents massive challenges for international cooperation as well as for national and private actors and scientific and technical institutions. It reflects a complex configuration of demands for institutional arrangements that support environmentally sustainable technical and socioeconomic change (2).

One of the most consistent of the Agenda 21 themes, and one of the most intractable issues, concerns "access to technology" (3). This can be as straightforward as diagnosing and improving the efficiency of a production process in a small manufacturing firm, or as complex as engineering a technological revolution in which production and consumption take place with virtually no material or energy loss to the environment. The selection of entry points for action is a critical strategic problem as well as an important operational issue. Examples of the kinds of initiatives frequently advocated to put the technological trajectory of the South on a more sustainable footing include: enhanced vertical and horizontal technical and industrial cooperation, better policy development, market development, capacity building, apppropriate financial measures, training exercises, better regulatory regimes, and improved indigenous technical support organizations. Most of these are among the abundant action items put forward by Agenda 21.

In this paper I first present a general overview of the structure and contents of Agenda 21, the Earth Summit's action plan for environmentally sustainable development. I then identify and describe new initiatives intended to improve the environmental performance of industry in the South, and find that they largely aim to promote incremental industrial innovation through international technology transfer and diffusion. This strategy raises many questions about how to promote effective technology transfer and diffusion. As the joint International Development Research Centre-Earth Council workshop on "Research Priorities in Technology and Environment" remarked, "many of the challenges in the field of environment and technology demand not so much new technologies or even new policy instruments, but rather new types of institutions to improve the diffusion and 'uptake' of existing technologies" (IDRC 1993c: 7). Some of these institutions and associated policy issues are discussed in a later section of the paper. In the final section I explore some of the limitations of the incrementalist approach to "clean" industrial innovation in the South.

Industrial Technology and Environment in Agenda 21

Although alarms about global environmental degradation have been sounded for the past three decades, the environmental situation today is different in four new ways (Rath and Herbert-Copley 1993: 7):

- rapid increase in the scale of pollution has accelerated loss of soil, species, clean water, and natural environments.
- tens of thousands of synthetic chemicals, most of which are untested as to toxic or environmental effects, are replacing natural pollutants.
- the transboundary impacts of environmentally disturbing human activities require international or transnational remedies that can be long and complex to put in place.
- because "the various environmental threats are inextricably linked, both in their causes and effects", they cannot be addressed or solved in isolation one from the others.

The issue of how to understand and promote environmentally sustainable industrial innovation in the less-developed countries (LDCs) is complex. Beyond the traditional narrow concerns about choice of techniques lie the deeper and more controversial issues of terms of trade, population, employment, debt, and social conditions. Also, the origins of the global environmental predicament lie in the patterns and velocity of production and consumption in the industrialized countries. Their commitment to unlimited growth and lavish consumption is deeply rooted in a worldview that regards nature as static and infinitely exploitable; prevailing analytic models "are based on reductionist and deterministic assumptions about resources, people, firms, and technology that bear little relationship to their counterparts in the real world" (Rees 1993).

UNCED produced five sets of documents: Agenda 21, the Earth Summit's action plan; the Rio Declaration on Environment and Development; two conventions (the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity); and a "non-binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests".

The Rio Declaration on Environment and Development articulated 28 principles accepted by all delegations. These include the principle that human beings are at the center of development, that the right to development exists and must be shared between present and future generations, and that environmental protection is an integral part of development. The Rio Declaration enjoins all countries to cooperate to eradicate poverty as an indispensable requirement for sustainable development, and it requests all states to cooperate to promote an open international trading system as the basis for economic growth and sustainable development. Furthermore, it endorses the precautionaury approach to pollution prevention, stating that "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

The negotiating goals of Northern and Southern countries differed substantially at UNCED. Southern countries emphasized problems of development, often interpreted in terms of growth, and sought access to technology for purposes of income generation and employment. Southern countries emphasized that many "global" environmental problems originated in industrialized countries, which are therefore primarily responsible for their solution. Southern countries sought to establish mechanisms and rules to favor the transfer of environmentally sound technologies from Northern countries on favorable, non-commercial terms. While insisting on their sovereign rights to development on their own terms, the South sought substantial additional new international funding to implement Agenda 21 and develop national capacity. The Southern countries attempted to extract concessions from the Northern countries in exchange for access to their genetic resources. The South preferred that funding be channelled through institutions expected to be be responsive to the developing countries' agenda. In many cases, these would be United Nations institutions, especially the United Nations Development Program and its resident representatives in Southern countries (Mullin 1993: 13).

The Northern countries, on the other hand, emphasized intellectual property protection and market development issues. They preferred that technology be transferred on commercial terms, and emphasized the importance of markets, appropriate prices, and business self-regulation as solutions to environmental degradation. Northern countries sought to focus attention in particular on technologies causing global warming, and they preferred to promote technological change through strengthening certain already-existing institutions under their control, notably the Global Environmental Facility. Some differences within the Northern group were apparent:

> *"The United States has tended to take the hardest line in terms of intellectual property rights and nonconcessional access. Other countries, notably Japan and Germany, have taken a softer line. This reflects their leading positions as suppliers of environmentally sound products, and the related perception that the principal economic benefits lie not in protecting rents associated with patents, but rather in aggressively promoting emerging environmental industries" (Rath and Herbert-Copley 1993: 17).*

In many respects the nature of the world environmental debate has not substantially changed since the early 1970s. The South's priorities remain income generation and poverty reduction. Many of its environmental priorities – sanitation, water, soil, and biomass conservation – are not global. In contrast, many of the the North's environmental priorities are global: "slowing tropical deforestation, reducing ozone-depleting and greenhouse gases, protecting international waters, protecting biological diversity" (Pearce *et al.* 1992: 310). However, the development priorities of the South – especially insofar as they require access to technologies and markets - often do have global dimensions.

Agenda 21 covers five broad sets of issues (socio-economic issues, resource management, waste management, roles of "major groups", and "cross-cutting" issues) in 110 program areas in forty chapters of negotiated agreements (4). The result is a

> *"vast and inaccessible document. Its 700-odd pages contain schemes for dealing with everything from toxic waste to safe drinking water, from international trade to Antarctic conservation". (Runnalls 1993: 141)*

The negative aspects of Agenda 21 as an action plan are its wordiness and complexity, its vagueness on many key issues and its multiple contradictions on others, and its conspicuous weaknesses regarding mechanisms to translate principles into action at the international, national, or local levels. Agenda 21's positive aspects are its comprehensiveness; the degree of consensus it was able to build and express; its insistence that environment and development are two sides of the same coin; international acknowledgement that the problems of poverty, equity, and sustainability are interlinked; acknowledgement also of private enterprise as a legitimate form of activity; and recognition of the need for national capacity building as a path toward solution of international environment and development problems.

The two Agenda 21 chapters bearing most directly on industrial innovation are Chapter 30, "Strengthening the Role of Business and Industry", and Chapter 34, "Transfer of Environmentally Sound Technology, Cooperation, and Capacity Building" (5).

Chapter 30 emphasizes the important role of business and industry, "including transnational corporations", in sustainable development (6). The Chapter urges firms to "recognize environmental management as among the highest corporate priorities and as a key determinant to sustainable development". Responsible corporate behavior implies "adoption of cleaner and more efficient production methods, engagement in partnerships to transfer and diffuse technologies and management practices to other firms, and use of relatively transparent accounting methods" (IDRC 1993b: 211). Chapter 30 suggests that self-regulation, persuasion, enhanced market forces, regulations, profit-seeking, and altruistic behavior among firms can lead to cleaner production. The Chapter proposes two programs for international public and private action: promotion of cleaner production (viewed largely as a problem of information transfer), and promotion of responsible entrepreneurship (viewed mainly as a problem of inducing responsible business practices in small and medium sized firms). Measures advocated to promote responsible entrepreneurship include regulatory mechanisms, dedicated venture capital funds, training, and partnerships within industry.

Chapter 34 ("Transfer of Environmentally Sound Technology, Cooperation, and Capacity Building") proposes action on five fronts:

- improve access to scientific and technical information;
- promote, facilitate, and finance access to and transfer of technologies;
- facilitate maintenance and promotion of indigenous technologies;
- strengthen endogenous capacity to assess, adopt, manage, and apply technologies;
- promote long-term technological partnerships between holders and users of technologies. (IDRC 1993b: 237).

The Chapter proposes two specific initiatives: establish regional information clearinghouses to link existing information systems at the national, regional, or international levels; and establish a collaborative international network of research centers on environmentally sound technologies. The estimated annual costs between the years 1993 and 2000 of implementing Chapter 34 recommendations are from $ 450 to $ 600 million.

Neither chapter provides more than a general framework for action. Some of the difficulties in implementing the ideas and proposals in these two chapters are as follows (IDRC 1993c):

- concern about implementation was not Agenda 21's strong suit. No particular institutions were designated as implementing agencies, or volunteered themselves; no dedicated resources were freed up for purposes of implementation; no specific follow-up mechanisms were provided for.
- the range of technologies potentially falling under the ambit of Agenda 21 proposals is vast. "Environmental technologies" are not an easily identifiable subset of all technologies, since most production technologies have environmental implications. The notion of "environmental soundness" is relative.
- technologies are not just hardware, but "software" as well, including management practices, firm-level skills, and factors contributed by supporting institutions. The traditional focus on intellectual property issues in North-South encounters obscures the diversity of factors that affect technology transfer. For example, successful transfer of complex technology implies a long term, iterative process between users and suppliers. Prior or concurrent domestic capacity building is a key component of successful technology transfer, although it is not necessarily easy to specify the capacities to be developed in view to facilitating a particular technology transfer.
- neither Chapter 30 nor Chapter 34 devotes much attention to effects of various environmentally improved technologies on employment, income distribution, or gender issues.

Some issues and proposals for international initiatives did not survive the negotiation process in the four preparatory meetings. Several issues raised in preparatory meetings but absent from the official texts concern "rules of the game" for international technology transfer: for example, measures to increase competition among technology suppliers, increase market access for LDCs, or restrictions on environmentally damaging technologies (IDRC 1993c).

In sum, the Earth Summit did not produce breakthrough agreements or major transformation of North-South relations in matters of technology, environment, and development. The chapters covering business and technology place more emphasis on information sharing and capacity building than on issues of intellectual property and concessional financing. In the case of proposals for substantially new institutions, as for example in the proposal for an international collaborative network of R&D institutions on environmental technologies, the rationales are not elaborated well enough to be convincing nor are serious follow-up measures envisaged. The absence of significant implementation mechanisms and the de facto preference for bilateral or unilateral actions over multilateral actions have meant that, as far as environmentally sound industrial innovation in the South is concerned, the immediate post-Earth Summit period has been characterized by a plethora of largely unrelated initiatives.

Access to Environmentally Sound Technology: where are the entry points?

Most innovation policies and strategies aim to promote economic viability or "competitiveness" at some level: the firm, the sector, the region, or the nation. The scholarly and practitioner literature on innovation policy and management largely reflects this concern about competitiveness. On the other hand, environmental sustainability has not been a major consideration among mainstream innovation policy and management researchers. Winn and Roome (1993) searched the core R&D management literature of the previous two decades for work on environmental issues, and identified only nine articles. Clarke and Reavely's (1993) 9000-item bibliography of core science and technology management literature contains references to only 31 documents that focus explicitly on environmental issues. Similarly, the literature on "green" innovation policies is relatively small and dispersed among the literatures on environmental management, environmental economics, risk assessment, and economics of innovation.

Policy and management aim to influence behavior. As Freeman (1992) points out, the issue of eco-efficient industrial development hinges on estimates of the feasibility with which an "accelerated orientation of the science-technology system in the desired direction" can be brought about. What are the strategic entry points, the key leverage points, to influence the environmental performance of industry? How high or low should actions aim in the hierarchy of causes of technical change? Agenda 21 contains as many grand statements of principals for hypothetical industrial social systems, as recommendations for minor improvements to systems which to the candid observer appear largely unsustainable.

One useful set of distinctions is employed by evolutionary economists such as Freeman (1992), Kemp and Soete (1992), and others in their discussion of "green" innovation: the distinction between innovation at the level of the *firm*, the *production system*, the *technology system*, and the *technoeconomic paradigm*. These distinctions identify, at the same time, progressively larger changes in current practices, and progressively larger systems taken as reference points. Incremental innovations are minor cumulative changes continously occurring in firms, adding up over time to significant improvements in productivity and efficiency. Radical innovations are discontinuities in the production system. Nylon and the oxygen steelmaking process are historical examples. More recently, radical innovations "are usually the result of deliberate research and development in enterprises and/or in university and government laboratories" (Freeman 1992). Changes of "technology system" are the result of clusters of radical innovations that create "far-reaching changes in technology, affecting several branches of the economy, as well as ultimately giving rise to entirely new sectors". Synthetic materials and the associated manufacturing techniques are examples. Technological revolutions, or change of "technoeconomic paradigm", are "new technology systems which have such pervasive effects on the economy as a whole that they change the style of production and management throughout the economy" (Freeman 1992). The introduction of electricity is an example.

Distinctions between minor and major forms of technological innovation suggest ways of distinguishing between tactical and strategic approaches to technological change. Tactical interventions aim to accelerate incremental improvements in the environmental efficiency of industry by reducing wastage and increasing recycling. They would put in place policy and economic incentives and disincentives, management paradigms, technology diffusion mechanisms, and investment and training strategies to produce many small improvements on a broad front. Strategic interventions aim to innovate substantially improved technologies or radically improved technological systems.

The distinction between innovation of minor and major magnitude is being taken up by national and international policy and program agencies. For example, the OECD foresees a three-pronged transition to the "fourth industrial revolution", the clean industrial production revolution comparable to the steam, steel-electricity, and electronics revolutions.

- The first thrust is to induce incremental improvements in industrial performance by acting to identify, deploy and implement existing cleaner technologies through provision of information, removal of barriers to trade and implementation, government purchasing programs, etc.;
- The second thrust is to accelerate technical and technological change by acting to promote innovative development and widespread implementation of new generations of cleaner technologies, through enunciation of coherent goals and policies such as Japan's New Earth 21 Plan or the Netherlands' National Environment Policy Plan Plus, which sets long term environmental quality goals;
- The third thrust is to maintain environmentally sound industrial innovation by acting to ensure that cleaner technologies become and remain the basis for economic development in the long term through education and collective action, promotion of new generations of cleaner technologies, etc. (OECD 1993, ix-x).

Some might argue that the OECD program is not so much revolutionary as evolutionary, since its three thrusts aim, in increasing degrees, to inflect and accelerate technological change along the present trajectory rather than identify possible other, more sustainable technoeconomic paradigms. But the OECD program has the virtues of feasibility and implementability. It also permits us to observe that increments of technical change can be quite large, especially from the point of view of a small or medium firm without significant technological resources, before becoming "radical".

The key characteristic of cleaner technologies is that they are cleaner than prior technologies with respect to materials flow, energy efficiency, or toxicity. Cleaner technologies:

- extract and utilize natural resources and prepare products as efficiently as possible;
- use as little energy and raw materials as possible per unit of product output and per unit of utilization (useful lifetime) of the product;
- generate products with reduced or no potentially harmful components;
- minimize releases to air, water, and soil during fabrication and use of product;

- ensure that any residua of production and use which are generated are managed in an environmentally sound manner;
- ensure, for non-perishable goods, that product durability and lifetimes are maximized insofar as practicable; and, after the useful function is ended, products or their key components are recoverable insofar as possible (OECD 1993: 2).

These characteristics can apply to many techniques and practices across the entire range of industries. Participants at the Earth Summit encountered difficulty in identifying kinds of "clean" or environmentally sound technologies to promote and diffuse to developing countries. Since no technologies are perfectly clean or entirely environmentally sound, cleanliness or environmental soundness is relative.

The Precautionary Principle and the Cleaner Production Paradigm

The traditional approach to industrial pollution control is to implement end-of-pipe (EOP) technologies. This approach is still widely used, especially in developing countries, although its main effect is to displace the pollution charge from one medium to another. Traditionally, concommittant with this approach to environmental technology policy are regulatory regimes based on concepts of environmental assimilative capacity or critical pollution loads (7). The permitting and compliance regulatory frameworks of industrialized countries created a demand for add-on pollution abatement techniques, a demand reflected in national science and technology policies. In the former West Germany, for example, governmental support for R&D on clean technologies focussed largely on invention of end-of-pipe pollution abatement techniques (Bongaerts and Heinrichs 1987).

There is growing acceptance of the "precautionary principle" in environmental management. The precautionary principle, which the Earth Summit endorsed, discourages attempts to establish environmental management strategies based on calculations of the pollution carrying capacity of the environment, with innovation aimed largely at waste management strategies and production of end-of-pipe pollution abatement techniques. Instead, the precautionary principle advocates reduction to zero of all emissions of substances that are "persistent, toxic and liable to bioaccumulate... even where there is no scientific evidence to prove a causal link between emissions and actions" (Jackson 1991: 8). The clean production paradigm advocates approaches such as product lifecycle assessment and closed-cyle industrial ecological design to foster across-the-board prevention of pollution in industrial systems (Dethlefsen, Jackson, and Taylor, 1993; Hirschhorn, Jackson, and Baas, 1993). The principles of "clean production" are precaution (i.e. reduction of anthropogenic inputs into the environment), prevention (i.e. extend the analysis of environmental implications of production as far upstream as possible), and integration of environmental protection measures across system boundaries (i.e. integration of protection measures into the production process) (Jackson 1993). The United States Environmental Protection Agency defines pollution prevention as "source reduction" eliminating or reducing pollutants through improvements in equipment, technology, processes or procedures, redesign or reformulation of products, substitution of raw materials, and "improvements in housekeeping, maintenance, training and inventory control". Recycling, re-use, and end-of-pipe pollution control are excluded by definition.

The Technology Innovation and Economics Committee of the U.S. National Advisory Council for Environmental Policy and Technology goes a step further and advocates a hierarchy of technological approaches to environmental improvement: "in order of desirability, these are: technologies that prevent pollution (including waste minimization and source reduction technologies), recycling technologies, environmental control [i.e. end-of-pipe] technologies, and cleanup [i.e. remedial] technologies" (EPA 1991).

Hirschorn (1992) proposes a four-stage model of implementation of pollution prevention activities in developing countries, beginning with simple common sense or "good housekeeping" modifications of industrial practice. These cost little and often yield significant reductions in waste. Stage 2, "information driven waste reduction", requires "significant detailed technical data about wastes and how, why, and where they are produced", but remedies are available with existing technologies. Stage 3, "analysis driven waste reduction", requires detailed economic and technical analysis as well as significant capital investment. Stage 4, "R&D driven waste reduction", is required when no appropriate commercial technology is available and new equipment, material, technologies, or processes are necessary.

Under regulatory or price conditions providing appropriate incentives and disincentives, the firm-level transition to cleaner production can begin with simple substitution of a cleaner technology for a less clean one. The transition can also begin with a waste audit, a systematic look at opportunities to improve efficiency and productivity. A waste audit is the "first step in an on-going program designed to achieve maximum resource optimisation and improved process performance. It is a common sense approach to problem identification and problem solving" (UNEP/UNIDO 1991b). The waste auditing procedure advocated by the United Nations agencies:

- defines sources, quantities and types of wastes being generated;
- collates information on unit operations, raw materials, products, water usage and wastes;
- highlights process inefficiencies and areas of poor management;
- helps set targets for waste reduction;
- permits the development of cost-effective waste management strategies;
- raises awareness in the workforce regarding the benefits of waste reduction;
- increases management's knowledge of these processes;
- helps to improve process efficiency (UNEP/UNIDO 1991b: 3-4).

The result of a waste audit is the development and implementation of an action plan to reduce waste and improve production efficiency. Many case studies of industrial implementation of cleaner production methods are avalaible (8).

From the point of view of the concerns of developing countries to have access to cleaner technologies, the findings of the Dutch PRISMA program, a precursor of later UNEP/UNIDO cleaner production initiatives, are significant. The PRISMA waste auditing procedure identified about 200 hundred pollution prevention options among a group of corporate participants. Only 30 % of these options implied technological modifications;

30 % implied improvement in housekeeping procedures, 30 % implied changes in materials and raw materials, and 10 % implied product modifications (Huisingh and Baas 1991: 28).

Taken together, housekeeping procedures, material inputs, production technologies, and product parameters constitute "industrial practice". It is clear that significant economic benefits can be gained from incremental improvements in existing industrial practice, especially in developing countries where the stock of equipment and the skill sets of workers and managment are all likely to be farther from good practice than in the high-income industrial countries. Opportunities for energy conservation in the industrial sector in developing countries are estimated at 10 to 30 percent. Many of these improvements can be achieved by implementing standard good industrial practice, that is, without major investments in equipment. In Thailand "good housekeeping alone would lead to a 12 percent improvement in energy efficiency, while process improvement would lead to a further 16 per cent improvement" (Tolba 1992: 339). According to UNEP/UNIDO, "a general rule of thumb in industrial waste minimization is that as much as 50 % of the reduction can be achieved through more effective operation and maintenance, along with small process modifications. The remaining 50 % depends on the introduction of inherently cleaner (and more efficient) production processes" (1991a: 34). Hirschorn (1992) provides examples of rapid payback periods for adopters of American pollution prevention technologies: six months for adopters of high volume, low pressure paint spray guns; five months for a process to recycle solvents using water-based cleaners; three years for a wastewater recycling system in a fertilizer manufacturing plant; 2.5 years for a chrome recovery system in a tanning mill.

In the industrialized North, 21st century corporations may find it essential to innovate and operate competitively while behaving in an environmentally responsible manner. Shifts in thinking about the strategic importance of ecoefficiency are apparent among businesses (Davis and Smith, 1994). In one survey of 200 senior executives in the United States, 90 % said that environmental considerations were part of their strategic planning process. In another survey of 250 European companies, almost three quarters were found to have specific plans to improve environmental performance. A 1991 report from the Canadian Federation of Independent Business states that 99 % of their members are concerned about the state of the natural environment, and that 60 % have made, or are about to make, significant changes to their businesses to respond to environmental concerns. The Canadian Standards Association has been working to develop environmental management systems analogous to the ISO 9000 series of Quality Management Standards.

Institutional Arrangements and Environmentally Sound Industrial Innovation in the South

What kinds of public and private institutional arrangements, markets, and national and international policy regimes are desirable for rapid diffusion of cleaner production techniques and practices in developing countries? The scholarly and institutional literature provides some tentative answers to this question.

Much recent research shows that industrial innovation, in addition to rarely conforming to the venerable common-sense linear model which inspired a great deal of science policy two and three decades ago, is organizationally complex. The "institutional domain of technology diffusion" is inhabited not just by suppliers, producers, and end users, but also by an array of actors whose participation in the innovation process is often critical (Reddy, Aram and Lynn 1991). These include non-market institutions such as universities, research institutions, innovation support agencies, and trade associations, sources of technological complementarities such as strategic alliances or affiliate firms, and firms' "vertical complementary assets" such as service or marketing capability. The externalities supplied by the institutional environment are likely to be important factors in the development and maintainance of technological learning capability within firms. In open economies characterized by rapid technological change, innovation-supporting infrastructure is a growing area of concern of technology policy.

In the absence of vigorous local markets for technology and producer services, the best alternative for developing countries may be to establish some form of innovation support institution. These can be classified on a four-point scale of increasing involvement in the firm's decision-making (Doyle 1992). At level one, the institution provides information and networking services. This is the kind of institution many UNCED participants had in mind when they emphasized the need for transfer of information about cleaner production technologies. Many environmental technology databases and referral services are now available, including ICPIC, the International Cleaner Production Information Clearinghouse, and many other information-delivery services have been established on an experimental basis. For example, in late 1991 the United States Environmental Protection Agency awarded a contract to Teltech Resource Network of Minnesota for a pilot project to provide three kinds of customized services to clients in developing countries: direct telephone access to an expert network in U.S. institutions to provide information on pollution control and energy efficiency, an interactive literature searching service, and a directory of U.S. environmental technology and service vendors. Similarly, the World Environmental Center, a private not-for-profit agency based in New York, is establishing regional environmental information centers in Bangkok, Jakarta, and Prague.

At Level Two, in addition to providing information the institution brokers specialized services such as business planning, market assessment, and identification of financial sources. Many Chambers of Commerce and Business Innovation Centers operate at this level. UNIDO and UNEP have established technology databases and, more recently, about a half dozen National Cleaner Production Centers, which are essentially technical advisory centers using national consultants.

At Level Three, the institution provides technical and financial infrastructure support, including (for example) operation of incubators, prototyping services, technical assistance, and arm's-length financial assistance. This is a hands-on technical assistance role that requires vigorous, proactive behavior on the part of the institution. Many industrial research institutes in the developing world were intended to play this role with respect to industrial technologies, and have failed. An example of a Level Three environmental technology institution in the United States is NETAC, the National Environmental

Technology Applications Corporation. NETAC provides business evaluations, technology evaluations, regulatory and intellectual property assistance, training, and technical services such as testing and demonstration. It also has a product evaluation center specialized in bioremediation technologies.

At Level Four, the institution participates directly in the firm through equity investments and close technical and management ties. I know of no examples in the area of environmental technology. However, a general example is the Finnish National Fund for Research and Development (SITRA), an independent public fund of about US$ 100 M with the mission to take research to market. It supports new ventures through minority equity participation (Doyle 1992).

Discussion at UNCED about access to technology led to certain conclusions about desirable institutional arrangements. These conclusions may merit review. For example, it is more than likely that access to information is a necessary but not sufficient condition of adoption of cleaner technologies. The point has often been made that technology cannot be reduced to information because it is not largely codifiable (David 1992). This factor is likely to be important in the case of transfer of cleaner production processes for several reasons. In the first place, cleaner processes are unlikely to be perfectly substitutable for dirtier processes, necessitating more or less technical and institutional "stretching" by the receiver of the technology to adjust and adapt it (9). In the second place, cleaner production appears to be based on a certain "philosophy" or business outlook that can best be acquired interactively. In the third place, many incremental improvements in technology do not require new hardware, but modification of industrial practices. In the fourth place, estimates of economic costs or benefits are often paramount in decisions regarding adoption of cleaner technologies. Demonstration of the economic advantages of adopting a cleaner production technology are as important as demonstration of the feasibility of new production techniques.

However, from a technology diffusion point of view, evidence suggests that passive information centers (Level One institutions in the above schema) are unlikely to prove useful organizational arrangements in developing countries. Level Two institutions are likely to be useful in situations where available services must be brokered and where solvent demand for services is strong. More probably, however, is the need for Level Three institutions, which have the internal capability to provide technical and business assessments, as well as financial facilities. It is possible to imagine Level Three institutions of regional, sectoral, or even international scale. Since shortages of capital are likely to afflict potential adopters of clean technologies in developing countries, the financial facilities may turn out to be important.

Level Four innovation support institutions may be appropriate when firms are attempting to commercialize indigenous environmental technologies. The issue of whether an institution of this sort is required at an *international scale* deserves consideration.

A UNIDO/UNEP background paper on the National Cleaner Production Centre Program offered the following thoughts on the most appropriate and effective institutional arrangements for promoting cleaner production in developing countries:

"An important lesson from the United States is that cleaner production outreach programs can take many different forms. There is considerable variation in the

pollution prevention programs managed by the 50 states. The programs are located in a variety of institutions and provide a diverse array of services. The lesson from this is that UNIDO and UNEP should encourage each country to design a program that best responds to its own situation... Important lessons from the ongoing UNIDO demonstration of cleaner production techniques in Egypt and Mexico are the importance of a highly motivated national expert and the ability of company employees, on the basis of a waste reduction audit and with the assistance of a sectoral expert, to identify several source reduction measures" (UNIDO/UNEP 1992: 7).

These comments confirm the view that vigorous local technical support institutions with the requisite skills and services in cleaner production are likely to be critical actors in the improvement of the environmental performance of Southern industry. However, analyses of attempts to institute cleaner production in developing countries (i.e. Hirschhorn 1992 and 1993; Wang and Ke 1992; Yhdego 1992) indicate that bottlenecks in the supply of local technical services are not the only or even the primary limiting factors, which I briefly review below.

The domestic environmental policy regime.

Many developing countries are establishing environmental policy regimes based not on the precautionary principle but on prior regulatory models. "Historically, technology diffusion has played a limited and subordinate role to regulation, permitting, and compliance in the regulation-based environmental management system" (EPA 1992: 15). This is because the regulation-based environmental policy systems encourage investments in pollution control technologies rather than in environmental improvement of processes, products, housekeeping, and materials handling. Once investments have been made in end-of-pipe pollution control technologies, there is little incentive to adopt the more comprehensive pollution prevention management paradigm. Furthermore, suppliers of pollution control solutions may resist movement toward a precautionary policy environment: "experience in the U.S. has shown this to be a significant issue, because the end-of-pipe approach has advocates and a large industry selling the hardware of pollution control (e.g. scrubbers, incinerators, waste treatment plants)" (Hirschhorn 1992: 11).

A comprehensive pollution prevention environmental policy regime should include 1) pollution prevention technical assistance programs as described above; 2) pollution prevention education and training; 3) pollution prevention financial incentives; 4) increased use of liability regulations; and 5) "regulations specifically requiring the development of waste reduction plans and the submission to governments of regular reports on their progress in waste reduction" (Baas *et al.* 1992: 14; Yakowitz and Hanmer, 1993). The structure of incentives and disincentives to invest in minor or major forms of industrial innovation having some relation with environmental sustainability is clearly of central importance. The design of environmental policy from an industrial innovation perspective must ensure that counterproductive policy measures from other domains, such as economic subsidies for energy, water, or local raw materials, are detected and dealt with.

International technology transfer of environmentally sound technologies.

International technology transfer issues have always been a sore point in the North-South relationship. Software, agrobiotechnology, and pharmaceuticals are examples of industries in which major trade-related intellectual property issues have arisen in the past decade. Many participants in the Earth Summit assumed that intellectual property issues, in particular, were important negotiating points. However, it seems disproportionate to single out intellectual property issues as the critical problem affecting the international transfer of the current generation of environmentally sound technologies.

As we have seen, up to 70% of the pollution prevention options of a firm as it begins to implement a cleaner production program concern housekeeping, materials, and product design. Corrective action is likely to require technical and management skills which may be located outside the firm, but purchase or license of hardware or industrial designs governed by intellectual property legislation may not be a major factor. Furthermore, if purchase of machinery is necessary, it is likely to be commercially available, in which case financing and foreign exchange credits rather than intellectural property rules are likely to be a key considerations. Whether or not an international institution or brokerage agency could usefully facilitate the international transfer of environmental technologies is an important issue currently under discussion in international agencies (Barnett, Bell, and Freeman 1993; Maltezou 1992) (10).

Three issues concerning international technology transfer deserve perhaps greater immediate attention than the intellectual property issue. The first has to to with the growing salience of environmental technologies in the international trade and assistance strategies of industrialized countries. The world market for environmental technologies was estimated in 1992 at US$ 200 billion to US$ 400 billion (Doyle 1992; McCann 1992) (11). Most of this market is expected to be in the OECD countries, but about 10% of the market is in the developing world. Most OECD countries are incorporating environmental technology export promotion goals into their foreign policy programs, and the rising commercial salience of environmental industries makes it more than likely that environmental technology- and service-exporting countries will establish strategies and policies to guide program initiatives (12).

For example, in 1991 Japanese firms, with the support of MITI, established the International Center for Environmental Technology (ICETT), which is expected to implement the "10,000 Training Plan" for trainees from developing countries in areas of advanced environmental and energy technologies. Japan is also hosting the new UNEP International Environmental Technology Center (UNEP/ITEC) in the Kansai Science City with ICETT and the new Research Institute of Innovative Technology for the Earth (RITE). Other industrial countries are taking similar actions. In 1993 the United Kingdom announced a Technology Partnership Initiative to promote the transfer of British environmental technologies to developing countries. The initiative includes a guide to U.K. suppliers of technology and a network for communication between U.K. firms and technology transfer organizations. In 1992 the Canadian International Development Agency unveiled a Cdn$ 5 million program to promote transfer of environmental technologies to developing countries. The program aims to foster joint ventures between Canadian firms and those in developing countries. In 1991 the United States announced a US$ 100 million, five-year United States-Asia Environmental Partnership, based in Hong Kong and designed to train Asians in technical, commercial, management, and policy aspects of environmental issues The initiative encompasses fellowships and training, technology cooperation, and R&D on energy efficiency and biodiversity.

In short, a web of programs and policies to transfer environmental technologies and management skills to developing countries is growing up around the bilateral international development agencies and, to a lesser degree, under multilateral auspices. The unabashedly export-promoting bilateral initiatives are part of a new wave of technological competition among industrialized countries. It is important to understand the ways these programs and policies affect access to cleaner production technologies in the South.

The second international environmental technology transfer issue deserving of attention concerns the suggestion, frequently expressed in UNCED documents and in the "green" international business literature, that sustainable development induces – or should induce – a new kind of cooperation in traditionally competitive business relations. Trisoglio asks if the sustainability question might not induce a mixture of cooperation and competition representing "a middle way", and suggests that "as the links between environmental and economic performance grow stronger, we may expect co-operative business relationships to become an increasingly important component of economic success" (1993: 92). Two kinds of cooperation are mentioned. One is collective voluntary self-regulation, as in the chemical industry's "Responsible Care" initiative, which requires member companies to make a formal commitment to improvement of environmental performance. The second is "technology cooperation", which Stephen Schmidheiny of the Business Council on Sustainable Development proposes as a replacement for the term technology transfer. Technology cooperation is defined as a form of business-to-business relationship which "entails a broader range of objectives [than simple technology transfer] and is sharply focussed on business development... Technology cooperation should put particular emphasis on building up the infrastructure, wealth-generating capacity, and competitiveness of a country" (Schmidheiny 1992: 118).

However, the notion of "technology cooperation" is now being stretched to encompass a huge range of business relationships, from commercial sales of hardware to long term strategic partnerships. For example, Schmidheiny illustrates his discussion of technology cooperation with the international arms trade (because it is accompanied by training), the Green Revolution (because it involved various kinds of partnerships), the sale of Indian software to the City of London, publicly-organized Scandinavian investments in environmentally sound ventures in Eastern Europe, self-imposed environmental charters in Japanese firms, a Japanese trading company's experiments with tropical reforestation techniques, various MNCs' investments to upgrade local affiliates, collective technical and political services for SMEs, local upstream and downstream linkages of an MNC affiliate, MNC training programs for local personnel, and a cooperative arrangement to eliminate ozone-depleting substances in the Mexican electronics industry (*ibid.*).

The shift in focus from multinational corporations (MNCs) as agents of technology transfer to MNCs as key agents of technological accumulation and learning is consonant with the growing trend of MNCs to establish international networks to support their innovatory activities. MNCs establish two kinds of networks: internal transnational production and R&D networks which replace satellites or branch plants, and interfirm networks which include strategic alliances and dense local linkages with customers and suppliers (Cantwell 1993). The point made by those who speak of an expansion of largely private-sector technology cooperation is that MNCs are becoming involved in a broader range of innovatory activities with a broader range of local actors than was previously the case. Furthermore, these linkages are not taking place for altruistic reasons, but for business development purposes. The question for environmentally sustainable industrial innovation in the South is what kinds of technological learning opportunities are afforded by involvement in various forms of industrial linkages, and how do these affect firms' economic and environmental performance?

The third issue concerning international technology transfer may be briefly mentioned. Although UNCED was meant to find ways of reconciling the environmental and development agendas, it can also be viewed as the latest event in a postwar trend of international events and institutions established to manage and regulate environmentally degrading behavior by public and private actors. Early examples of international environmental agreements to regulate use of water or natural resources can be found at the beginning of the century, but it is especially in the post-World War Two period that agreements and institutions have been established for environmental regulation. Of the approximately 130 multilateral environmental treaties in force in 1990, about 120 were established after 1945 (Choucri 1991). International conventions are increasingly making provision for technology transfer and technology cooperation. The 1989 Basel convention on hazardous wastes requires signatories to cooperate to develop technical capacity among the parties and to assist developing countries to implement the treaty. The amended 1989 Montreal protocol on the phaseout of CFCs "not only required signatories to transfer the best available technologies on fair and favorable terms, it created a multilateral fund to help developing countries with the extra cost of meeting emission standards" (Schmidheiny 1992: 120). The principle of a fund for technological reconversion is of interest. The Montreal Protocol on ozone depletion has a dedicated implementation fund. However, Northern countries have been able to block use of this fund to support research on CFC substitutes in Southern countries, preferring to use it instead to subsidize sales of their own technologies (Rinne and Schwank 1994).

Beyond Incrementalism: the Selection Environment and the Technology Frontier

As we move from the scientifically conceivable to the technologically feasible, and from there to the economically viable and the socially acceptable, we have decreasing degrees of freedom (Perez 1983). Radical social innovation for environmental sustainability is especially problematic. Massive changes in lifestyles and consumption would require social engineering, coercive policies, or extremely rapid social learning on an unprecedented scale (13). Never in human history has a new technoeconomic paradigm been deliberately innovated. The proportions of such an undertaking regarding environmental sustainability are staggering and the socioeconomic feasibility is problematic.

The issue of access to technologies is about how to develop endogenous capacity to assess, adopt, manage, and apply environmentally improved technologies. The precautionary principle and the clean production paradigm hint that they can move toward major changes of technology systems through incremental improvements in production and transformation of management philosophy. But capacity to create technologies is rarely mentioned in the context of developing countries.

The world is currently on the brink of a new technoeconomic paradigm based upon information and image technologies, biotechnology, new materials, and a range of improved energy technologies. The technical characteristics of radically different technologies for long term environmental sustainability are still largely speculative, and the environmental implications of various configurations of the emerging technoeconomic paradigm are only beginning to be explored (OECD 1991; Freeman 1992).

As a World Resources Institute report observes, "today the climate for innovation seems uniquely rich, poised between technological revolutions in progress and others just emerging" (Heaton, Repetto, and Sobin 1991: 7). A huge reservoir of untapped technological potential in biotechnology, materials, and informatics exists which could increase energy efficiency and reduce waste production. A WRI report proposes environmentally critical technologies for the United States (14) and recommends a package of environmental technology policy initiatives including a federal Institute for Environmental Technology, new funding arrangements to support environmental technological innovation, new missions for national laboratories, new patterns of R&D cooperation, new arrangements for international cooperation, regulatory reform, and reorientation of existing programs (Heaton, Repetto, and Sobin, 1992).

Most industrialized countries have taken measures to stimulate innovation of new generations of environmentally sound technologies. The Japanese are probably the most ambitious in this respect. Their "New Earth 21" plan aims develop a new industrial paradigm to restore the Earth's natural functions over the next century by returning the emission of global warming gases to pre-industrial revolution levels. They have established RITE, the Research Institute of Innovative Technology for the Earth, for development and global promotion of next generation environmental technologies. RITE is applying advanced technologies to problems of renewable energy, energy efficiency, new manufacturing processes, and capture and fixation of carbon dioxide.

Deliberate innovation of a new, environmentally sustainable technoeconomic paradigm presupposes a degree of purposiveness and instrumentality that is not present in the international system nor possibly in the "national systems of innovation" of many advanced industrial countries, although presumably these and some advanced industrializing countries have the scientific and technical capacity to substantially inflect the world's technoeconomic trajectory in the direction of radical innovation or even toward greater discontinuities, under appropriate economic and political circumstances.

Much of the literature on environmentally sound industrial innovation suffers from the difficulty of identifying and describing those variables that link the technical and the social dimensions that are accessible to deliberate management, policy, or political interventions. Philosophers of industrial metabolism and industrial ecology are attempting to locate principles of extrafirm regulation in efficient systems of transactions among firms, while a growing current of research in the North attempts to locate the principles of a strong socially determined "selection environment" in processes of social negotiation of technical change (15). The notion of cleaner production, which ultimately wants to talk about the social appropriateness of products and processes (see Jackson 1993b), is initially effective when it is presented as a doctrine of technical efficiency. Mechanisms and instruments of deliberate social choice of technological systems, especially ones that are feasible under regimes of democratic governance, are a relatively unknown part of the non-market "selection environment" and are likely to become increasingly important concerns of innovation policy in North and South alike.

NOTES

I am grateful to my colleague Brent Herbert-Copley for useful comments on a previous draft. The views expressed here are not necessarily those of the International Development Research Centre.

1) On the emergence of international responses to environmental issues see Caldwell (1990).

2) The term "institution arrangements" encompasses the entire spectrum of organizations, formal as well as nonformal, as well as "rules of the game" and explicit or implicit conventions and norms.

3) For a useful overview of the technology-environment-development issue area see Rath and Herbert-Copley (1993). For useful commentaries on Agenda 21 see IDRC (1993a,b).

4) The macrostructure of Agenda 21 and the titles of its forty chapters are presented in Appendix 1.

5) For a more detailed analysis of the contents and implications of these and other Agenda 21 chapters see IDRC 1993a and 1993b.

6) This recognition within United Nations fora of the legitimacy of private enterprise is quite novel.

7) On attempts to found environmental management regimes on scientific understanding of the behavior of various pollutants in the environment see Chadwick and Nilsson (1993).

8) The International Cleaner Production Information Clearinghouse (ICPIC) contains several hundred case studies.

9) This is why it may be misleading to distinguish between "diffusion" and "innovation", as the Technology Innovation and Economics Committee of the U.S. National Advisory Council for Environmental Policy and Technology has done in its policy report on improving the diffusion of technologies for environmental protection (EPA 1992). The issues at stake are: what kinds of in-house and external technical and management skills are required for adoption and adaptation of these technologies, and how much adaptation do cleaner technologies and cleaner production processes of various kinds really require?

10) For example, it was proposed that the industrialized countries purchase the patents and property rights to certain unspecified environmental technologies and make them available to developing countries (Cramer 1992).

11) In the latter formulation, environmental technologies are defined as solid, liquid, gaseous, and hazardous waste management, including waste prevention and minimization techniques, recycling, waste treatment, and waste disposal; sustainable agricultural; energy technologies, including energy efficient technologies; and monitoring equipment (McCann 1992).

12) See for example the 1991 report of the U.S. International Environmental Technology Transfer Board described in Kasman (1992), which contains recommendations for a focussed U.S. policy and strategy regarding transfer of environmental technologies to developing countries.

13) On the efforts (largely in Northern countries) to define frameworks for "green" political action see Eckersley (1992) and Dobson (1990). On the question of the politics of the social transition to sustainability see, for example, Kassiola (1990), especially chapter 9, "Social Transformation into a Transindustrial Community".

14) These are: energy capture (photovoltaics, geothermal, solar thermal electricity, nuclear fission); energy storage and application (batteries, superconductors, hydrogen storage, heat storage, fuel cells); special energy end-uses (transportation, buildings); agricultural biotechnology; improved agricultural techniques; manufacturing monitoring, modeling, and control; catalysis; separations; precision fabrication; materials design and processing; information, communications, and computing; and contraception.

15) See for example Irwin and Vergragt (1989).

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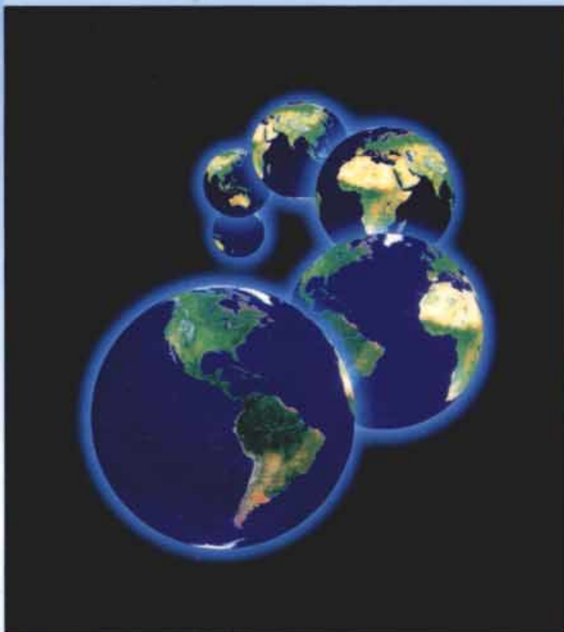

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